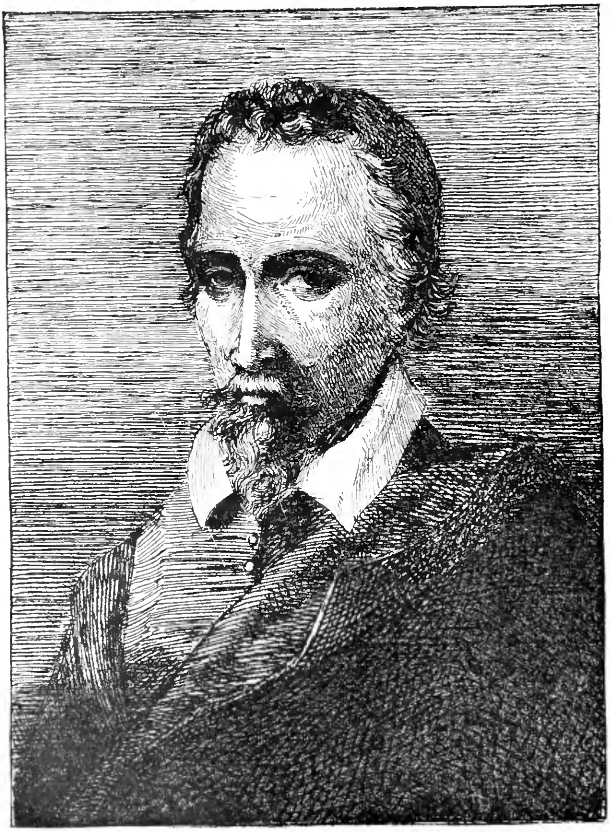

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THE

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ILLUSTRATIONS OF THE LOGIC OF SCIENCE.

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FIRST PAPER.—THE FIXATION OF BELIEF.

I.

FEW persons care to study logic, because everybody conceives himself to be proficient enough in the art of reasoning already. But I observe that this satisfaction is limited to one's own ratiocination, and does not extend to that of other men.

We come to the full possession of our power of drawing inferences the last of all our faculties, for it is not so much a natural gift as a long and difficult art. The history of its practice would make a grand subject for a book. The mediæval schoolmen, following the Romans, made logic the earliest of a boy's studies after grammar, as being very easy. So it was, as they understood it. Its fundamental principle, according to them, was, that all knowledge rests on either authority or reason; but that whatever is deduced by reason depends ultimately on a premise derived from authority. Accordingly, as soon as a boy was perfect in the syllogistic procedure, his intellectual kit of tools was held to be complete.

To Roger Bacon, that remarkable mind who in the middle of the thirteenth century was almost a scientific man, the schoolmen's conception of reasoning appeared only an obstacle to truth. He saw that experience alone teaches anything—a proposition which to us seems easy to understand, because a distinct conception of experience has been handed down to us from former generations; which to him also seemed perfectly clear, because its difficulties had not yet unfolded themselves. Of all kinds of experience, the best, he thought, was interior illumination, which teaches many things about Nature which the external senses could never discover, such as the transubstantiation of bread.

Four centuries later, the more celebrated Bacon, in the first book of his "Novum Organum," gave his clear account of experience as something which must be open to verification and reëxamination. But, superior as Lord Bacon's conception is to earlier notions, a modern reader who is not in awe of his grandiloquence is chiefly struck by the inadequacy of his view of scientific procedure. That we have only to make some crude experiments, to draw up briefs of the results in certain blank forms, to go through these by rule, checking off everything disproved and setting down the alternatives, and that thus in a few years physical science would be finished up—what an idea! "He wrote on science like a Lord Chancellor," indeed.

The early scientists, Copernicus, Tycho Brahe, Kepler, Galileo, and Gilbert, had methods more like those of their modern brethren. Kepler undertook to draw a curve through the places of Mars;[1] and his greatest service to science was in impressing on men's minds that this was the thing to be done if they wished to improve astronomy; that they were not to content themselves with inquiring whether one system of epicycles was better than another, but that they were to sit down to the figures and find out what the curve, in truth, was. He accomplished this by his incomparable energy and courage, blundering along in the most inconceivable way (to us), from one irrational hypothesis to another, until, after trying twenty-two of these, he fell, by the mere exhaustion of his invention, upon the orbit which a mind well furnished with the weapons of modern logic would have tried almost at the outset.

In the same way, every work of science great enough to be remembered for a few generations affords some exemplification of the defective state of the art of reasoning of the time when it was written; and each chief step in science has been a lesson in logic. It was so when Lavoisier and his contemporaries took up the study of chemistry. The old chemist's maxim had been, "*Lege, lege, lege, labora, ora, et relege.*" Lavoisier's method was not to read and pray, not to dream that some long and complicated chemical process would have a certain effect, to put it into practice with dull patience, after its inevitable failure to dream that with some modification it would have another result, and to end by publishing the last dream as a fact: his way was to carry his mind into his laboratory, and to make of his alembics and cucurbits instruments of thought, giving a new conception of reasoning, as something which was to be done with one's eyes open, by manipulating real things instead of words and fancies.

The Darwinian controversy is, in large part, a question of logic. Mr. Darwin proposed to apply the statistical method to biology. The same thing had been done in a widely different branch of science, the

[1] Not quite so, but as nearly so as can be told in a few words.

theory of gases. Though unable to say what the movements of any particular molecule of a gas would be on a certain hypothesis regarding the constitution of this class of bodies, Clausius and Maxwell were yet able, by the application of the doctrine of probabilities, to predict that in the long run such and such a proportion of the molecules would, under given circumstances, acquire such and such velocities; that there would take place, every second, such and such a number of collisions, etc.; and from these propositions were able to deduce certain properties of gases, especially in regard to their heat-relations. In like manner, Darwin, while unable to say what the operation of variation and natural selection in any individual case will be, demonstrates that in the long run they will adapt animals to their circumstances. Whether or not existing animal forms are due to such action, or what position the theory ought to take, forms the subject of a discussion in which questions of fact and questions of logic are curiously interlaced.

II.

The object of reasoning is to find out, from the consideration of what we already know, something else which we do not know. Consequently, reasoning is good if it be such as to give a true conclusion from true premises, and not otherwise. Thus, the question of its validity is purely one of fact and not of thinking. A being the premises and B the conclusion, the question is, whether these facts are really so related that if A is B is. If so, the inference is valid; if not, not. It is not in the least the question whether, when the premises are accepted by the mind, we feel an impulse to accept the conclusion also. It is true that we do generally reason correctly by nature. But that is an accident; the true conclusion would remain true if we had no impulse to accept it; and the false one would remain false, though we could not resist the tendency to believe in it.

We are, doubtless, in the main logical animals, but we are not perfectly so. Most of us, for example, are naturally more sanguine and hopeful than logic would justify. We seem to be so constituted that in the absence of any facts to go upon we are happy and self-satisfied; so that the effect of experience is continually to contract our hopes and aspirations. Yet a lifetime of the application of this corrective does not usually eradicate our sanguine disposition. Where hope is unchecked by any experience, it is likely that our optimism is extravagant. Logicality in regard to practical matters is the most useful quality an animal can possess, and might, therefore, result from the action of natural selection; but outside of these it is probably of more advantage to the animal to have his mind filled with pleasing and encouraging visions, independently of their truth; and thus, upon unpractical subjects, natural selection might occasion a fallacious tendency of thought.

That which determines us, from given premises, to draw one inference rather than another, is some habit of mind, whether it be constitutional or acquired. The habit is good or otherwise, according as it produces true conclusions from true premises or not; and an inference is regarded as valid or not, without reference to the truth or falsity of its conclusion specially, but according as the habit which determines it is such as to produce true conclusions in general or not. The particular habit of mind which governs this or that inference may be formulated in a proposition whose truth depends on the validity of the inferences which the habit determines; and such a formula is called a *guiding principle* of inference. Suppose, for example, that we observe that a rotating disk of copper quickly comes to rest when placed between the poles of a magnet, and we infer that this will happen with every disk of copper. The guiding principle is, that what is true of one piece of copper is true of another. Such a guiding principle with regard to copper would be much safer than with regard to many other substances—brass, for example.

A book might be written to signalize all the most important of these guiding principles of reasoning. It would probably be, we must confess, of no service to a person whose thought is directed wholly to practical subjects, and whose activity moves along thoroughly-beaten paths. The problems which present themselves to such a mind are matters of routine which he has learned once for all to handle in learning his business. But let a man venture into an unfamiliar field, or where his results are not continually checked by experience, and all history shows that the most masculine intellect will ofttimes lose his orientation and waste his efforts in directions which bring him no nearer to his goal, or even carry him entirely astray. He is like a ship in the open sea, with no one on board who understands the rules of navigation. And in such a case some general study of the guiding principles of reasoning would be sure to be found useful.

The subject could hardly be treated, however, without being first limited; since almost any fact may serve as a guiding principle. But it so happens that there exists a division among facts, such that in one class are all those which are absolutely essential as guiding principles, while in the others are all which have any other interest as objects of research. This division is between those which are necessarily taken for granted in asking whether a certain conclusion follows from certain premises, and those which are not implied in that question. A moment's thought will show that a variety of facts are already assumed when the logical question is first asked. It is implied, for instance, that there are such states of mind as doubt and belief—that a passage from one to the other is possible, the object of thought remaining the same, and that this transition is subject to some rules which all minds are alike bound by. As these are facts which we must already know before we can have any clear conception of reasoning at all, it cannot be supposed to be any longer of much interest to inquire into their truth or falsity. On the other hand, it is easy to believe that those rules of reasoning which are deduced from the very idea of the process are the ones which are the most essential; and, indeed, that so long as it conforms to these it will, at least, not lead to false conclusions from true premises. In point of fact, the importance of what may be deduced from the assumptions involved in the logical question turns out to be greater than might be supposed, and this for reasons which it is difficult to exhibit at the outset. The only one which I shall here mention is, that conceptions which are really products of logical reflection, without being readily seen to be so, mingle with our ordinary thoughts, and are frequently the causes of great confusion. This is the case, for example, with the conception of quality. A quality as such is never an object of observation. We can see that a thing is blue or green, but the quality of being blue and the quality of being green are not things which we see; they are products of logical reflection. The truth is, that common-sense, or thought as it first emerges above the level of the narrowly practical, is deeply imbued with that bad logical quality to which the epithet *metaphysical* is commonly applied; and nothing can clear it up but a severe course of logic.

III.

We generally know when we wish to ask a question and when we wish to pronounce a judgment, for there is a dissimilarity between the sensation of doubting and that of believing.

But this is not all which distinguishes doubt from belief. There is a practical difference. Our beliefs guide our desires and shape our actions. The Assassins, or followers of the Old Man of the Mountain, used to rush into death at his least command, because they believed that obedience to him would insure everlasting felicity. Had they doubted this, they would not have acted as they did. So it is with every belief, according to its degree. The feeling of believing is a more or less sure indication of there being established in our nature some habit which will determine our actions. Doubt never has such an effect.

Nor must we overlook a third point of difference. Doubt is an uneasy and dissatisfied state from which we struggle to free ourselves and pass into the state of belief; while the latter is a calm and satisfactory state which we do not wish to avoid, or to change to a belief in anything else.[1] On the contrary, we cling tenaciously, not merely to believing, but to believing just what we do believe.

[1] I am not speaking of secondary effects occasionally produced by the interference of other impulses.

Thus, both doubt and belief have positive effects upon us, though very different ones. Belief does not make us act at once, but puts us into such a condition that we shall behave in a certain way, when the occasion arises. Doubt has not the least effect of this sort, but stimulates us to action until it is destroyed. This reminds us of the irritation of a nerve and the reflex action produced thereby; while for the analogue of belief, in the nervous system, we must look to what are called nervous associations—for example, to that habit of the nerves in consequence of which the smell of a peach will make the mouth water.

IV.

The irritation of doubt causes a struggle to attain a state of belief. I shall term this struggle *inquiry*, though it must be admitted that this is sometimes not a very apt designation.

The irritation of doubt is the only immediate motive for the struggle to attain belief. It is certainly best for us that our beliefs should be such as may truly guide our actions so as to satisfy our desires; and this reflection will make us reject any belief which does not seem to have been so formed as to insure this result. But it will only do so by creating a doubt in the place of that belief. With the doubt, therefore, the struggle begins, and with the cessation of doubt it ends. Hence, the sole object of inquiry is the settlement of opinion. We may fancy that this is not enough for us, and that we seek, not merely an opinion, but a true opinion. But put this fancy to the test, and it proves groundless; for as soon as a firm belief is reached we are entirely satisfied, whether the belief be true or false. And it is clear that nothing out of the sphere of our knowledge can be our object, for nothing which does not affect the mind can be the motive for a mental effort. The most that can be maintained is, that we seek for a belief that we shall *think* to be true. But we think each one of our beliefs to be true, and, indeed, it is mere tautology to say so.

That the settlement of opinion is the sole end of inquiry is a very important proposition. It sweeps away, at once, various vague and erroneous conceptions of proof. A few of these may be noticed here.

1. Some philosophers have imagined that to start an inquiry it was only necessary to utter a question or set it down upon paper, and have even recommended us to begin our studies with questioning everything! But the mere putting of a proposition into the interrogative form does not stimulate the mind to any struggle after belief. There must be a real and living doubt, and without this all discussion is idle.

2. It is a very common idea that a demonstration must rest on some ultimate and absolutely indubitable propositions. These, according to one school, are first principles of a general nature; according to another, are first sensations. But, in point of fact, an inquiry,

to have that completely satisfactory result called demonstration, has only to start with propositions perfectly free from all actual doubt. If the premises are not in fact doubted at all, they cannot be more satisfactory than they are.

3. Some people seem to love to argue a point after all the world is fully convinced of it. But no further advance can be made. When doubt ceases, mental action on the subject comes to an end; and, if it did go on, it would be without a purpose.

V.

If the settlement of opinion is the sole object of inquiry, and if belief is of the nature of a habit, why should we not attain the desired end, by taking any answer to a question which we may fancy, and constantly reiterating it to ourselves, dwelling on all which may conduce to that belief, and learning to turn with contempt and hatred from anything which might disturb it? This simple and direct method is really pursued by many men. I remember once being entreated not to read a certain newspaper lest it might change my opinion upon free-trade. "Lest I might be entrapped by its fallacies and misstatements," was the form of expression. "You are not," my friend said, "a special student of political economy. You might, therefore, easily be deceived by fallacious arguments upon the subject. You might, then, if you read this paper, be led to believe in protection. But you admit that free-trade is the true doctrine; and you do not wish to believe what is not true." I have often known this system to be deliberately adopted. Still oftener, the instinctive dislike of an undecided state of mind, exaggerated into a vague dread of doubt, makes men cling spasmodically to the views they already take. The man feels that, if he only holds to his belief without wavering, it will be entirely satisfactory. Nor can it be denied that a steady and immovable faith yields great peace of mind. It may, indeed, give rise to inconveniences, as if a man should resolutely continue to believe that fire would not burn him, or that he would be eternally damned if he received his *ingesta* otherwise than through a stomach-pump. But then the man who adopts this method will not allow that its inconveniences are greater than its advantages. He will say, "I hold steadfastly to the truth, and the truth is always wholesome." And in many cases it may very well be that the pleasure he derives from his calm faith overbalances any inconveniences resulting from its deceptive character. Thus, if it be true that death is annihilation, then the man who believes that he will certainly go straight to heaven when he dies, provided he have fulfilled certain simple observances in this life, has a cheap pleasure which will not be followed by the least disappointment. A similar consideration seems to have weight with many persons in religious topics, for we frequently hear it said, "Oh, I could not believe so-and-so, because I should be wretched if I did." When an ostrich buries its head in the sand as danger approaches, it very likely takes the happiest course. It hides the danger, and then calmly says there is no danger; and, if it feels perfectly sure there is none, why should it raise its head to see? A man may go through life, systematically keeping out of view all that might cause a change in his opinions, and if he only succeeds—basing his method, as he does, on two fundamental psychological laws—I do not see what can be said against his doing so. It would be an egotistical impertinence to object that his procedure is irrational, for that only amounts to saying that his method of settling belief is not ours. He does not propose to himself to be rational, and, indeed, will often talk with scorn of man's weak and illusive reason. So let him think as he pleases.

But this method of fixing belief, which may be called the method of tenacity, will be unable to hold its ground in practice. The social impulse is against it. The man who adopts it will find that other men think differently from him, and it will be apt to occur to him, in some saner moment, that their opinions are quite as good as his own, and this will shake his confidence in his belief. This conception, that another man's thought or sentiment may be equivalent to one's own, is a distinctly new step, and a highly important one. It arises from an impulse too strong in man to be suppressed, without danger of destroying the human species. Unless we make ourselves hermits, we shall necessarily influence each other's opinions; so that the problem becomes how to fix belief, not in the individual merely, but in the community.

Let the will of the state act, then, instead of that of the individual. Let an institution be created which shall have for its object to keep correct doctrines before the attention of the people, to reiterate them perpetually, and to teach them to the young; having at the same time power to prevent contrary doctrines from being taught, advocated, or expressed. Let all possible causes of a change of mind be removed from men's apprehensions. Let them be kept ignorant, lest they should learn of some reason to think otherwise than they do. Let their passions be enlisted, so that they may regard private and unusual opinions with hatred and horror. Then, let all men who reject the established belief be terrified into silence. Let the people turn out and tar-and-feather such men, or let inquisitions be made into the manner of thinking of suspected persons, and, when they are found guilty of forbidden beliefs, let them be subjected to some signal punishment. When complete agreement could not otherwise be reached, a general massacre of all who have not thought in a certain way has proved a very effective means of settling opinion in a country. If the power to do this be wanting, let a list of opinions be drawn up, to which no man of the least independence of thought can assent, and let the faithful be required to accept all these propositions, in order to segregate them as radically as possible from the influence of the rest of the world.

This method has, from the earliest times, been one of the chief means of upholding correct theological and political doctrines, and of preserving their universal or catholic character. In Rome, especially, it has been practised from the days of Numa Pompilius to those of Pius Nonus. This is the most perfect example in history; but wherever there is a priesthood—and no religion has been without one—this method has been more or less made use of. Wherever there is an aristocracy, or a guild, or any association of a class of men whose interests depend or are supposed to depend on certain propositions, there will be inevitably found some traces of this natural product of social feeling. Cruelties always accompany this system; and when it is consistently carried out, they become atrocities of the most horrible kind in the eyes of any rational man. Nor should this occasion surprise, for the officer of a society does not feel justified in surrendering the interests of that society for the sake of mercy, as he might his own private interests. It is natural, therefore, that sympathy and fellowship should thus produce a most ruthless power.

In judging this method of fixing belief, which may be called the method of authority, we must, in the first place, allow its immeasurable mental and moral superiority to the method of tenacity. Its success is proportionately greater; and, in fact, it has over and over again worked the most majestic results. The mere structures of stone which it has caused to be put together—in Siam, for example, in Egypt, and in Europe—have many of them a sublimity hardly more than rivaled by the greatest works of Nature. And, except the geological epochs, there are no periods of time so vast as those which are measured by some of these organized faiths. If we scrutinize the matter closely, we shall find that there has not been one of their creeds which has remained always the same; yet the change is so slow as to be imperceptible during one person's life, so that individual belief remains sensibly fixed. For the mass of mankind, then, there is perhaps no better method than this. If it is their highest impulse to be intellectual slaves, then slaves they ought to remain.

But no institution can undertake to regulate opinions upon every subject. Only the most important ones can be attended to, and on the rest men's minds must be left to the action of natural causes. This imperfection will be no source of weakness so long as men are in such a state of culture that one opinion does not influence another—that is, so long as they cannot put two and two together. But in the most priestridden states some individuals will be found who are raised above that condition. These men possess a wider sort of social feeling; they see that men in other countries and in other ages have held to very different doctrines from those which they themselves have been brought up to believe; and they cannot help seeing that it is the mere accident of their having been taught as they have, and of their having been surrounded with the manners and associations they have, that has caused them to believe as they do and not far differently. And their candor cannot resist the reflection that there is no reason to rate their own views at a higher value than those of other nations and other centuries; and this gives rise to doubts in their minds.

They will further perceive that such doubts as these must exist in their minds with reference to every belief which seems to be determined by the caprice either of themselves or of those who originated the popular opinions. The willful adherence to a belief, and the arbitrary forcing of it upon others, must, therefore, both be given up, and a new method of settling opinions must be adopted, which shall not only produce an impulse to believe, but shall also decide what proposition it is which is to be believed. Let the action of natural preferences be unimpeded, then, and under their influence let men, conversing together and regarding matters in different lights, gradually develop beliefs in harmony with natural causes. This method resembles that by which conceptions of art have been brought to maturity. The most perfect example of it is to be found in the history of metaphysical philosophy. Systems of this sort have not usually rested upon any observed facts, at least not in any great degree. They have been chiefly adopted because their fundamental propositions seemed "agreeable to reason." This is an apt expression; it does not mean that which agrees with experience, but that which we find ourselves inclined to believe. Plato, for example, finds it agreeable to reason that the distances of the celestial spheres from one another should be proportional to the different lengths of strings which produce harmonious chords. Many philosophers have been led to their main conclusions by considerations like this; but this is the lowest and least developed form which the method takes, for it is clear that another man might find Kepler's theory, that the celestial spheres are proportional to the inscribed and circumscribed spheres of the different regular solids, more agreeable to *his* reason. But the shock of opinions will soon lead men to rest on preferences of a far more universal nature. Take, for example, the doctrine that man only acts selfishly—that is, from the consideration that acting in one way will afford him more pleasure than acting in another. This rests on no fact in the world, but it has had a wide acceptance as being the only reasonable theory.

This method is far more intellectual and respectable from the point of view of reason than either of the others which we have noticed. But its failure has been the most manifest. It makes of inquiry something similar to the development of taste; but taste, unfortunately, is always more or less a matter of fashion, and accordingly metaphysicians have never come to any fixed agreement, but the pendulum has swung backward and forward between a more material and a more spiritual philosophy, from the earliest times to the latest. And so from this, which has been called the *a priori* method, we are driven, in Lord Bacon's phrase, to a true induction. We have examined into this *a priori* method as something which promised to deliver our opinions from their accidental and capricious element. But development, while it is a process which eliminates the effect of some casual circumstances, only magnifies that of others. This method, therefore, does not differ in a very essential way from that of authority. The government may not have lifted its finger to influence my convictions; I may have been left outwardly quite free to choose, we will say, between monogamy and polygamy, and, appealing to my conscience only, I may have concluded that the latter practice is in itself licentious. But when I come to see that the chief obstacle to the spread of Christianity among a people of as high culture as the Hindoos has been a conviction of the immorality of our way of treating women, I cannot help seeing that, though governments do not interfere, sentiments in their development will be very greatly determined by accidental causes. Now, there are some people, among whom I must suppose that my reader is to be found, who, when they see that any belief of theirs is determined by any circumstance extraneous to the facts, will from that moment not merely admit in words that that belief is doubtful, but will experience a real doubt of it, so that it ceases to be a belief.

To satisfy our doubts, therefore, it is necessary that a method should be found by which our beliefs may be caused by nothing human, but by some external permanency—by something upon which our thinking has no effect. Some mystics imagine that they have such a method in a private inspiration from on high. But that is only a form of the method of tenacity, in which the conception of truth as something public is not yet developed. Our external permanency would not be external, in our sense, if it was restricted in its influence to one individual. It must be something which affects, or might affect, every man. And, though these affections are necessarily as various as are individual conditions, yet the method must be such that the ultimate conclusion of every man shall be the same. Such is the method of science. Its fundamental hypothesis, restated in more familiar language, is this: There are real things, whose characters are entirely independent of our opinions about them; those realities affect our senses according to regular laws, and, though our sensations are as different as our relations to the objects, yet, by taking advantage of the laws of perception, we can ascertain by reasoning how things really are, and any man, if he have sufficient experience and reason enough about it, will be led to the one true conclusion. The new conception here involved is that of reality. It may be asked how I know that there are any realities. If this hypothesis is the sole support of my method of inquiry, my method of inquiry must not be used to support my hypothesis. The reply is this: 1. If investigation cannot be regarded as proving that there are real things, it at least does not lead to a contrary conclusion; but the method and the conception on which it is based remain ever in harmony. No doubts of the method, therefore, necessarily arise from its practice, as is the case with all the others. 2. The feeling which gives rise to any method of fixing belief is a dissatisfaction at two repugnant propositions. But here already is a vague concession that there is some *one* thing to which a proposition should conform. Nobody, therefore, can really doubt that there are realities, or, if he did, doubt would not be a source of dissatisfaction. The hypothesis, therefore, is one which every mind admits. So that the social impulse does not cause me to doubt it. 3. Everybody uses the scientific method about a great many things, and only ceases to use it when he does not know how to apply it. 4. Experience of the method has not led me to doubt it, but, on the contrary, scientific investigation has had the most wonderful triumphs in the way of settling opinion. These afford the explanation of my not doubting the method or the hypothesis which it supposes; and not having any doubt, nor believing that anybody else whom I could influence has, it would be the merest babble for me to say more about it. If there be anybody with a living doubt upon the subject, let him consider it.

To describe the method of scientific investigation is the object of this series of papers. At present I have only room to notice some points of contrast between it and other methods of fixing belief.

This is the only one of the four methods which presents any distinction of a right and a wrong way. If I adopt the method of tenacity and shut myself out from all influences, whatever I think necessary to doing this is necessary according to that method. So with the method of authority: the state may try to put down heresy by means which, from a scientific point of view, seem very ill-calculated to accomplish its purposes; but the only test *on that method* is what the state thinks, so that it cannot pursue the method wrongly. So with the *a priori* method. The very essence of it is to think as one is inclined to think. All metaphysicians will be sure to do that, however they may be inclined to judge each other to be perversely wrong. The Hegelian system recognizes every natural tendency of thought as logical, although it be certain to be abolished by counter-tendencies. Hegel thinks there is a regular system in the succession of these tendencies, in consequence of which, after drifting one way and the other for a long time, opinion will at last go right.

And it is true that metaphysicians get the right ideas at last; Hegel's system of Nature represents tolerably the science of that day; and one may be sure that whatever scientific investigation has put out of doubt will presently receive *a priori* demonstration on the part of the metaphysicians. But with the scientific method the case is different. I may start with known and observed facts to proceed to the unknown; and yet the rules which I follow in doing so may not be such as investigation would approve. The test of whether I am truly following the method is not an immediate appeal to my feelings and purposes, but, on the contrary, itself involves the application of the method. Hence it is that bad reasoning as well as good reasoning is possible; and this fact is the foundation of the practical side of logic.

It is not to be supposed that the first three methods of settling opinion present no advantage whatever over the scientific method. On the contrary, each has some peculiar convenience of its own. The *a priori* method is distinguished for its comfortable conclusions. It is the nature of the process to adopt whatever belief we are inclined to, and there are certain flatteries to the vanity of man which we all believe by nature, until we are awakened from our pleasing dream by some rough facts. The method of authority will always govern the mass of mankind; and those who wield the various forms of organized force in the state will never be convinced that dangerous reasoning ought not to be suppressed in some way. If liberty of speech is to be untrammeled from the grosser forms of constraint, then uniformity of opinion will be secured by a moral terrorism to which the respectability of society will give its thorough approval. Following the method of authority is the path of peace. Certain non-conformities are permitted; certain others (considered unsafe) are forbidden. These are different in different countries and in different ages; but, wherever you are, let it be known that you seriously hold a tabooed belief, and you may be perfectly sure of being treated with a cruelty less brutal but more refined than hunting you like a wolf. Thus, the greatest intellectual benefactors of mankind have never dared, and dare not now, to utter the whole of their thought; and thus a shade of *prima facie* doubt is cast upon every proposition which is considered essential to the security of society. Singularly enough, the persecution does not all come from without; but a man torments himself and is oftentimes most distressed at finding himself believing propositions which he has been brought up to regard with aversion. The peaceful and sympathetic man will, therefore, find it hard to resist the temptation to submit his opinions to authority. But most of all I admire the method of tenacity for its strength, simplicity, and directness. Men who pursue it are distinguished for their decision of character, which becomes very easy with such a mental rule. They do not waste time in trying to make up their minds what they want, but, fastening like lightning upon whatever alternative comes first, they hold to it to the end, whatever happens, without an instant's irresolution. This is one of the splendid qualities which generally accompany brilliant, unlasting success. It is impossible not to envy the man who can dismiss reason, although we know how it must turn out at last.

Such are the advantages which the other methods of settling opinion have over scientific investigation. A man should consider well of them; and then he should consider that, after all, he wishes his opinions to coincide with the fact, and that there is no reason why the results of these three methods should do so. To bring about this effect is the prerogative of the method of science. Upon such considerations he has to make his choice—a choice which is far more than the adoption of any intellectual opinion, which is one of the ruling decisions of his life, to which, when once made, he is bound to adhere. The force of habit will sometimes cause a man to hold on to old beliefs, after he is in a condition to see that they have no sound basis. But reflection upon the state of the case will overcome these habits, and he ought to allow reflection its full weight. People sometimes shrink from doing this, having an idea that beliefs are wholesome which they cannot help feeling rest on nothing. But let such persons suppose an analogous though different case from their own. Let them ask themselves what they would say to a reformed Mussulman who should hesitate to give up his old notions in regard to the relations of the sexes; or to a reformed Catholic who should still shrink from reading the Bible. Would they not say that these persons ought to consider the matter fully, and clearly understand the new doctrine, and then ought to embrace it, in its entirety? But, above all, let it be considered that what is more wholesome than any particular belief is integrity of belief, and that to avoid looking into the support of any belief from a fear that it may turn out rotten is quite as immoral as it is disadvantageous. The person who confesses that there is such a thing as truth, which is distinguished from falsehood simply by this, that if acted on it will carry us to the point we aim at and not astray, and then, though convinced of this, dares not know the truth and seeks to avoid it, is in a sorry state of mind indeed.

Yes, the other methods do have their merits: a clear logical conscience does cost something—just as any virtue, just as all that we cherish, costs us dear. But we should not desire it to be otherwise. The genius of a man's logical method should be loved and reverenced as his bride, whom he has chosen from all the world. He need not contemn the others; on the contrary, he may honor them deeply, and in doing so he only honors her the more. But she is the one that he has chosen, and he knows that he was right in making that choice. And having made it, he will work and fight for her, and will not complain that there are blows to take, hoping that there may be as many and as hard to give, and will strive to be the worthy knight and champion of her from the blaze of whose splendors he draws his inspiration and his courage.

THE GROWTH OF THE STEAM-ENGINE.[1]

By Professor R. H. THURSTON,
OF THE STEVENS INSTITUTE OF TECHNOLOGY.

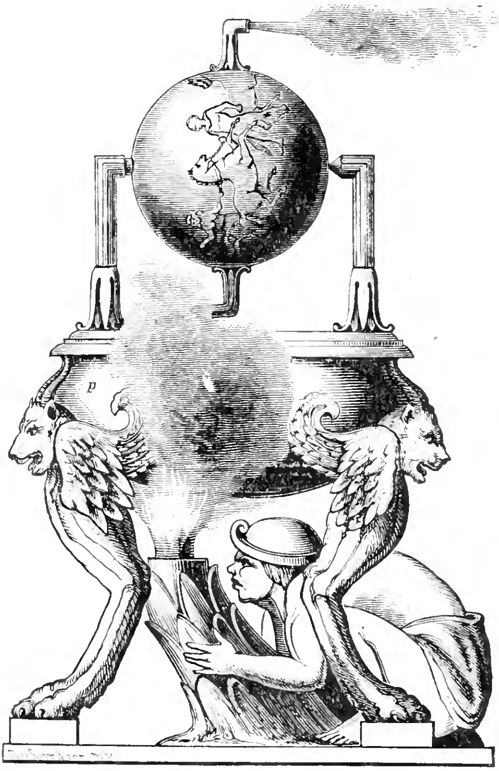


Fig. 1.—The Grecian Idea of the Steam-Engine.

[1] This sketch is condensed from lectures originally written for delivery to an audience of engineers and mechanics, at the Stevens Institute of Technology, in the winter of 1871–'72, and from lectures since prepared for classes in the Department of Mechanical Engineering, and revised to date. The most novel portion—referring to the practical realization of the "perfect steam-engine"— is here more fully developed than it had previously been, and the paper, as a whole, is for the first time here published. The illustrations are principally from Stuart and Farey, and from the article "Steam-Engine," prepared by the writer of these lectures for Appletons' Cyclopædia, new edition.

A very complete history of "The Growth of the Steam-Engine" has been prepared by

I.

THE STEAM-ENGINE AS A SIMPLE MACHINE.

["A machine, receiving at distant times and from many hands new combinations and improvements, and becoming at last of signal benefit to mankind, may be compared to a rivulet, swelled in its course by tributary streams until it rolls along a majestic river, enriching in its progress provinces and kingdoms. In retracing the current, too, from where it mingles with the ocean, the pretensions of even ample subsidiary streams are merged in our admiration of the master-flood. But, as we continue to ascend, those waters which, nearer the sea, would have been disregarded as unimportant, begin to rival in magnitude, and divide our attention with, the parent stream; until, at length, on our approaching the fountains of the river, it appears trickling from the rock, or oozing from among the flowers of the valley. So, also, in developing the rise of a machine, a coarse instrument or a toy may be recognized as the germ of that production of mechanical genius whose power and usefulness have stimulated our curiosity to mark its changes and to trace its origin. The same feelings of reverential gratitude which attached holiness to the spots whence mighty rivers sprung, also clothed with divinity, and raised altars in honor of the saw, the plough, the potter's wheel, and the loom."—STUART.]

[. . . . "And, last of all, with inimitable power, and 'with whirlwind-sound,' comes the potent agency of steam. In comparison with the past, what centuries of improvement has this single agent comprised in the short compass of fifty years! Everywhere practicable, everywhere efficient, it has an arm a thousand times stronger than that of Hercules, and to which human ingenuity is capable of fitting a thousand times as many hands as belonged to Briareus. Steam is found in triumphant operation on the seas; and, under the influence of its strong propulsion, the gallant ship—

'Against the wind, against the tide,
Still steadies with an upright keel.'

It is on the rivers, and the boatman may repose on his oars; it is on highways, and exerts itself along the courses of land-conveyance; it is at the bottom of mines, a thousand feet below the earth's surface; it is in the mill, and in the workshops of the trades. It rows, it pumps, it excavates, it carries, it draws, it lifts, it hammers, it spins, it weaves, it prints. It seems to say to men, at least to the class of artisans: 'Leave off your manual labor; give over your bodily toil; bestow but your skill and reason to the directing of my power, and I will bear the toil, with no muscle to grow weary, no nerve to relax, no breast to feel faintness!' What further improvement may still be made in the use of this astonishing power it is impossible to know, and it were vain to conjecture. What we do know is, that it has most essentially altered the face of affairs, and that no visible limit yet appears beyond which its progress is seen to be impossible."—DANIEL WEBSTER.]

SECTION I. *The Period of Speculation.* HERO TO WORCESTER. B. C. 200 to A. D. 1700.—1. The history of the steam-engine is a subject that interests greatly every intelligent mind.

As Religion has always been, and still is, the great *moral* agent in

the same author, and is about to be published, finely illustrated, in the "International Series."

civilizing the world, and as Science is the great *intellectual* promoter of civilization, so the steam-engine is, in modern times, the most important physical agent in that great work.

It would be superfluous to attempt to enumerate the benefits which it has conferred upon the human race, for such an enumeration would include an addition to every comfort, and the creation of almost every luxury that we now enjoy.

"It has increased the sum of human happiness, not only by calling new pleasures into existence, but by so cheapening former enjoyments as to render them attainable by those who before could never have hoped to share them."[1]

2. The wonderful progress of the present century is, in a very great degree, due to the invention and improvement of the steam-engine, and to the ingenious application of its power to kinds of work that formerly tasked the physical energies of the human race. We cannot examine the methods and processes of any branch of industry without discovering somewhere the assistance and support of this wonderful machine.

Relieving mankind from manual toil, it has left to the intellect the privilege of directing the power formerly absorbed in physical labor into other and more profitable channels. The intelligence which has thus conquered the powers of Nature now finds itself free to do brain-work; the force formerly utilized in the carrying of water and the hewing of wood is now expended in the Godlike work of *thought.*

What, then, can be more interesting than to trace the history of the growth of this wonderful invention, the greatest among the many great creations of one of God's most beneficent gifts to man, the power of invention.

3. While following the records and traditions of the steam-engine, I propose to call to your attention the fact that its history illustrates the very important truth that great inventions are never, and great discoveries are seldom, the work of any one mind.

Every great invention is really an aggregation of minor inventions, or the final step of a progression. It is not usually a creation, but a growth, as truly so as is the growth of the trees in the forest.

Hence the same invention is frequently brought out in several countries and by several individuals simultaneously.

Frequently, an important invention is made before the world is ready to receive it, and the unhappy inventor is taught, by his failure, that it is as unfortunate to be in advance of the age as to be behind it.

Inventions only become successful when they are not only needed, but when mankind is so far advanced in intelligence as to appreciate and to express the necessity for them, and at once to make use of them.

4. About a half-century ago, an able New England writer, in a

[1] Dr. Lardner.

communication to an English engineering periodical, described the new machinery which was built at Newport, Rhode Island, by John Babcock and Robert L. Thurston, for one of the first steamboats that ever ran between that city and New York. He prefaced his description with a frequently-quoted remark to the effect that, as Minerva sprang, mature in mind, in full stature of body, and completely armed, from the head of Jupiter, so the steam-engine came forth, perfect at its birth, from the brain of James Watt.

But we shall see, as we examine the records of its history, that, although James Watt was *an* inventor, and probably the greatest of the inventors of the steam-engine, he was still but one of the many men who have aided in perfecting it, and who have now made us so familiar with its tremendous power and its facile adaptation to labor, that we have almost ceased to admire it, or to wonder at this product of the workings of the more admirable intelligence that has so far perfected it.

5. Twenty-one centuries ago, the political power of Greece was broken, although Grecian civilization had risen to its zenith.

Rome, ruder than her polished neighbor, was growing continually stronger, and was rapidly gaining territory by absorbing weaker states.

Egypt, older in civilization than either Greece or Rome, fell but two centuries later before the assault of the younger states, and became a Roman province. Her principal city was at this time Alexandria, founded by the great soldier whose name it bears when in the full tide of his prosperity. It had now become a great and prosperous city, the centre of the commerce of the world, the home of students and of learned men, and its population was the wealthiest and most civilized of the then known world.

It is among the relics of this ancient Egyptian civilization that we find the first record of the early history of the steam-engine.

6. In Alexandria, the home of Euclid, the great geometrician, and possibly contemporary with that talented engineer and mathematician Archimedes, a learned writer, Hero, produced a manuscript which he entitled "Spiritalia seu Pneumatica."

The work is still extant, and has been several times republished. In it are described a number of interesting though primitive forms of water and heat engines, and, among the latter, that shown in Fig. 2,[1] an apparatus moved by the force of steam.

This earliest of steam-engines consisted of a globe, *a*, suspended between trunnions, *G L*, through one of which steam enters through pipes, *C M*, *F E*, from the boiler, *D*, below.

The hollow bent arms, *H* and *K*, cause the vapor to issue in such a direction that the reaction produces a rotary movement of the globe, just as the rotation of reaction water-wheels is produced by outflowing water.

[1] *Vide* Woodcroft's "Translation of Hero."

It is quite uncertain whether this machine was ever more than a toy, although it has been supposed by some authorities that it was actually used by the Greek priests for the purpose of producing motion of other apparatus in their temples.

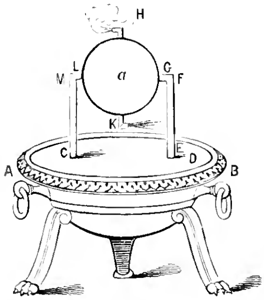


FIG. 2.—HERO'S ENGINE, B. C. 200.

7. It seems sufficiently remarkable that, while the power of steam had been, during all the many centuries that man has existed upon the globe, so universally displayed in so many of the phenomena of natural change, mankind lived almost up to the Christian era without making it useful in giving motion even to a toy; but it must excite still greater surprise that, from the time of Hero, we meet with no good evidence of its application to any practical use for many hundreds of years.

Here and there, in the pages of history and in special treatises, we find a hint that the knowledge of the force of steam is not forgotten; but it is not at all to the credit of biographers and of historians that they have devoted so little time to the task of seeking and recording information relating to the progress of this and other important inventions and improvements in the mechanic arts.

8. In the year 1825, the Superintendent of the Royal Spanish Archives at Simancas furnished an account, which had been there discovered, of an attempt made in 1543, by Blasco de Garay, a Spanish navy-officer, under Charles I.,[1] to move a ship by paddle-wheels, driven, as was inferred from the account, by a steam-engine.

It is impossible to say to how much confidence the story is entitled; but, if true, it was the first attempt, so far as is now known, to make steam useful in developing power for practical purposes. Nothing is known of the form of the engine employed, it only having been stated that a "vessel of boiling water" formed a part of it.

The account is, however, in other respects, so circumstantial that it has been credited by many, but it is looked upon as very doubtful by the majority of writers upon the subject. It was published in 1825

[1] Charles V., Emperor of Germany, was also Charles I. of Spain.

by M. de Navarrete, in the form of a letter from Tomás Gonzales, Director of the Royal Archives at Simancas, Spain.

9. In 1601 Giovanni Battista della Porta, in his work "Spiritali," described an apparatus by which the pressure of steam might be made to raise a column of water, and the method of operation included the application of the condensation of steam to the production of a vacuum into which the water would flow. He used a separate boiler. Fig. 3 is copied from an illustration in a later edition of his work.[1]

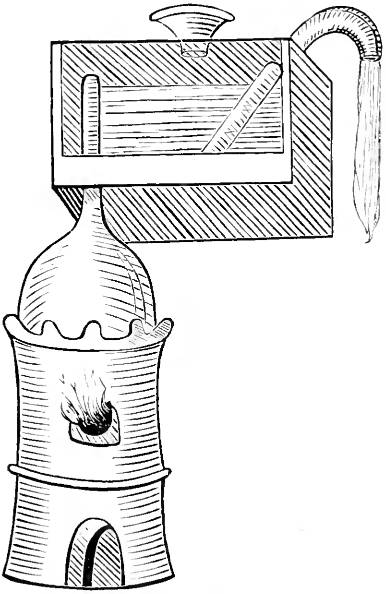


Fig. 3.—Porta's Apparatus, A. D. 1601.

10. In 1615 Salmon de Caus, who had been an engineer and architect under Louis XIII. of France, and later in the employ of the British Prince of Wales, published a work at Frankfort, entitled "Les Raisons des Forces Mouvantes avec diverses machines tant utile que plaisantes," in which he illustrated his proposition, "Water will, by the aid of fire, mount higher than its level," by describing a machine designed to raise water by the expanding power of steam. (*See* Fig. 4.)

This consisted of a metal vessel partly filled with water, and in which a pipe was fitted leading nearly to the bottom and open at the top.

Fire being applied, the steam, formed by its elastic force, drove the water out through the vertical pipe, raising it to a height depending upon either the wish of the builder or the strength of the vessel.

11. In 1629 Giovanni Branca, of Lovetto, an Italian town, de-

[1] "I Tre Libri Spiritali," Napoli, 1606.

scribed, in a work published at Rome, a number of ingenious mechanical contrivances, among which was a steam-engine (Fig. 5), in which the steam, issuing from a boiler, impinged upon the vanes of an horizontal wheel.

This it was proposed to apply to many useful purposes.

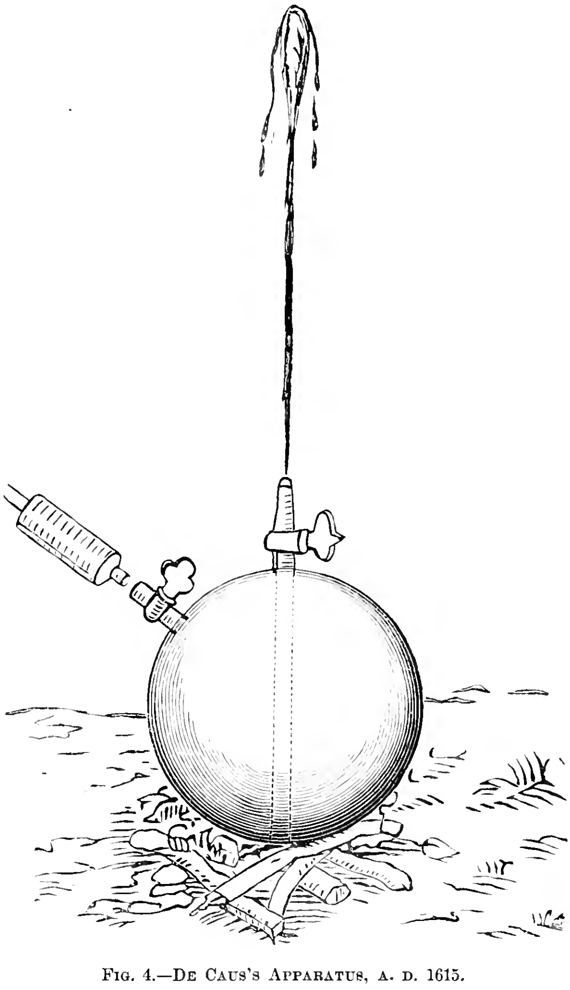


Fig. 4.—De Caus's Apparatus, A. D. 1615.

12. In illustration of the singular manner in which old inventions disappear only to reappear in latter times, it may be remarked that this contrivance was brought forward quite recently by a sanguine inventor, who spent a considerable sum in building what he considered a great improvement upon existing forms of steam-engines.

The engine of Hero also has been frequently reinvented, and, under the designation of "steam turbine," it has been applied with some satisfactory effect to the production of very high velocity of rotation.

13. We now come to the first instance in which the expansive

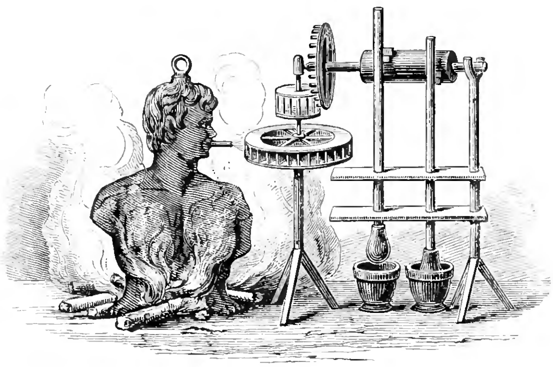


Fig. 5.—Branca's Steam-Engine, a. d. 1629.

force of steam is supposed to have actually been applied to do important and useful work.

In 1663, Edward Somerset, second Marquis of Worcester, published a curious collection of descriptions of his inventions, couched in ob-

Edward Somerset, Second Marquis of Worcester.

scure and singular language, and called a "Century of the Names and Scantlings of Inventions by me already practised."

One of these inventions is an apparatus for raising water by steam.

The description was not accompanied by a drawing, but the sketch here given (Fig. 6), probably resembles his contrivance very closely.

Steam is generated in the boiler *D*, and thence is led into the vessel *A*, already nearly filled with water. It drives the water in a jet out through a pipe, *F* or *F'*. The vessel *A* is then shut off from the

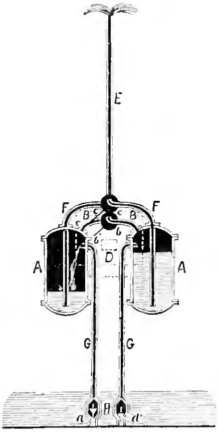


Fig. 6.—Worcester's Engine, A. D. 1650.

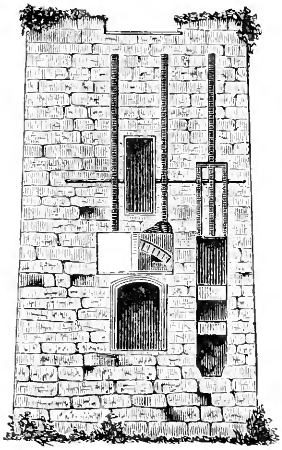


Fig. 7.—Wall of Raglan Castle.

boiler and again filled "by suction" after the steam has condensed through the pipe *G*, and the operation is repeated, the vessel *B* being used alternately with *A*.

The instruments of Porta and of De Caus were "steam fountains," and were applied, if used at all, merely for ornamental uses.

That of the Marquis of Worcester was used for the purpose of elevating water for practical purposes at Vauxhall, near London. It was still earlier used at the home of Worcester, Raglan Castle, where the openings cut in the wall for its reception are still to be seen, as in Fig. 7.

14. The *separate boiler*, as here used, constitutes a very important improvement upon the preceding forms of apparatus, although the idea was original with Porta.

The "water-commanding engine," as its inventor called it, was, therefore, the first instance in the history of the steam-engine in which the inventor is known to have "reduced his invention to practice."

It is evident, however, that the invention, important as it was, does not entitle the marquis to the honor claimed for him by many authorities of being *the inventor* of the steam-engine. Somerset was simply *one* of those whose works collectively make the steam-engine.

Section II. *The Period of Application of the Early Type of Steam-Engine. Morland, Savery, and Desaguliers.*—14. The invention of the Marquis of Worcester was revived twenty years later, by Sir Samuel Morland, but in what form is not now known.

In a memoir,[1] which he wrote upon the subject in 1683, he exhibited a degree of familiarity with the properties of steam that could hardly have been expected of any one at that early date.

In his manuscript, now preserved in the Haarlem Collection of the British Museum, he states the size of the cylinders required in his machine to raise given quantities of water per hour, and gives very exactly the relative volumes of equal weights of water and of steam under atmospheric pressure.

He tells us that one of his engines, with a cylinder six feet in diameter and twelve feet long, was capable of raising 3,240 pounds of water through a height of six inches, 1,800 times an hour.

15. From this time forward the minds of many mechanicians were earnestly at work on this problem—the raising of water by aid of steam.

Hitherto, although many ingenious toys, embodying the principles of the steam-engine separately, and sometimes, to a certain extent, collectively, had been proposed and even occasionally constructed, the world was only just ready to profit by the labors of inventors in this direction.

But, at the end of the seventeenth century, English miners were beginning to find the greatest difficulty in clearing their shafts of the vast quantities of water which they were meeting at the considerable depths to which they had penetrated, and it had become a matter of vital importance to them to find a more powerful aid in that work than was then available.

They were, therefore, by their necessities, stimulated to watch for, and to be prepared promptly to take advantage of, such an invention when it should be offered them.

16. The experiments of Papin, and the practical application of known principles by Savery, placed the needed apparatus in their hands.

When Louis XIV. revoked the Edict of Nantes, by which Henry IV. had guaranteed protection to the Protestants of France, the terrible persecutions at once commenced by the papists drove from the kingdom some of its greatest men.

Among these was Denys Papin, a native of Blois, and a distinguished philosopher. He studied medicine at Paris, and, when expatriated, went to England, where he met the celebrated philosopher Boyle, who introduced him into the Royal Society, of which Papin became a member, and to whose "Transactions" he contributed several valuable papers.

He invented, in 1680, the "Digester," in which substances, unaf-

[1] "Élévation des Eaux, par toutes Sortes de Machine, reduite à la Mesure, au Poids et à la Balance."

fected by water boiling under atmospheric pressure, can be subjected to the action of water boiling under high pressure, and thus thoroughly "digested," or cooked.

The danger of bursting these vessels caused him, in 1681, to in-

DENYS PAPIN.

vent and apply the *lever safety-valve*,[1] now an indispensable appurtenance to every steam-boiler.

17. In 1690 he constructed a working model of an engine, consisting of a steam-cylinder with a piston which was raised by steam-pressure, and which descended again when the condensation of the steam produced a vacuum beneath it.

This apparatus the inventor proposed to use as a motor for working pumps and for driving paddle-wheels; but he never built a successful working machine on this plan, so far as we can ascertain; and he did not then propose a separate boiler, but made the same vessel serve at once as a boiler, steam-cylinder, and condenser, evaporating water in the cylinder itself;[2] and, after raising the piston, removing the cylinder from the fire, or the fire from under the cylinder, to effect condensation by the gradual loss of heat by radiation.

18. The most important advance in actual construction was made by Thomas Savery.

The constant and embarrassing expense, and the engineering difficulties presented by the necessity of keeping the British mines, and

[1] Other forms of safety-valve had been previously used.

[2] "Recueil des diverses Pièces touchant quelques nouvelles Machines et autres Sujets philosophiques," M. D. Papin, Cassel, 1695.

particularly the deep pits of Cornwall, free from water, and the failure of every attempt previously made to provide effective and economical pumping machinery, were noted by Savery, who, July 25, 1698, patented the design of the first engine which ever was actually employed in this work.

Thomas Savery.

A working model was submitted to the Royal Society of London, in 1699,[1] and successful experiments were made with it.

This engine is shown in Fig. 8, as described by Savery himself in 1702, in the "Miner's Friend."

L L is the boiler, in which steam is raised, and through the pipes *O O* it is alternately let into the vessels *P P*.

Suppose it to pass into the left-hand vessel first. The valve *M* being closed and *r* being opened, the water contained in *P* is driven out and up the pipe *S* to the desired height, where it is discharged.

The valve *r* is then closed, and also the valve in the pipe *O*. The valve *M* is next opened, and condensing water is turned upon the exterior of *P* by the cock *Y*, leading water from the cistern *X*. As the steam contained in *P* is condensed, forming a vacuum, a fresh charge of water is driven by atmospheric pressure up the pipe *T*.

Meantime, steam from the boiler has been let into the right-hand vessel *P*, the cock *W* having been first closed and *R* opened. The charge of water is driven out through the lower pipe and the cock *R*, and up the pipe *S* as before, while the other vessel is refilling preparatory to acting in its turn.

[1] "Transactions of the Royal Society," 1699.

The two vessels thus are alternately charged and discharged as long as is necessary. Savery's method of supplying his boiler with water was at once simple and ingenious.

The small boiler *D* is filled with water from any convenient source, as from the stand-pipe *S*. A fire is then built under it, and, when the pressure of steam in *D* becomes greater than in the main boiler *L*, a communication is opened between their lower ends and the water

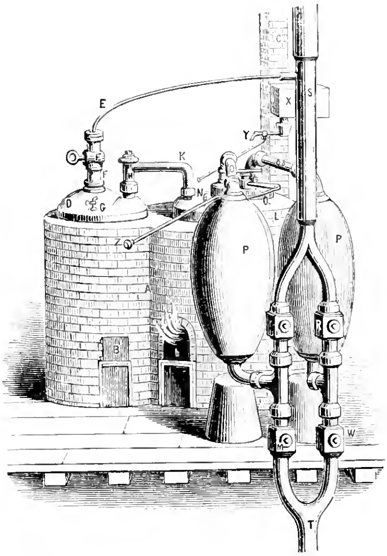


Fig. 8.—Savery's Engine, a. d. 1699.

passes under pressure from the smaller to the larger boiler which is thus "fed" without interrupting the work. *G* and *N* are *gauge-cocks* by which the height of water in the boilers is determined, and these attachments were first adopted by Savery.

19. Here we find, therefore, the first really practicable and commercially valuable steam-engine. Thomas Savery is entitled to the credit of having been the first to introduce into general use a machine in which the power of heat, acting through the medium of steam, was rendered useful.

It will be noticed that Savery, like the marquis of Worcester, and like Porta, used a boiler separate from the water-reservoir.

He added to the "water-commanding engine" of the marquis the system of *surface condensation*, by which he was enabled to change his vessels when it became necessary to refill them; and the secondary boiler, which enabled him to supply the working boiler with water without interrupting its action.

The machine was capable of working uninterruptedly for a period of time only limited by its own endurance.

Savery never fitted his boilers with the safety-valve, although it was subsequently used on Savery engines by Desaguliers; and in deep mines he was compelled to make use of higher pressures than his rudely-constructed boilers could safely bear.

The introduction of his machines was, therefore, greatly retarded by the fear, among miners, of the explosion of his boilers; in fact, such explosion did occur on more than one occasion.

20. The Savery engine was improved, about 1716 or 1718, by Dr. Desaguliers, who attached to it Papin's safety-valve, and substituted a jet injection from the stand-pipe into the "forcing-vessels" for the surface condensation of Savery's original arrangement.

21. The Savery engine, however, after all improvement in design and construction, though a working and a useful machine, was still a very wasteful one. The steam from the boiler, passing into the cold, wet water-reservoir or forcing-vessel, was condensed in large quantity, and also to a very serious extent, by coming into actual contact with the water itself.

Papin, who has already been referred to, in 1707 proposed[1] to avoid this loss, to some extent at least, by the use of his piston, which

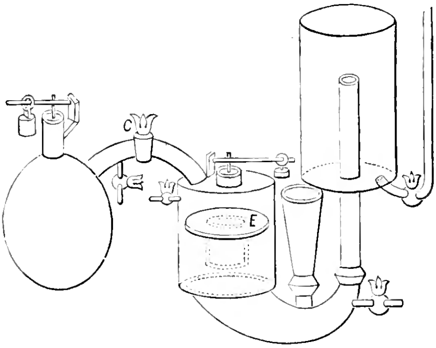


Fig. 9.—Papin's Steam-Engine, a. d. 1707.

he interposed between the steam and the water, as in Fig. 9, which is copied from a sketch given by Papin himself.

This engine is, in principle, a Marquis of Worcester engine, in which the piston E is introduced to separate the steam from the water which it impels, and thus to reduce the amount of loss by condensation.

This engine was never constructed, except experimentally, however, and is principally of interest in a history of the steam-engine from the fact that it was a useful suggestion to succeeding inventors.

Papin had, as early as 1698, abandoned his earlier but more ad-

[1] "Nouvelle Manière de lever l'Eau par la Force de Feu, mise en Lumière." Par M. D. Papin, Docteur en Médecine, Professeur en Mathematique à Cassel, 1707.

vanced project of a piston, driven by steam-pressure on one side, assisted by a vacuum produced on the other; and he can only be regarded, therefore, as an ingenious and intelligent though unfortunate projector, and not as a successful inventor, notwithstanding his acknowledged ability and learning.

THE LAW OF CONTINUITY.

By GEORGE ILES.

WHEN the details of knowledge had in modern times accumulated to so great an extent as to demand some organization of them into principles, thoughtful men cast about for some law which might serve to relate and connect together, in part at least, the multitude of facts and theories which were in an isolated and incoherent state.

At this important stage of scientific development, Galileo was the first to recognize the value of Plato's thought as to the continuous action of natural forces. By arranging in serial order the cases of a law, he showed that phenomena which might be supposed to be radically distinct were really due to one cause; and he said that, where links of connection were unknown, they should be sought for diligently.

Galileo, however, was too busy a man to work out many of the suggestions of the law of continuity, and it remained for Leibnitz to be the first to apply it extensively in the test of physical theories, and in the reduction of fragmentary knowledge to order and intelligibility. He affirmed that nothing passes from one state to another without passing through all intermediate states, and established the truth of his proposition by showing the absurdity of the contrary. If a change were to happen without the lapse of time, the thing changed must be in two different conditions at the same instant, which is manifestly impossible.

From this principle, for example, if it be known that a body at one moment had a temperature of 20°, and at another moment a temperature of 40°, it is certain that at some intervening moment its temperature was 30°. Although this law is so simple when stated as to seem almost axiomatic, yet its cases are frequently so obscure as to have caused much hesitation in its acceptance as a universal or even a widely-operating law. Some of its illustrations, lately discovered, are among the hardest-won triumphs of experimental skill, and have demanded the aid of the most refined modern apparatus.

A typical example of continuity has long been familiar to students of geometry; figures which may differ so much in graphic delineation as the circle, the ellipse, parabola, and hyperbola, may be united by the insensible modifications of surface afforded by the inclination, more and more, of a plane dividing a cone asunder.

Similarly, in mechanics, the arc of a vibrating pendulum may be gradually enlarged by successive impacts until it becomes a circle. The part of a rotation differs generically from a complete one, yet it may approach infinitely near to it, and with only such a difference as exists between one arc and another slightly shorter.

The works on physics issued during the last century abound with distinctions which close and accurate investigations have since removed. Iron was once thought to be the only substance endowable with magnetism; now, not only all the metals, but all bodies whatever, are proved to present this polar force. In like manner, with respect to heat and electricity, conductors and non-conductors were ranged as two opposite classes; this disposition is still practically useful, since most substances conduct either very well or very ill; but it has given way as a precise statement of truth before the demonstration that all substances may be placed in unbroken order as to conductive power. For, while no material transmits either heat or electricity without some resistance, that resistance is in no case indefinitely great.

The transmission of light is another property which is not now confined within a narrow area; transparency is no longer attributed to a few bodies only—air, glass, and the like—it is extended to matter universally, experiment and reason both warranting the belief that any substance whatever, if reduced to a sufficiently thin film, would be pervious to light. Gold, one of the densest metals, can now be deposited by electricity in such tenuity as to be easily penetrated by the solar ray, and, although science is unable to give us any metal but gold in a translucent state, we know the degrees at which such light as passes through every member of the metallic catalogue is refracted. This curious piece of information has been attained by extending to the cases concerned a law, which, as far as experiment has gone, has been found true—namely, that the angle of a ray polarized by reflection always makes 90° with the angle of a refracted ray. Now, the particular angles at which lead, copper, and the rest, polarize light by reflection being observed, a simple calculation tells us how much deflection a beam may undergo in piercing metallic plates. This is an instance of how Science appropriates territory, one might deem ever to be undiscovered, by availing itself of the relationship of laws binding all things together, and interweaving the known and the unknown.

Chemists have taken their acids and alkalies, that were formerly adjudged as possessing qualities diametrically opposite, and now include them in one catalogue, no two consecutive members of which are much more than distinguishable in character. The same order has also been adopted in the electro-chemical arrangement of metals. Upon the possibility of placing all bodies in a continuous list under the head of any property whatever—cohesion, elasticity, and so on—the opinion is now entertained that all matter is capable of receiving, holding, and giving forth, any kind of force.

The varieties of force themselves have been instructively reduced to a single basis—that of motion; electricity, gravity, light, and all the rest, are at present referred to the movement in particular orbits and planes of the ultimate particles which build up all masses. For any sort of force can be converted by suitable means into any other, and all into common mechanical motion. Now, as transformations of energy are incessant in Nature—changes whereby heat becomes electricity, electricity light, and light chemical action—it must be that there are intermediate phases which a body assumes while passing from the manifestation of one of these forces to another. It must be that the ordinary forms of force just named, which seem to be so broadly marked off from each other, must be really united in transmutation by processes of motion too unstable to be caught and detained by our comparatively rude methods of detection and arrest. The extremes of a series we see, the links between elude us.

The kinds of motion to which are given names in our works on physics are, perhaps, only the stable varieties of an indefinitely great number. The swiftness of the transitions from one stable form to another may explain and excuse the notion long held that the different kinds of force were individual entities, unrelated to each other.

Here one of the chief lessons taught us by the law of continuity comes in: we are confronted by a variety of seemingly isolated forces; we find them taking on indifferently one another's forms; and, although we know not how they do so, yet we can see the danger of over-estimating the apparent, while much more may be present though hidden from our sight. The comprehension of all the varieties of force under the one category of motion is hardly fraught with any deduction more suggestive than that which inclines us to acknowledge that mere permanence has hitherto unduly influenced our ideas of what the modes of motion may be in extent and diversity. The existence of electricity was unsuspected, except in the case of rubbed amber, until within a few generations; the fleeting character of the force evading the scrutiny of the majority of the acutest investigators of Nature who have lived.

The noble generalization of the conservation of energy affords another fact and hint of much value. It tells us of the radical identity of all sorts of force, whether as that of the descending clock-weight; or in a simple form of much fixity, as that of heat; or evanescent and easily convertible, as electricity; or intricate and with many paths of working, as chemical affinity; or beyond the reach of any but vague and general means of examination, as the forces of nerve and brain.

Every one of these is within the jurisdiction of the laws of mechanics, even when the motions are so exalted in degree and dignity as to seem of other stock than their real parents. Or, to change the metaphor, the tortuous labyrinth of the whole series diverges by clear and continuous avenues from one simple highway, where the elementary laws of motion are visibly obeyed.

The consistences of matter, as well as its properties, illustrate in a remarkable manner the principle of continuity. Sir William Herschel long ago ventured on general grounds to predict that the solid, liquid, and gaseous states of matter would be found to shade off imperceptibly into each other. Twenty years afterward, the labors of Prof. Andrews, of Belfast, proved the great astronomer right. By the most ingenious appliances, he detained for convenient inspection processes of transition from gas to liquid, which, in their ordinary progress, coalesce so abruptly as to seem instantaneous. In some familiar cases we can perceive changes of the same kind going on; as, for example, in the melting of wax we can follow the alteration from brittle hardness to plasticity, and thence to viscosity and liquefaction. From facts such as these, here very briefly indicated, has arisen the conviction that all matter can assume any of the three consistences. Faraday liquefied, by cold and great pressure, several of what had been called permanent gases, and improvements in the means of producing pressure and cold will doubtless enable us in the future to liquefy the remainder. Although the greatest heat we can bring to bear on carbon does not fuse it, still the tendency of our knowledge is to induce us to believe that coal in burning for a brief instant, too short for observation, exists in the liquid state. A second of time is divisible into millionths quite as perfectly as a geological cycle.

The thread of continuity has, in a variety of cases, been established in the laboratory. No two physical facts would seem to stand more decidedly apart than chemical union and mechanical admixture, yet we find them inextricably joined when we add sulphuric acid and water together. In all possible percentages do these liquids chemically combine, and this at variance with the generally-obeyed law of definite proportions. The same departure from the usual rule also obtains among other complex unions, and corroborates what first principles affirm—namely, that chemical forces are but intense and involved mechanical ones.

In the progress of science there has been much speculation as to the method by which light, electricity, and gravitation, are propagated through space. It is the old question again, "Can matter act where it is not?" Newton found the idea inconceivable, and imagined an ether as the vehicle of motions between the suns and planets of the universe. This position has been criticised by Mill, who says that inconceivableness is no test of truth, and who asserts, with a lack of his usual caution, that scarcely any living thinker of eminence now doubts that matter can act where it is not. What light have recent researches shed upon this interesting question, heretofore little more than metaphysical?

The solar atmosphere has been found to extend to more than half a radius beyond its surface; at the top of its corona, high above the hydrogen, there are vast masses of a gas which emits a simple, green ray, not corresponding with that of any known substance. In auroral displays on earth, in the uppermost regions of our atmosphere, the same simple ray has been detected; whence it has been supposed that atmospheres are not restrictedly planetary nor solar, but continuous and cosmical; and that it may be a gas indefinitely rarefied that conveys to us through the depths of space not only light-motion, but the yet more inappreciable tremors of electricity and gravitation.

The ordinary definitions of the interstellar ether are open to the objections urged by Mill, because of a dread there seems to be abroad of ascribing materiality to it; while its infinitesimal materiality is not only within the bounds of possibility, but well agrees with the facts. All motion takes time; light has a measurable velocity; chemical action of the most violent kind and even explosions are not instantaneous. Were it otherwise, the hypothesis of no medium or of an immaterial one might be entertained. Now, the decidedness in amount of a body's weight as a mass, or in its particles, has no necessary connection with its efficiency as a medium of motion. Just the reverse: we find that as matter is smaller and lighter in its ultimate parts or gross masses, the more rapidly can it communicate motion, and the greater is its capacity for motion. It is a familiar fact that, in the use of machinery, a small wheel can, proportionately to its weight, contain and transmit more motion than a large one, the plain reason of which is that it can be driven at a higher peripheral speed, its smaller bulk causing less centrifugal strain at the axis than if it were larger.

Sound travels nearly four times faster in hydrogen than in air, and in quickness of elastic recoil it is, when compressed, preferable to air in the same degree. Its extraordinary chemical energy, far transcending that of denser gases, is a fact of parallel bearing.

If we can imagine a gas as much thinner than hydrogen as the square of light's velocity exceeds the speed of sound in hydrogen (about 4,000 feet a second), we have a reasonable presentation of what the luminous medium may be—its marvelous tenuity being vastly more than compensated by the mobility of its molecules. And, therefore, the most subtile aëriform fluid conceivable is of enormously more utility in propagating impulses from star to star than solid steel would be. The ether of space perhaps sustains some such relation to a gas as a gas does to a liquid; and the current disputes as to the materiality or immateriality of a cosmic medium recall very suggestively the days, not very distant, when wise men doubted the materiality of air, and the still more recent times when it was found that gases other than air had existence.

Some further speculations, enkindled by the green ray observed in the sunshine, may be here presented as relevant to the subject. Dumas, the eminent French chemist, sought by very careful determination to prove that all atomic weights were exact multiples of that of hydrogen. He found them to be multiples of a number one-fourth that of hydrogen, whence the tenuous masses which lie above the hydrogen on the sun's surface are supposed to be one-fourth the specific gravity of the lightest gas we commonly know. And, as the spectrum it yields is the simplest known or even possible, it is thought that this new unit of the atomic scale may be primal matter, and the source of all material forms. This conjecture is not unsupported by other considerations, for, in the four kinds of stars regarded in the order of their brightness and heat, there is a progressively increasing variety of gases as they approach a lower temperature—a suggestion this as to the origin of our sixty-three so-called elements in chemistry.

In domains above the plane of physics, we can observe many beautiful cases of the law of continuity. On a window-pane in winter we can notice structural forces beginning their work where there has been, as far as we could see, no structure. We may breathe on the glass, and no microscope can there reveal any definite direction in the disposal of the moisture. Yet, from it a symmetrical architecture of frost slowly arises. We may take a crystal just deposited from a solution, break off a corner from it, and replace it in the liquid whence it came, when the damage will be accurately repaired.

Between the inorganic and the organic kingdoms of Nature the old partition-walls have at many points been removed. Formic acid, such as ants secrete, has been made artificially by the synthesis of its elements; and so have other products, formerly regarded as purely organic. Prof. Huxley maintains the opinion that, in the past, highly-complex chemical compounds have passed into the state of what he calls protoplasm, the simplest basis of organic life. The controversy about spontaneous generation is not whether the organic is contained and potential in the inorganic, but whether the transition can be artificially effected now.

Plants, like the fly-catcher, which closes on venturesome insects and absorbs their juices, show us how powers, commonly supposed to be exclusively animal, may be shared by members of the vegetable world. The sensitive-plant has something very like the nervous system which marks the highest types of life, for it not only shrinks when rudely touched, but also when exposed to fumes of chloroform. In the same direction points what in plants generally seems to parallel instinct in animals. If a layer of soil near the surface of the ground be unusually rich and moist, the rootlets in growth are spread almost wholly along that layer, while in any other case they descend.

The tendrils of vines find points for attachment an inch or two from their stems; in cellars and caverns the feeble sprouts grow toward the light which they seem to feel is their life.

Is not all this conformable to the law by which motion takes the path of least resistance, as in the case of the waters of a broken reservoir descending to a valley by the shortest channel; or discharges of electricity harmlessly betaking themselves to the earth through a purposely-exposed conductor?

Instinct, especially in insects, borders on and at times invades the higher realm of intelligence. The shapes of birds'-nests, wax-cells, and so on, are not rigidly invariable, but are always more or less adapted to circumstances. Glass rods have been placed in a bee-hive, and the little workers to avoid them have sprung all sorts of buttresses and arches, such probably as neither they nor any of their progenitors ever undertook before.

Natural history, in the discussions which have recently shaken the world, illustrates how difficult, if not impossible, is the task of trying to draw lines of demarkation, hard and fast, in Nature. The arguments *pro* and *con* as to what constitutes a true species might be gathered into a very bulky volume, and the end of the discussion is not yet.

The probability of truth, on the side of those naturalists who affirm the principle of continuity as explaining the genesis of species, has been strengthened by that principle being made the basis of the best method of zoölogical classification yet produced.

Profs. Huxley and Haeckel describe a tree of life: the main branches of it are the great classes; the divergent limbs, the families; and the minor branches, the species. The wide gaps between the groups of organisms now extant are in considerable measure bridged by recourse to fossils, and the suggestions of embryology—which science studies the phases an animal passes through from conception to birth, and observes the affiliations indicated in antenatal history.

As the gulfs existing between living things present the most formidable difficulty in the way of the reception of the principle of continuity in its broadest claims, it may be admissible here to present some of the explanations given by Lyell and others to account for the fact that so many links of genetic connection are missing. It is most important to a species that it should preserve and intensify some definite method of subsistence—a habit of diving, climbing, swimming, digging, or of catching some particular prey, or finding and living on some special plant. There is a natural premium set upon some expertness of this kind, which we must mark is very apt to run in a narrow groove; and there is a yet greater reward for any new expertness, the occupying of a new field of animal possibility, or an adaptation to circumstances changed by the great forces of Nature—as in the mighty revolutions brought about by astronomical and geological causes.

In periods of transition we can well imagine that an elasticity in stationary circumstances, usually all but dormant in an organism, comes into play with all its power; and hence that the type fit for the new conditions is, comparatively speaking, soon formed and fixed. We may thus understand how it is that a wide diversity among living forms has been brought about, and why it is that few fossils intermediate between them have been discovered. Some very striking ones have been unearthed, but it would be an unwarrantable digression to describe them in a paper of these limits.

The remote extremes which may be joined together by gentle and imperceptible modifications are well illustrated in the facts of ordinary growth. Newton had once to be taught that two and two make four, yet from that day to the culmination of his powers there was no abrupt accession of knowledge or insight. He came by steady advances from the ignorance of a babe to the full stature of the first physical philosopher in Europe.

All this teaches us the supreme importance of looking at things in their dynamic as well as in their static aspect; of regarding the mechanics not less earnestly than the geometry of Nature. For differences in degree may gradually accumulate until they become differences in kind. We have seen how various sources of obscurity may veil processes of genesis, and lead any but a minute and careful observer to mistake a new form for a new identity. We have noticed how the possession of qualities usually in extremes may conceal the fact that the qualities are general—as in the magnet, which is but an exaggerated case of any mass whatever.

We have noticed how the vast differences in the time required in transmutation may tend to confuse the similarity of two cases of a law. The embrowning of a pine fence in the course of years is due to the same cause which chars in a few minutes the same wood when used as fuel. We have remarked, also, the enormous differences in the stability of natural forces: some of them, as heat, are metamorphosed with great difficulty; others, as electricity, are of very weak permanence; and others, again, in whose existence we have good reasons to believe, are too evanescent to be detected by the keenest scrutiny.

It has also appeared that mere complexity of resultant lines, as simple forces interact, may yield the erroneous supposition that new and higher causes than the real ones have come into action.

It has been briefly stated how diverse properties merge into one another, and various consistencies overpass the bounds of common definition; and, leaving the region of fact for that of speculation, it has been shown how the principle of continuity may account for the genesis of our chemical elements, and the transfer of impulses across the diameter of the heavens.

All these facts, probabilities, and suggestions, lead to the conviction that continuity is a universal law; that it prevails everywhere, and has prevailed throughout all time; that its present innumerable and intricate threads have been spun forth from the simplest conceivable state of matter and motion, which from the beginning have been subject to a uniform code of law—a code of law growing more complicated with time by the interaction and mutual influence of primitive principles.

The study of continuity presents many results very pertinent to the great question, "How has Nature assumed the infinite beautiful forms which engage our attention and admiration to-day?" The probabilities in favor of the solution offered by the evolution theory are much enhanced when we consider how insignificant in area, and transient in operation, are many of the bridges connecting together the islands and continents of forces and life.

As we trace out with great pains the unbroken links stretching between the most diverse facts and appearances, links which a cursory view would never discover, we find that that theory which supposes a community of origin and descent for all that now is, has a remarkable body of evidence adducible in its favor.

That Nature has arrived at its present state by the continuous action of forces such as are now at work around us, has become so widely-prevalent a conviction that Mill said, speaking of the inclusion of special laws in general ones convergently, that the question Science now asks is, "What are the fewest and simplest assumptions which, being granted, the existing order of Nature would follow?"

MODERN TROGLODYTES.

By FELIX L. OSWALD, M. D.

THE Troglodytes or Cave-dwellers of ancient Nubia belonged to a tribe which seems to have formed an intermediate link between the Semitic and Ethiopian races, but which has become entirely extinct before the second century of the Christian era. Between Sidi Elgor and Port Er-nassid (the ancient Berenice), on the shores of the Red Sea, Dr. Brehm examined many of the limestone-caverns which were the favorite haunts of these singular beings, and found no difficulty in distinguishing the bones of the Coptic and Arabian burial-places from the Troglodyte skeletons, which could be recognized by their demi-simian skulls, their attenuated brachial and femoral bones, and especially their narrow chests.

These peculiarities Dr. Brehm ascribes to the unnatural habits of the wretched cave-men, who, from cowardice or constitutional sloth, passed the greater part of their existence in the penetralia of their foul burrows, while their neighbors preferred a manlier way of securing themselves against enemies and wild beasts, and saved themselves from the glow of the midsummer sun by cultivating shade-trees. "Herodotus speaks of persecutions," the doctor remarks, "but this fixed custom of theirs may perhaps be attributed to vicious habit, strengthened by hereditary transmission, quite as much as to necessity, for men can become fond of vitiated air, as they contract a passion for fermented drink or decayed food."

It seems really so, if we reflect on the hereditary perversity of millions of Europeans and North American citizens, who in the midst of social security, and without the excuse of the persecuted Nubians, insist on secluding themselves and their children in the foul atmosphere of tenement-houses, factories, and workshops, which might just as cheaply be supplied with pure as with warm air.

The air we breathe, which a great English physician calls gaseous food, may become impure to the degree of being *indigestible* to our lungs and utterly unfit for the performance of functions which are quite as important as those of our solid and fluid victuals. Dull headaches, nausea, loss of appetite and of the sense of smell, and the sadness produced by the unsatisfied hunger after oxygen, are only incidental and secondary evils; the great principal curse of the troglodyte-habit is its influence on the respiratory organs. In 1853, when Hanover and other parts of Northern Germany were visited by a very malignant kind of small-pox, the great anatomist Langenbeck tried to discover "the peculiarity of organic structure which disposes one man to catch the disease while his neighbor escapes . . . . I have cut up more human bodies than the Old Man of the Mountain with all his accomplices," he writes from Göttingen in his semi-annual report, "and, speaking only of my primary object, I must confess that I am no wiser than before. But, though the mystery of small-pox has eluded my search, my labors have not been in vain; they have revealed to me something else—the origin of consumption. I am sure now of what I suspected long ago, viz., that pulmonary diseases have very little to do with intemperance or with erotic excesses, and much less with cold weather, but are nearly exclusively (if we except tuberculous tendencies inherited from *both* parents, I say *quite* exclusively) produced by the breathing of foul air. The lungs of all persons, minors included, who had worked for some years in close workshops and dusty factories, showed the germs of the fatal disease, while confirmed inebriates, who had passed their days in open air, had preserved their respiratory organs intact, whatever inroads their excesses had made on the rest of their system. If I should go into practice and undertake the cure of a consumptive, I should begin by driving him out into the *Deister* (a densely-wooded mountain-range of Hanover), and prevent him from entering a house for a year or two."

The ablest pathologists of the present time incline to the same view. "There *is* a cure for consumption," says Dio Lewis, "though I doubt if it will ever become popular. Even in its advanced stages the disease may be arrested by *roughing it;* I mean by adopting savage habits, and living out-doors altogether, and in all kinds of weather."

That low temperature in open air does not injure our lungs has been recognized even by old-school physicians, who now send their patients to Minnesota and Northern Michigan quite as often as to Florida; and is conclusively proved by the fact that of all nations of the earth, next to the inhabitants of the Senegal highlands, the Norwegians, Icelanders, and Yakuts of Northern Siberia, enjoy the most perfect immunity from tubercular diseases. Dry and intensely cold air preserves decaying organic tissue by arresting decomposition, and it would be difficult to explain how the most effective remedy came to be suspected of being the cause of tuberculosis, unless we remember that, where fuel is accessible, the disciple of civilization rarely fails to take refuge from excessive cold in its opposite extreme—an overheated artificial atmosphere—and thus comes to connect severe winters with the idea of pectoral complaints.

There is a rather numerous class of beasts whose lungs seem able to adapt themselves to an atmosphere almost devoid of oxygen, but the human animal and the Quadrumana do not belong to that class. Monsieur de la Motte-Baudin, who was connected with the scientific staff of the *Jardin des Plantes* as their "menagerie-doctor" for more than twenty years, never omitted to dissect his deceased patients before turning them over to the taxidermist, and invariably found that *all* monkeys had succumbed to some variety of phthisis, while the lungs of the badgers, bears, and foxes, were perfectly sound. The three last-named animals are natural cave-dwellers, and have been provided with organs especially contrived to resist the effluvia of their burrows; while the *Simiæ*, like man, are open-air creatures, whose proper atmosphere is the cordial air of woodlands.

Among the natives of Senegambia pulmonary affections are not only nearly but absolutely unknown; yet a single year passed in the over-crowded man-pens and steerage-hells of the slave-trader often sufficed to develop the disease in that most virulent form known as galloping consumption; and the brutal planters of the Spanish Antilles made a rule of never buying an imported negro before they had "tested his wind," i. e., trotted him up-hill and watched his respirations. If he proved to be "a roarer," as turfmen term it, they knew that the dungeon had done its work and discounted his value accordingly. "If a perfectly sound man is imprisoned for life," says Baron d'Arblay, the Belgian philanthropist, "his lungs, as a rule, will first show symptoms of disease, and shorten his misery by a hectic decline, unless he should commit suicide."

Our home statistics show that the percentage of deaths by consumption in each State bears an exact proportion to the greater or smaller number of inhabitants who follow in-door occupations, and is highest in the factory districts of New England and the crowded cities of our central States. In Great Britain the rate increases with the latitude, and attains its maximum height in Glasgow, where, as Sir Charles Brodie remarks, windows are opened only one day for every two in Birmingham, and every three and a half in London; but going farther north the percentage suddenly sinks from twenty-three to eleven, and even to six, if we cross the fifty-seventh parallel, which marks the boundary between the manufacturing counties of Central Scotland and the pastoral regions of the north.

It is distressingly probable, then, to say the least, that consumption, that most fearful scourge of the human race, is *not* a "mysterious dispensation of Providence," nor a "product of our outrageous climate," but the direct consequence of an outrageous violation of the physical laws of God. Dyspepsia (for which also open-air exercise is the only remedy), hypochondria, and not only obstruction but destruction of the sense of smell—"knowledge from one entrance quite shut out"—will all be pronounced mere trifles by any one who has witnessed the protracted agony of the Luft-Noth, as the Germans call it with horrid directness—the frantic, ineffectual struggle for life-air. Dr. Haller thought that, if God punishes suicide, he would make an exception in favor of consumptives; and there is no doubt that, without the merit of martyrdom, the victim of the cruel disease endures worse than ever Eastern despot or grand-Inquisitor could inflict on the objects of his wrath, because the same amount of torture in any other form would induce speedier death.

But not only the punishments but also the warnings of Nature are proportioned to the magnitude of each offense against her laws. Injurious substances are repulsive to our taste, incipient exhaustion warns us by a feeling of hunger or weariness, and every strain on our frame that threatens us with rupture or dislocation announces the danger by an unmistakable appeal to our sensorium. How, then, can it be reconciled with the immutable laws of life that the greatest bane of our physical organism overcomes us so unawares that consumption is proverbially referred to as the insidious disease? Should it really be possible that Nature has failed to provide any alarm-signals against a danger like this? The truth is, that none of her protests are more pathetic or more persistent than those directed against the habit that is fraught with such pernicious consequences to our respiratory organs.

It is probable that some of the victims of our numerous dietetic abuses have become initiated to these vices at such an early period of their lives that they have forgotten the time when the taste of tea and alcohol seemed bitter, or the smell of tobacco produced nausea; but I am certain that no man gifted with a moderate share of memory, who has grown up in the pest atmosphere of our city tenements, school-rooms, and workshops, can forget the passionate yearnings of his childhood for the free air of the woods and mountains; the wild outcry of his instinct against the process that inoculated him with the seeds of death, and stunted the development of his most vital faculties. The remorselessness of the pagan Chinese, who smother the life-spark of their infants in the swift embrace of the river-god, is mercy itself compared to the cruelty of Christian parents who suffocate their children by the slow process of stinting their life-air, through years and years of confinement in dungeons to which an enlightened community would not even consign their malefactors.

Honest Jean Paul relates that he used to secure a seat in a certain corner of an overcrowded village schoolhouse, where a knot-hole in the wall established a communication with the outer world. Through this orifice he imbibed comfort and inspiration as from a flask, but conceived conscientious scruples against the practice, as he never could indulge without becoming conscious of a temptation to abandon his old parents and his home, and join a troop of wood-cutters or gypsies, not from any vagrant tendencies, or want of dutiful sentiments, but from an almost irresistible desire to make the luxury of fresh air a permanent blessing. "I knew they would charge me with black ingratitude, if I should run away," he says. "Good God! how I longed to prove my affection by working for them in wind and weather, fetching in cord-wood from the woods and splitting it into the nicest, handiest pieces, carrying messages over the snow-covered mountains and be back in half the time any one else could make the trip—do anything that would save me—not from my books, but from that glowing Moloch of a big stove, and that stifling, soul-stifling smell of our dungeon!"

Even to the most inveterate believer in natural depravity this might suggest a doubt whether the repugnance of children to study may not be founded on a physical virtue rather than on moral perverseness. To whatever is really beneficent we are commonly drawn by natural attraction, and whatever appears violently repulsive to youthful minds may be justly suspected of containing more of evil than of good. The very disciple of Socrates who used to run sixteen miles a day to hear the *ἄριστος ἰατρων* (best of physicians), would have hesitated to purchase physic for his soul at the price of physical health; and we cannot blame our children for being unable to reconcile the precepts they hear with those they feel, and giving way now and then to the more consistent and more logical prompter.

The farmer's boy may look forward to each afternoon and each summer vacation as a refreshing interlude, and to the last term of his school-years as the last act of the tragedy; but in cities the end of the school-room bondage is too often the beginning of the endless slavery which awaits the young apprentice of the workshops, factories, and counting-houses. In Northwestern Europe and the Eastern States of North America, eleven million human beings, a fourth of that number minors, are performing their daily toil in an atmosphere that saps the vigor of their souls and bodies more effectually than a diet of potatoes and water could do it in the same time. A full third of the cotton-spinners of Lancashire and Massachusetts are girls and boys in their teens! They do not complain to a stranger, unless he should be able to interpret the language of their haggard faces and weary eyes; but no one who has fathomed the depth of their misery will charge me with exaggeration if I say that, to the vast majority of the unfortunates, loss of feeling and of reason would be a blessing. What *do* they feel but unsatisfied hunger in a hundred forms, and what can reason tell them but that they have been defrauded of their birthright to happiness; that not only their opportunity but their capacity for enjoyment is ebbing away; and that, whatever after-years may bring, their life has been robbed as a day of its morning or a year of its spring-time?

The opium-habit may be acquired in less than half a year, and the natural repugnance to alcohol and tobacco is generally overcome after four or five trials; but the factory-slave has to pass through ten or fifteen years of continual struggle against his physical conscience, before the voice of instinct at last becomes silent, and the painful longing for out-door life gives way to that anæsthesia by which Nature palliates evils for which she has no remedy. In more advanced years the habit becomes confirmed, and we find old *habitués* who actually enjoy the effluvia of their prisons, and dread cold air and "drafts" as they would a messenger of death. They avoid cold instead of impurity, just as tipplers on a warm day imagine that they would "catch their death" by a draught from a cool fountain, but never hesitate to swallow the monstrous mixtures of the liquor-vender.

Rousseau expresses a belief that any man, who has preserved his native temperance for the first twenty-five years, will afterward be pretty nearly proof against temptation, because very unnatural habits can only be acquired while our tastes have the pliancy of immaturity, and I think the same holds good of the troglodyte-habit: no one who has passed twenty or twenty-five years in open air can be bribed very easily to exchange oxygen for miasma.

Shamyl-ben-Haddin, the Circassian hero chieftain, who was captured by the Russians in the winter of 1864, was carried to Novgorod and imprisoned in an apartment of the city armory, which resembled a comfortable bedchamber rather than a dungeon, and was otherwise treated with more kindness than the Russians are wont to show their prisoners, as the Government hoped to use his influence for political purposes. But a week after his arrival in Novgorod the captive mountaineer demanded an interview with the commander of the armory, and offered to resign his liberal rations and subsist on bread and cabbage-soup like the private soldiers of his guard, and also to surrender some valuables he had concealed on his person, on condition that they would permit him to sleep in open air. One more week of such nausea and headache as the confinement in a closed room had caused him, would force him to commit suicide, he said, and, if his request was refused, God would charge the guilt of the deed on his tormentors. After taking due precautions against all possibility of escape, they permitted him to sleep on the platform in front of the guard-house; and Colonel Darapski, the commander of the city, informed his government in the following spring that the health and general behavior of his prisoner were excellent, but he had slept in open air every one of the last hundred nights, with no other covering but his own worn-out mantle, and a woollen cap he had purchased from a soldier of the guard to keep his turban from getting soiled by mud and rain.

General Sam Houston, the liberator of Texas, who had exiled himself from his native State in early manhood, and passed long years, not as a captive, but as a voluntary companion of the Cherokee Indians, was ever afterward unable to prolong his presence in a crowded hall or ill-ventilated room beyond ten or twelve minutes, and described his sensation on entering such a locality as one of "uneasiness, increasing to positive alarm, such as a mouse may be supposed to feel under an air-pump."

The cause of this uneasiness is less mysterious than our nature's wonderful power of adaptation that can help us ever to overcome it. The elementary changes in the human body are going on with such rapidity that the waste of tissue and organic fluids is only partially retrieved by the digestible part of the substances which we feed to the abdominal department of our laboratory twice or thrice in twenty-four hours. The difference is made up by the labors of the upper or pectoral department, which renews its supply of raw material independently, or even in spite of our will, twenty times per minute, or 70,000 times in twenty-four hours! With every breath we draw we take into our lungs about one pint of air, so that the quantity of *gaseous food* thus consumed by the body amounts in a day to 675 cubic feet. The truth, then, is that eating and drinking may be considered as secondary or supplementary functions in the complicated process performed by that living engine called the animal body, while the more important task falls to the share of the lungs. The stomach may suspend its labors entirely for twenty-four hours without serious detriment to the system, and for two or three days without endangering life, while the work of respiration cannot be interrupted for six minutes without fatal consequences.

The first object of respiration is to introduce elements needed in the preparation of blood, the second to remove gaseous carbon and other secretions of the air-cells. The deleterious consequences, therefore, of breathing the same air over and over again arise not only from the exhaustion of oxygen, but also from the circumstance that the confined atmosphere may become azotized or surcharged with carbon to the limit of its absorbing powers, just as water, after being saturated with certain percents of salt or sugar, refuses to dissolve any further additions. The act of reinspiring air, which has already been subjected to the process of pulmonary digestion, is thus precisely analogous to the act of a famished animal devouring its own fæces, and if performed habitually cannot fail to be attended with equally ruinous consequences. Corruption of the alimentary ducts would surely ensue in the latter (supposed) case, putrefaction of the respiratory organs *does* follow in the other. Working-men employed in localities whose azotized atmosphere is loaded besides with particles of flying cotton-fibre, metallic dust, or fatty vapors, inspire substances which are just as indigestible to their lungs as mercury and alcohol are to their stomachs, and like these cause a rapid deterioration of the tissues in proximity to which they are deposited.

The only wonder, then, is how Nature can resist outrages of this kind for any length of time; and it is a curious reflection to think what amounts of hardship of the primitive sort, such as hunger, fatigue, cold, heat, deprivation of sleep, etc., a healthy savage might accustom himself to, if he tried as hard as the poor children of civilization try to wean themselves from their hunger after life-air!

Can necessity be—we will not say an excuse, but—an explanation of such systematic self-ruin? We must utterly refuse to believe it. Wherever men barter life for bread, there is a violent presumption that they do not know what they are doing; for against recognized health-destroyers even the poorest of the poor will rebel with a promptitude that vindicates the dignity of human nature under the most abject conditions of bondage. Let a railroad contractor be caught in the trick of adulterating his flour with chalk or his sugar with alum, and see how quickly his navvies will leave him; or observe how firmly reckless Jack Tar insists on his anti-scorbutic raspberry-vinegar! Miners have left a colliery *en masse*, because the owner shirked his duty of providing safety-lamps; and the very negro slaves of a South Carolina plantation attempted the life of their master, who stinted their allowance of quinine brandy which his father had issued them to counteract the miasmatic tendencies of the rice-swamp.

Neither is it possible to suppose that want of hygienic education can be the origin of such ignorance; for Nature does not wait for the scientist to inform her children on questions of such importance. All normal things are good, all evil is abnormal; vice is a consequence of ignorance only in so far as it is a result of perverse education, and the troglodyte-habit is the direct offspring of mediæval monachism. Until after the fourth century of the Christian era, habitual in-door life between closed walls was known only as the worst form of punishment. Though the Greeks and Romans were familiar with the manufacture of glass, they never used it to obstruct their windows; in all the temples, palaces, and dwelling-houses of antiquity, the apertures provided to admit light admitted fresh air at the same time. The *tuguria* of the Roman peasants were simply arbors; and the domiciles of our hardy Saxon forefathers resembled the log-cabins of Eastern Tennessee—rough-hewed logs laid crosswise, with liberal interspaces that serve as windows on all sides except that opposed to the prevailing wind, north or northwest, where they are stopped with moss.

Men had to be utterly divorced from Nature before they could prefer the hot stench of their dungeons to the cool breezes of heaven, but our system of ethics has proved itself equal to the task. For eighteen hundred years our spiritual guides have taught us to consider Nature and everything natural as wholly evil, and to substitute therefor the supernatural and the artificial, in physical as well as in moral life. The natural sciences of antiquity they superseded by the artificial dogma, suppressed investigation to foster belief, substituted love of death for love of life, celibacy for marriage, the twilight of their gloomy vaults for the sunshine of the Chaldean mountains, and their dull religious "exercises" for the joyous games of the *palæstra*. This system taught us that the love of sport and out-door pastimes is wicked, that the flesh has to be "crucified" and the buoyant spirit crushed to make it acceptable to God; that all earthly joys are vain; nay, that the earth itself is a vale of tears, and the heaven of the Hebrew fanatic our proper home.

"The monastic recluse," says Ulric Hutten, "closes every aperture of his narrow cell on his return from midnight prayers, for fear that the nightingale's song might intrude upon his devotions, or the morning wind visit him with the fragrance and the greeting of the hill forests, and divert his mind to earthly things from things spiritual. He dreads a devil wherever the Nature-loving Greeks worshiped a god." These narrow cells, the dungeons of the Inquisition, the churches whose painted windows excluded not only the air but the very light of heaven, the prison-like convent-schools and the general control exercised by the Christian priests over the domestic life of their parishioners, laid the foundation of a habit which, like everything unhealthy, became a second nature in old *habitués*, and gave birth to that brood of absurd chimeras which, under the name of "salutary precautions," inspire us with fear of the night air, of "cold draughts," of morning dews, and of March winds.

I have often thought that *mistrust in our instincts* would be the most appropriate word for a root of evil which has produced a more plentiful crop of misery in modern times than all the sensual excesses and ferocious passions of our forefathers taken together. What a dismal ignorance of the symbolic language by which Nature expresses her will is implied by the idea that the sweet breath of the summer night which addresses itself to our senses like a blessing from heaven could be injurious! Yet nine out of ten guests in an overheated ballroom or travelers in a crowded stage-coach will protest if one of their number ventures to open a window after sundown, no matter how glorious the night or how oppressive the effluvia of the closed apartment. Pious men they may be, and most anxious to distinguish good from evil, but they never suspect that God's revelations are written in another language than that of the Hebrew dogmatist. Here, as elsewhere, men suppress their instincts instead of their artificial cravings. If we have learned to interpret the fact that a child whose mind is not yet biased by any hearsays is sure to prefer pure and cold air to the miasmatic "comfort" of a close room, the troglodyte-habit will disappear, as intemperance will vanish if we recognize the significance of that other fact—that to every beginner the taste of alcohol is repulsive, and that only the tenth or twelfth *dosis* of the obnoxious substance begins to be relished; just as the Russian stage-conductor relishes the atmosphere of his ambulant dungeon, whatever may have been his feelings of horror on the first trip.

If ever we recognize a truth which was familiar enough to the ancients, but seems to have been forgotten for the last ten or twelve centuries, viz., that our noses were given us for some practical purpose, the architecture of our dwellings, our factories, school-rooms, and places of worship, will be speedily corrected; and even the builder of an immigrant-ship will find a way to modify that floating Black Hole of Calcutta called the steerage. Prisons, too, will be modeled after another plan. Our right to diet our criminals on the ineffable mixture of odors which they are now obliged to accept as air depends on the settlement of the question whether the object of punishment is reform or revenge? In the latter case the means answer the purpose with a vengeance indeed: in the first case there is no more excuse for saturating the lungs of a prisoner with the seeds of tuberculosis than there would be for feeding him on trichinæ or inoculating him with the leprosy-virus.

The exegesis of consumption very nearly justifies Michelet's paradox—that the greatest evils might be easiest avoided. "There is no excuse for famine," says Varnhagen von Ense; "we could all live in clover if we did not misapply a large portion of our arable land to the production of tobacco, opium, and other poisonous weeds, and send ship-loads of our breadstuffs to the distillery. I am sure that if the spontaneous productions of the soil furnished us mountains of grain and rivers of honey, we would still manage to use it up in the manufacture of intoxicating poisons, and complain of hunger as before. If any one should doubt this, let him reflect on the fact that, while we are surrounded by a respirable atmosphere of more than 800,000,000 cubic miles, *civilization has contrived a famine of air!*"

THE SYSTEM OF SIRIUS,[1]

AND SOLAR SYSTEMS DIFFERENT FROM OURS.

By CAMILLE FLAMMARION.

EACH of the stars which glitter in the depths of space is a voluminous and massive sun like that which gives light to our earth. Distance alone reduces them to the appearance of fixed points. If we could approach any one of them we should experience the same impression as in passing from Neptune to the sun; the star would increase in size as we should approach it; it would soon exhibit a circular disk and continue to increase its proportions until they would be as large as the sun; finally, this luminous disk, continuing to increase in consequence of our approach, would expand and present itself as a fiery furnace filling the entire heavens—a colossal blaze, under which we would be reduced to nothing, melted like wax, vapor ized like a drop of water dropped on red-hot iron! Such is every star in the heavens.

Each sun in space has its special sphere of attraction, a sphere which extends to the limit of neutralization by another. This attraction diminishes in the inverse ratio of the square of the distances, but never becomes absolutely nothing. At the distance of Neptune the solar attraction is 900 times less than at the distance of the earth. While the earth if it were stopped in its course would fall toward the sun 294 hundred-thousandths of a metre during the first second of time, Neptune would fall only 327 hundred-millionths of a metre in the same time. At the aphelion distance of the comet of 1680 the fall toward the sun is only the minute distance of 416 hundred-billionths of a metre during the first second of time. This attraction continues thus to decrease as the distance increases. But, at the same time, if a body moves in the direction of one of the neighboring stars, it begins immediately to receive its influence. The star nearest us is at a distance 210,000 times greater than that which separates the earth from the sun, or eight trillions of leagues; it is the star Alpha Centauri, a brilliant double star whose orbit and mass I have calculated. This mass is equal to the half of that of the sun; it happens that if one could travel from the sun to this star a point would be reached where the attraction of the two would neutralize each other; this point is three-quarters of the distance which separates us, that is, six trillions of leagues from our sun, or, what is the same, two trillions of leagues from Alpha Centauri, the whole distance being eight trillions. At that point, a celestial body, a comet, would hesitate as to which course to pursue, would weigh nothing, would

[1] Translated from the French by P. A. Towne.

stop in its flight; but the feeblest outward influence would be felt, throwing it either into the sphere of attraction of our sun or into that of Alpha Centauri.

This sun called Centaurus is located in the southern sky, near the antarctic pole. It appears to us in the form of a bright star of the first magnitude. The sun nearest to us, next after this, is situated in the northern sky, in the constellation Cygnus, or the Swan. It is famous as 61 Cygni. Its distance is 400,000 times the radius of the earth's orbit, or about fifteen trillions of leagues. I have often observed this star: it is just visible to the naked eye, but to the telescope it is double, as the preceding, only its components do not move around each other, a conclusion which has much surprised me, although arrived at by comparing all the observations made during the last hundred years; its mass, therefore, cannot be determined. But, however that may be, the fact which should impress us is that the distances which separate the suns of the universe are reckoned not by millions, nor by billions, but by trillions of leagues.

The most brilliant star of our sky, Sirius, is a sun whose volume, judging from its light, should be 2,600 times larger than that of our sun. Its distance is about 897,000 times thirty-seven millions, that is about thirty-three *trillions* of leagues.

Let us mention again among "our neighbors" the sixty-second of Ophiuchus, situated near the equator. I have calculated that it weighs about *three times as much as our sun*, that is, 900,000 times more than the earth. Its distance is 1,400,000 times the semi-diameter of the earth's orbit, that is, fifty-four trillions of leagues.

Astronomers, since the time of Kepler, agree in admitting that each of the countless suns that fill infinite space is the centre of a system analogous to the planetary system of which we form a part. Each of these suns that we see in the sky shows to us a luminous fireside around which other human families are gathered. Our eyes are too feeble to see these unknown planets. The most powerful of our telescopes do not yet reach down to these depths. But Nature concerns itself neither with our eyes nor with our telescopes, and so, beyond the boundaries that stop the flight of our tired conceptions, she continues to display her boundless and magnificent works.

However, the hour has come when these planetary systems different from ours cease to slumber in the domain of hypothesis. In spite of the telescope, celestial mechanics have already revealed the existence of obscure stars, invisible in the rays of these distant suns, but which affect them in their proper movements across immensity; and already powerful telescopes have contemporaneously recognized several among the stars known before to exist only in hypothesis.

One of the most splendid conquests of sidereal astronomy has been the discovery of the system of Sirius, made some fifteen years since. For a long time, from careful measures of its position, it has been remarked that this brilliant star is slowly moving in space, like all the other stars, but that its proper movement is not uniform; and Bessel announced, thirty years ago, that at some time there would be discovered, without doubt, a world of its system moving around it and disturbing it in its progress. This discovery was made in 1862. The companion of Sirius was then almost exactly on the eastern side, quite small, and buried in the rays of the star. Since that year it has been constantly watched by the aid of powerful instruments, and it is seen to slowly gravitate around the Sirian sun.

But this companion certainly does not follow the theoretic orbit calculated to correspond to the perturbations noted in the proper movement of the brilliant star. Differences more and more marked are shown between the calculated ellipse and the observed ellipse. The following is the orbit calculated by the German astronomer Auwers in 1864 to correspond with recognized perturbations:

Passage by lower apsis	1793.890
Annual movement	7O.28475
Period ....years	49.418
Eccentricity	0.6010

The last orbit calculated by Auwers, placed in the form of the orbits of double stars, and given as definitive, is the following:

Perihelion passage	1843.275
Longitude of node	61°.57,8
Angle between node and perihelion	18°.54,5
Inclination	47°.8,7
Eccentricity	0.6148
Semi-major axis	7″.331
Period ....years	49.399

From these elements, the limits of distance ought to be 2.31″ at 302.5° in 1841, and 11.23″ at 71.7° in 1770, and the ephemeris is—

1862	85°.4	10″.10	1874	65°.0	10″.95
1865	79°.9	10″.78	1876	62°.1	10″.59
1868	75°.0	11″.15	1878	58°.4	10″.05
1871	70°.3	11″.20	1880	54°.2	9″.33

But, in making out my "Catalogue of Double Stars in Movement," I have found that all the observations on the satellite of Sirius give the following means for each year since its discovery:

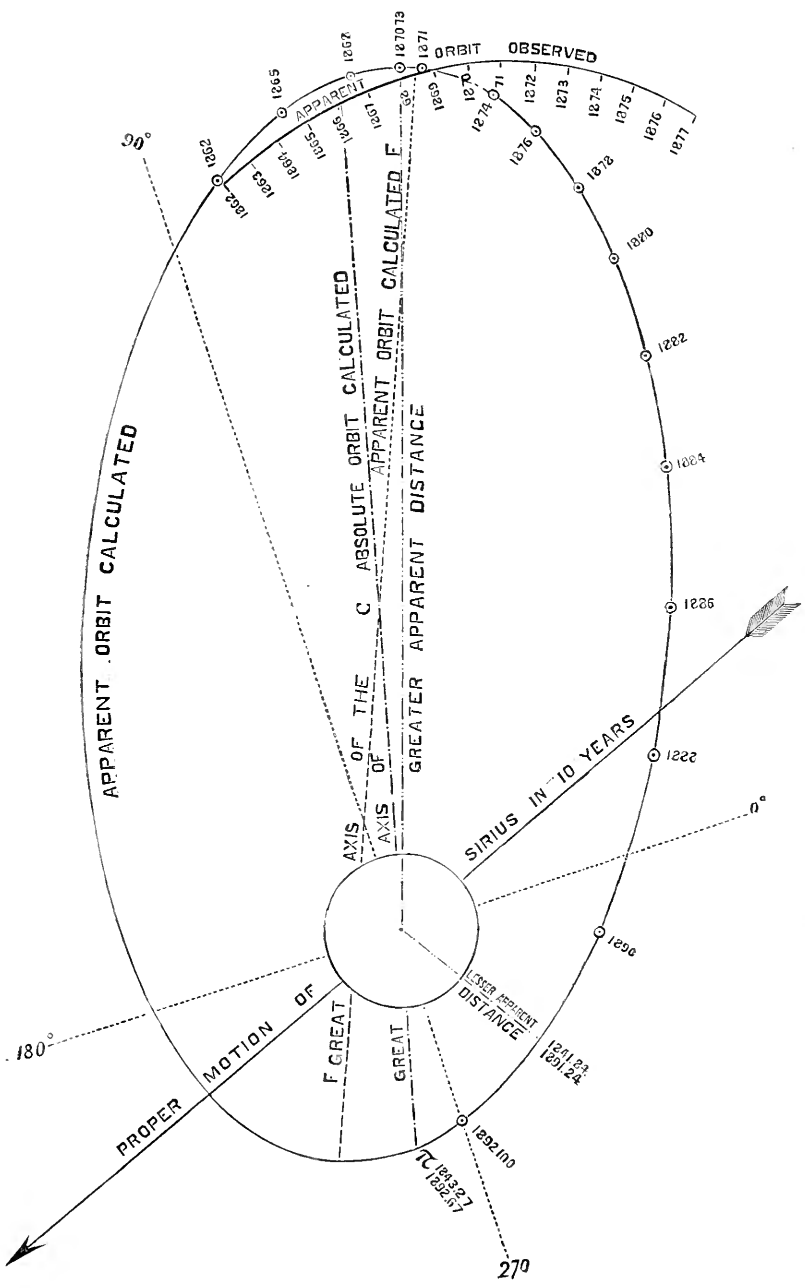
1862	84°.6	10″.08	1870	65°.0	12″.06
1863	82°.2	9″.84	1871	63°.0	11″.79
1864	79°.0	10″.33	1872	61°.3	11″.34
1865	76°.7	10″.56	1873	62°.7	11″.33
1866	75°.0	10″.61	1874	58°.5	11″.18
1867	73°.9	10″.39	1875	55°.5	11″.30
1868	70°.4	11″.18	1876	55°.2	11″.51
1869	72°.3	10″.92	1877	51°.0	11″.40

Pardon these figures! But they form the basis of the reasonings which constitute the groundwork of this article, and it is essential to consider them in order to know on what to rely in discussing the system of Sirius. In comparing these last numbers with those of the preceding ephemeris, we see at the first glance that the angle diminishes more rapidly than had been announced, while the distance has continued to increase since 1870 instead of having attained its maximum on that year, as the orbit of Auwers indicated. It is still further shown by the diagram I have constructed that the arc of the observed orbit crosses the calculated orbit about 1868 and is projected outside of it, pursuing a wholly different curve which must be larger than the orbit traced and less eccentric.

If the observed motion were the mean motion, the revolution of the satellite would be accomplished in a period of about one hundred and sixty-seven years. But the arc passed is yet too small to allow any positive conclusion, and, as the observed perturbations of Sirius demand a period of forty-nine years, we are brought to the conclusion that the observed companion continues to accelerate its motion and will be found in the west of Sirius in 1892, or else there is another body causing perturbation nearer Sirius, and moving more rapidly.

We should reserve all conclusions in regard to the existence of these other satellites, as well as all difference of period between the observed orbit and the calculated orbit; but the inevitable conclusion is, that the observed positions do not correspond with those of the ephemeris, and that the orbit thence resulting differs from the calculated orbit.

By the aid of all the observations I have constructed the figure, which shows the movement of the observed planet from 1862 to 1877. The central disk represents Sirius; the four cardinal points are indicated by dotted lines; the proper movement of Sirius in space is marked by the large arrow, whose length corresponds exactly to this movement during ten years (the figure is drawn to the precise scale of ten millimetres for a second). If the small star discovered in 1862 to the east of Sirius did not belong to it, if it was situated in the depths of space far beyond, it would have remained fixed, and Sirius would have moved from it in the direction indicated by the arrow. But, on the contrary, it belongs to Sirius, accompanies that sun in its progress as the earth accompanies its sun, and turns around it in an elliptic orbit. It has yet traversed, from 1862 to 1877, only the line marked on the figure—a curve not long enough to enable us to calculate the remainder of its orbit. As it is seen, this star is quite small by the side of Sirius, but still larger than Jupiter relatively to our sun. Is it an immense planet, totally opaque and shining only by reflection of the light of Sirius? This is not probable; it must still be self-luminous just as our own earth was during so many ages. It does not correspond exactly to the observed perturbations, a fact which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proves that the system of Sirius certainly contains other worlds yet unseen. Our lamented friend Goldschmidt believed he saw three other planets. Thus, in conclusion, we have a solar system, outside of our own, as an object of study.

We know a great number of stars which are accompanied by smaller stars moving around them like the earth around the sun. These systems, which are now numbered by hundreds, have been so carefully observed that we have been able to calculate the orbits and periods of the planets, brilliant or opaque, which compose them.

It is, then, no longer on mere hypothesis that we can speak of solar systems other than our own, but with certainty, since we already know a great number, of every order and of every nature. Single stars should be considered as suns analogous to our own, surrounded by planetary worlds. Double stars, of which the second star is quite small, should be placed in the same class, for this second star may be an opaque planet reflecting only the light of the large one, or a planet still giving out heat and light. Double stars of which the two components give the same brightness are combinations of two suns around each of which may gravitate planets invisible from this distance; these are worlds absolutely different from those of our system, for *they are lighted up by two suns*, sometimes simultaneous, sometimes successive, of different magnitudes, according to the distances of these planets from each of them; and they have double years of which the winter is warmed by a supplementary sun, and double days of which the nights are illuminated, not only by moons of different colors, but also by a new sun, a sun of night!

Those brilliant points which sparkle in the midnight sky, and which have, during so many ages, remained as mysteries in the imagination of our fathers, are therefore *veritable suns*, immense and mighty, governing, in the parts of space lighted by their splendor, *systems different from that of which we form a part.* The sky is no longer a gloomy desert; its ancient solitudes have become regions peopled like those in which the earth is located; obscurity, silence, death, which reigned in these far-off distances, have given place to light, to motion, to life; thousands and millions of suns pour in vast waves into space the energy, the heat, and the diverse undulations, which emanate from their fires. All these movements follow each other, interfere, contend, or harmonize, in the maintenance and incessant development of universal life.

THE DIFFERENCES OF THINGS.

By JOHN W. SAXON.

COULD a man do himself up into a mathematical point and throw himself into the middle of infinite empty space, wherever that is, he would be surprised at the flatness of life under such circumstances. Infinite empty space is absolute *sameness.* It is, so far as I have traveled the field of mental possibilities, the only specimen of the thinkable or the unthinkable of which we can say, "It is all alike."

Should we melt up the matter which is supposed to be scattered throughout infinite space, and then, by increased heat, turn it into gas, and expand it till all the systems of the universe became one infinitely-extended and equally-distributed universe of intermingled gases, we should have about as little variety as in the case of empty space.

Having unshackled the universe, and brought chaos back again, having secured a condition somewhat like that in which the advocates of the nebular theory suppose it to have been, consider what a dull time we should have if we were unable to find some little nook outside of infinite space, and, as a result, be obliged to amuse ourselves with such monotonous surroundings! It would be as wearisome as staring day after day at a blank wall without so much as a rain-streak on it.

But Nature seems to have understood that variety is not only "the spice of life," but life itself; and no sooner does she get in hand her raw material, than she sets herself to the work of creating *differences.* True, some astronomers reject the nebular theory; but, if not true, it will serve as an illustration. It seems to have been the great work of Nature to multiply differences. For instance, there was a time or an eternity in which Nature turned out her first owl, just as the first patent Yankee washing-machine must have had its day. But the inventors of the owl and of the washing-machine have gone on differentiating with unlike results. Most of the washing-machines are at rest. The fittest even scarcely survives. The owls are hooting still in varieties uncounted, and if, here and there, a specimen, discouraged and disgusted with the "modern improvements" of the Cainozoic period, gave up the ghost, and laid himself away with the old saurians —his Darwinian ancestors—he now finds himself resurrected, his bones neatly wired together, and the human owls hooting over him still. Like the immortal Webster, he "still lives" as a witness of Nature's wonderful resources as a differentiator—a difference-maker.

But let us look further into Nature's method of creating varieties. Shortly after the beginning of eternity, Nature began to put the universe in order. She at once began to make *distinctions* by getting her material together, and turning out worlds. It was the first step. Leaving other worlds to themselves, watch the progress of affairs at home. As soon as the first flurry is over, Nature settles down to the creation of differences. She puts the solid earth as a foundation, and piles the hot atmosphere above it; then she takes the water from the atmosphere, and we have air, earth, and water. With these she gets up some low forms of life. But, as she has only begun her work, she makes very little difference between the opposite ends of these forms. One end of a worm is so much like the other end that you may cut him in two, and one part putting on a tail and the other a head, you will in a short time have two very respectable worms. From these low forms, which carry as much life in one end as in the other, Nature goes on differentiating, till at last we find her getting up forms whose parts are so widely different that each has its own work to do, and one part cannot be substituted for another. A man losing any organ is imperfect; and many of his organs are such that the loss of one of them requires that he should go back into Nature's melting-pot, and be moulded over again into a new form of life—a Rhode Island pippin it may be, as good Roger Williams was. There is no record of any surgeon's having cut a man in two, and having made two men of the pieces. Nature is not content with multiplying species alone. She shows the same love for difference in varieties, and even in individuals, so that, as we are often told, there are no two peas exactly alike.

The utilitarian may ask: "But what is the need of all this variety? Why not have all peas alike?" This brings me to the important part of my essay; for, whimsical as some of my notions may appear to others, the conclusion to which I hope to bring my readers is to me a source of moral rest:

1. *Relation of Difference to Consciousness.*—How is it that we gain a knowledge of the external world whereby we become conscious intelligences? Simply by a perception of differences. What would follow were there no difference in color or shade? Go into a dark cellar with an extinguished candle to find a black cat that is not there. I know black is said to be no color, but it answers as an illustration. Your eyes are wider open than when above-ground in broad daylight, looking for a white cat that is there. Things being "all of a color," as common people remark when left in the dark, you are for the time as blind as the eyeless fish. Were white light put in the place of darkness, and each object to reflect it with absolute sameness, you would be just as unable to distinguish between objects, or between an object and its background. Were the black cat there eating a white rabbit, the cat having become white you could not tell where cat left off and rabbit began; neither could you tell where cat and rabbit ended and cellar-floor began. Everything would be of a piece.

You could make out nothing, though you had as many eyes as the "devil's-darning-needle" of our boyhood, and each eye were "in fine frenzy rolling." Call, now, that cellar the universe, and then see if you can show cause why we may not consider the sense of sight as practically gone, and all knowledge that comes through sight a sealed book; ay, more, that nothing would be left to give us a hint that such knowledge could possibly exist.

How is it that we receive knowledge through the ear? By noting the difference between sounds, and between sound and silence. But, if there were no difference, there could be no hearing. If we had always listened only to a single tone, varying neither in pitch nor force, we should not be aware of the sense of hearing. We should be as one born deaf. It is the difference of sounds that gives us through the ear knowledge and harmony.

As with the senses named, so with smell, taste, and touch. Did all substances affect these senses in exactly the same way, however acute those senses, we should not be aware of their existence. Ask any one what is the smell of pure air, and he will tell you, "No smell." But how do we know that to be the case? As it has always been in contact with our smelling-nerves, we cannot judge of its odor. A dweller in Jupiter coming to visit his mundane cousins might, when he struck our atmosphere, expand his nostrils, as one sniffs the air when he all at once smells something very nice, or he might turn up his Jovian nose, as though he smelt something very bad. It is an open question whether or not the atmosphere is odorless, or, as a layman would put it, whether it smells the same as empty space. Could an intelligent man be put under an exhausted receiver, get the smell of a perfect vacuum, and survive to tell about it, he might throw some light on the question.

To sum up my reasoning, it comes to this: Were the universe one of *sameness*, instead of the universe of *differences* that it is, we should be unconscious of any external world, or of our own existence, no matter though we were the best-born specimens of the scientific stirpiculturist. In fact, we should be an army of negations. I am aware there is something a little queer in the logic of this paragraph, but yet there is a great deal of sound logic in it after putting aside the "queer," which will, however, pass current with all except professional detectives.

2. *Relation to Knowledge.*—What is knowledge? Only a perception of differences. How is a knowledge of natural history, for instance, obtained? Simply by finding out differences. In this way child and philosopher classify the horse and the ox. Progress in knowledge is possible in proportion—1. To objective differences; and, 2. To perceptive ability. Take botany. It is easy to classify those plants which have obvious differences into genera; but, when we come to the classification of sub-species, the work is more difficult. A stu-

pid child can tell a piece of Boston brown-bread from a ginger-snap; but he cannot always tell whether his bread is spread with Orange County butter or oleomargarine.

Again, one man is color-blind, and in a knowledge of colors can make little progress. As an engineer, he would mistake a green for a red light; as a paint-mixer, he would be a failure; and, as a matcher of dress-goods, he would be little troubled by the sweet creatures to whom he belonged. Another man can distinguish not only the seven colors of the rainbow, but many shades of each. The progress of these two men in all knowledge resting upon color must differ widely. As in this, so in all departments of education: the man who is skillful in detecting differences holds the key to knowledge.

3. *Relation to Happiness.*—The wise and the good of all religions and the philosophers of every school are puzzled over what they term the evils of life. Assuming the Creator to be wise, good, and omnipotent, they wonder that he should allow these evils. They cannot understand the problem of pain and misery which meets them at every turn, and importunes for a solution. Why should there be any condition but happiness?

The philosophers best satisfied with the present order of things are those whom I shall name the *protoplasmics*. Denying the existence of a personal God, and falling back upon *protoplasm* as a substitute, they think that, taking into account the humble character of their protoplasmic god, he has done remarkably well. They are therefore very hopeful in their evolution theory, and in this respect have the advantage of their more orthodox brethren. They look upon creation with much the same feeling as that with which we look upon the first house built from cellar-drain to chimney-top by a self-made artisan. As a house pure and simple, it may be a failure, but as a self-made artisan's first attempt it is a wonderful success.

The great army of reformers, each in his way anxious to show himself the savior of the world, is but another proof of this widely-spread belief that the world is in a very bad fix.

That this problem of evil is as old as the race is shown in the golden-age idea, whether it comes up in the Hebrew religion with its Garden of Eden, or in the mythology of the Greeks and the Romans. The explanation is, perhaps, this: Man clothes his god with the highest attributes he finds in himself. These qualities he magnifies, and joins to them infinite power. Seeing that the world is evil, and, conscious of evil tendencies in himself, he finds his way out of the dilemma by asserting that there was once a golden age, the condition of the universe as it came from the hand of its Maker, and that all the evil that has crept into it has come from man alone. Thus he solves the problem of evil, and saves the character of his god. We must admit that the theory shows a good degree of charity, humility, and logic. It would be a still better scheme if in it there could be found a place for charity toward the poor devil whom as yet neither charity nor logic can dispose of.

But there are other philosophers, among whom I count myself—I say it in all modesty, it runs in our family—who are not satisfied with any of these explanations, and very naturally ask: "Is the world a failure? Is it not a very good world? Is it not, in fact, as good as it can be? Were the united wisdom and goodness of the race supplemented with omnipotence and allowed to reconstruct the universe, could they improve upon the world as it is? Are these, that we name so, evils, or is it that we have failed to find out their character and use?" I purpose to answer these questions by applying to them the Law of Difference, which I conceive to be the panacea for the ills of life. Keep in mind that, as all knowledge comes to us as the result of the *different*, so do all emotions of pain or of pleasure. Every quality that is thinkable implies its opposite, or at least its different in degree. Happiness and misery are only relative terms. Absolute happiness cannot exist any more than a magnetic needle with only one pole. The sick man who rises for the first time for weeks from a bed of pain and is led out into the sunshine is very happy; while the strong man who has not known sickness for years is unhappy from some slight indisposition which scarcely interferes with his daily work. Why this difference? Simply from the contrast with the previous condition. He who would enjoy must suffer. The lives of some people pass so smoothly that we count them happy. They are simply in the possession of something whose value they have never known, hence it is to them worthless. If you want to know the full value of a clear conscience you must go through the hands of remorse. If you want to know the comfort of owning two shirts at a time, you must know the discomfort of owning no shirt at a time. Whence comes the pleasure we feel from our progress in knowledge? From the difference between the knowing and the not knowing of anything. Take the happiness that comes from social position in life. It arises from the fact that we are higher up than some one else. Bring all to the same level and it would be enough to make an angel weep to see how much happiness some people would lose. Many would be bankrupt. Take the tramps and vagabonds out of society, and the whole fabric would be cut down one story; for, to change the figure, they put one more round into the ladder—it matters not that it is at the bottom—and give the climber a chance to go one round higher. It is the length of the ladder that counts, no matter where the bottom is placed. What are wealth and poverty? Only relative terms. There is none so rich as the poor boy who has just received his first dollar after a week of hard work. We waste a great deal of pity on those who are born in the humbler ranks of life. It is my impression that, on the whole, it is better to be born poor, and work your way up to wealth and honor, than to have wealth and honor thrust upon you at birth, even though retained through life.

Nature has done much to create differences, and human egotism has come in to second the efforts of Nature, and supplement her work by getting up differences in our favor where no such thing in point of fact exists. B may be a fool, but thinks himself wiser than C, who is in truth far wiser than B. C thinks himself much wiser than he really is, and in comparing himself with B gets the full benefit of the real difference, with a large surplus from the inflation. Thus are both men made happy. Indeed, should you take each man's estimate of himself, you might, to find a fool, be obliged to do as Diogenes did to find an honest man. But, if you should take each man's opinion of other men's abilities, the fools would outnumber the wise men ten to one, that one being himself. Alas! what should we philosophers do were there no simple souls whereby to measure our colossal intellects? Thank God for wise men, but thank God for fools! Every fool as well as every knave has done a great deal for human happiness. Woe is the day when fools and knaves shall be no more! O stirpiculturist, stay thy hand, and leave us still a background to the great picture of life! And thank God for egotism, which enables us to make so much out of so little. It was not the philosopher that "Oh'd!" when the poet wrote:

> "Oh, wad some power the giftie gie us
> To see oursels as ithers see us!"

He was wiser who wrote—

> "Where ignorance is bliss 'tis folly to be wise."

It will be a black-letter day when we find ourselves out. Why not let us go on, each one thinking himself the biggest toad in the puddle, and being happy? Why not let us still have the difference in our favor, since it is so cheap a happiness, and withal so innocent?

Those who agree with me thus far may yet ask: "But is not the number as well as the degree of differences too great? Has not Nature rather overdone the thing when she gets up a hell-bender" (*vide* Webster and the Aquarium), "or gives us not only an Apollo whom we admire, but a leper whom we loathe?" Why, my dear sir, after all the orthodox animals were made—though I don't know where you would draw the line between the regulars and the irregulars—you and I both could find much pleasure in looking at a hell-bender, and he no doubt finds far more pleasure in being a hell-bender than in being nobody. However many forms we may have seen, we still want to see something different. Yes, but how about the miserable, suffering leper? How about these extremes of wretchedness? Something in the way of music may be got up from the eight simple tones of a simple octave. If you are to have music worth hearing, you must extend the scale through the octave above and the octave below; but, if you would have music with all its pathos, power, and sublimity, you must make use of all the octaves that are at the command of the orchestra, from the low thunder of the big Boston organ to the shrillest wail of the Cremona fiddle. Nor do you want the major chords alone, you must have the minor tones, and discords, even. Can you spare the lowest octave from the big organ? If so, you bring the extremes an octave nearer, and so far restrict the range of the instrument, and by repeating the removal of the lowest notes you would at last find it impossible to play even the thinnest of tunes. So with human society. As you bring the extremes together, you take from life that which makes life worth having. The extremes in deep-water oyster society are very near each other, but each member of that society is only an oyster.

But how about the reformers? If things are all right as they are, why try to change them? My dear, short-sighted brother, the reformer can do no harm. He is a benefactor. He is only helping Nature out. He may cut off now and then a low note, but by adding two high ones he widens the range of the instrument. Society as a whole advances, but its extremes are probably farther apart than ever before. Moreover, if we take the world as a whole, we can still better understand the value of the reformer. Compare unreformed Africa, with its cannibalism and slow travel, with America, the land of the Grahamite and the home of the telegraph, and see if the various reformers have not made it a glorious thing to be a Caucasian! Every step in the moral world secured by the reformers makes greater the distance from the top to the bottom of the moral ladder. The day of the Inquisition and witch-burning has gone by; but the history of them still remains. We have only to read the old records, to find out what nice folks we are at the present day. I admit the conceit of some of these troublesome people, who believe they have a mission; but they are a necessary and important variety of the race. It is very plain that this world is the proper stamping-ground of the reformer.

Hence, variety is a necessity of life. The man that lives upon one kind of food only must deteriorate in body; the student who gives all his thought to one idea, will become crotchety; while the devotee to a single phase of religion will in time be a bigot, which is but another name for monomaniac. Sameness is the border-land of insanity. Have you ever been "possessed" by a whimsical idea, or a bit of poetry that would give you no let-up? If so, you can form some notion of the lunatic who was haunted with the idea that he carried in his stomach the twelve Apostles! There is many a man living a life of excessive toil or of idleness, of so fixed a routine that he is partially insane. It should be the aim of every man to so arrange his life as to bring into it a good degree of variety if he would secure physical, mental, and moral health. In this particular, division of labor often works mischief to the individual, however advantageous it may be to the community. Imagine the stupidity that must creep over the mind of a man who spends year after year pointing pins! It may be well to inquire as to whether or not the social and business framework of society is not doing much to reduce some of its members to a state little better than monomania.

To enforce the lesson taught by the Law of Differences we will pass by a million years, while I give the reader a picture of the reconstructed universe. It had been reformed to that degree that the wildest dream of the idealist had been realized. Desiring to have one more look at the old homestead, I came back from spirit-land, was "materialized," and once more walked the solid earth as was my wont a million years before. I need not say I was not quite up to the times. The first thing I noticed was that my physical geography was all at fault. There were no burning sands, no icy wastes, no earthquake, no tornado, no flood, no drought. The whole earth from pole to pole was on the golden-age pattern. In this respect, desire was satisfied. For centuries no one had been heard to complain of any imperfection. All was lovely. To me, with a recollection of what I had suffered in my youth in cold and barren New England—ten in the family, and all big eaters—the change was delightful. But what was my surprise not to find a single soul to share my pleasure! When I talked to those I met of their beautiful world, I spoke in an unknown tongue. I might as well have tried to convince Jones, the druggist, that pure air was as fragrant as the odors which blew from Araby the blest, or any other Araby. Jones would have told me, "I have had air in my nose for fifty years, and, if there is any smell in it, don't you suppose I should have found it out in that time?" They were as stolid as marble, and as unenthusiastic as a proper woman who never felt the slightest twinge of hope, fear, love, hate, or anything else, except propriety. "It is strange," said I, "that no one understands what I feel. . . . Well," I thought, "they have never known anything *different*, and as a result they do not know this."

I was no less agreeably surprised at the men and women whom I found peopling the globe. The stirpiculturist had finished his work and gone home. There was not a physical deformity of any kind among the millions that walked the earth. All were brought up to the highest type of physical beauty. There was not a woman I met with whom I did not instantly fall in love, though it was like Caliban falling in love with the houris. Every man was an Apollo, and every woman a Venus. But I was surprised to see them so blind to each other's charms. The men were the slowest of slow lovers; the women as responsive as lay-figures. "Ah! well," I sighed, "they never saw in man or in woman anything but beauty, and now they see not that." It seemed that a sight of me, which some of them could not endure without a shudder, had begun to awaken in them a new sense of which the stirpiculturist had robbed them—a sense of the beautiful.

Being by nature benevolent, and inheriting a missionary spirit, it did me good to think that I was serving so useful a purpose, and starting a mission for the conversion of these heathen in æsthetics. With a force that almost took away my breath, it came to me that we owe a great debt to the deformed, the hideous, and the wicked; that those, the morally hideous, whom society hunts down as its worst enemies, spend their lives in serving the very class that seeks to destroy them.

Then, too, the goodness and holiness of the reconstructed world! There were met with only those with whom, having been so well generated for a thousand years, regeneration was impossible. A long line of physical, mental, and moral saints were the ancestors of the race. "What a perfect heaven!" I said to them. But I found upon their faces only a gingerbread-rabbit expression. Such words as heaven and hell conveyed to them no more idea than green or red conveys to a blind man. I was in despair at such a lack of appreciation. Here was practically the heaven upon earth which the race had worked for, prayed for, agonized for; and, now that it had come, no one seemed to enjoy it, or even to know of its existence. It is truly a misfortune to be born in and always to live in heaven. The eternal Law of Differences holds us fast. Hell is a necessity, which must be as deep as heaven is high. The world was better as it was before the reconstructers got hold of it. Give us back the iron age! All is not gold that glitters. My prayer was answered, and I found myself once more in this world of sin and holiness, joy and sorrow—in a word, back in this world of differences.

MAN AND THE GLACIAL PERIOD.

By THOMAS BELT, F. G. S.

CONCERNING the Glacial period, geologists hold the most varied opinions, both with regard to its origin and to the mode of action of the ice. Thus at the very threshold of the geological record we tread on uncertain ground, and every guide points to a different path. The relation that palæolithic man bore to the great ice age might seem to be of easier solution; but even this question is unsettled, and a subject of controversy and doubt. Prof. Prestwich is believed by many to have proved that palæolithic man was post-glacial. Messrs. Croll and Geikie urge that there were two or more glacial periods in post-tertiary times, and that he flourished in a mild interglacial period. I, on the contrary, have been gradually forced to conclude that, in the British Isles, all the remains in caves and valley-gravels referred to palæolithic man are preglacial, in the sense that they are of earlier date than the glaciation of the districts in which they are found.

I propose to state briefly some of the general arguments that have influenced my opinion, and then to deal with the special question of the age of the deposits at Hoxne, which the advocates of the post-glacial theory put forward as being undoubtedly in their favor.

Let us first take into consideration the age of the beds containing the remains of the mammoth, the woolly rhinoceros, and their companions, with which the palæolithic implements are so often found. Wherever, in Europe, the relation of these beds to the bowlder-clay can be clearly seen, they are of distinctly older age. Thus, in Russia, Sir Roderick I. Murchison has recorded the discovery of the bones of the mammoth and woolly rhinoceros, near Moscow, in reddish clay covered with erratic blocks, on the plains thirteen miles distant from the river.[1] And if we follow the northern drift southward from Moscow, as I have done, we find it gradually changes from clay with bowlders to the clay without bowlders that covers the southern plains. Around the sea of Azov, cliffs of this glacial clay, one hundred feet high, can be followed continuously for miles, and its junction below with the older beds is sharply defined. It rests on a fresh-water deposit containing shells of species of *Unio*, *Cyclas*, and *Paludina*, and at this horizon fragments of the tusks and bones of the mammoth are abundant, and are always undoubtedly older than the glacial clay. In a similar position the same remains have been found at Odessa and other places in the south of Russia.

Nor has the theory of the post-glacial age of the remains of the mammoth remained unchallenged by eminent geologists in England. Prof. Phillips[2] and Mr. Godwin Austen[3] long ago recorded their conviction that they belonged to an earlier period than the deposition of the bowlder-clay, and that when they occur in newer beds they have been derived from an older formation. The remains are so plentiful in the caves of the north of England that it is certain that the mammoth and rhinoceros were abundant. Yet nowhere in the glaciated parts of the country have the bones been found excepting where preserved from the action of the ice in caverns and fissures.

Thus, in tracing the limits of the northern ice on the eastern side of England, I have found that Durham and Northumberland were probably completely overflowed by it, excepting the upper parts of the Cheviots, as pointed out to me by Mr. Richard Howse. The ice streamed through from the west, around the southern and northern flanks of the Cheviots, down the valleys of the Tyne and the Tweed, and when approaching the eastern coast was deflected to the south by the great mass of ice that occupied and was flowing down the bed of

[1] "Geology of Russia in Europe," p. 650.

[2] "Geology of Yorkshire," 1829, vol. i., pp. 18, 52.

[3] "British Association Reports," 1863, p. 68.

the German Ocean. In Yorkshire the ice from the west was held back by the Pennine Chain, and did not coalesce with the German Ocean glacier, but stopped short, somewhere about an irregular line drawn from Keighley, northeastward to near the mouth of the Tees. The German Ocean glacier only, as it were, grazed the high land bordering the coast until it reached the northern shores of Norfolk that stood out across its track. A large portion of Yorkshire was thus never glaciated by land-ice, and in this area remains of the great extinct mammals have been found in and below the lowland gravels, as at Leeds and Market Weighton; but when we pass northwestward into the country where the striæ on the rock-surfaces bear witness to the passage of land-ice, no such remains are found, excepting in caverns and fissures of the old rocks.

The northwestern side of England is much more glaciated than the northeastern, and the mammalian remains have only been found where preserved in caves. The ice filling the Irish Sea reached to a height of 2,000 feet on the western flank of the Pennine Chain. Probably reënforced from the westward it continued, in scarcely decreasing thickness, across the whole of Lancashire and Cheshire, and passed over into the drainage area of the Severn, down which valley it appears to have flowed for some distance. As soon as we get beyond its influence we again meet with mammalian remains in the lowland gravels, and in most of the southern valleys they are abundant.

If the mammoth and its associates roamed as far as the north of England, and even into Scotland, after the Glacial period, their remains ought to be found in the valley-gravels of the glaciated districts. They are, however, absent; and if we should be led to infer from this that they lived before the glaciation of the country, and accept the conclusion of Prof. Phillips and Mr. Godwin Austen that the mammoth and the woolly rhinoceros lived before and not after the Glacial period in Great Britain, we can scarcely refrain from going further than these geologists and concluding that the makers of the palæolithic implements were also preglacial. For no geological inference seems based upon sounder evidence than that palæolithic man was contemporaneous with the mammoth and its associates. The implements of the one and the bones of the others are found together in the same stratum of the cave-earth, and in all the numerous caverns that have been searched in England and Wales there is no record of palæolithic implements being found at a higher horizon; when flint weapons do so occur they are invariably of the neolithic type. If geological evidence of contemporaneity is of any value, the occupation of the caves by palæolithic man ceased at the same time as the great mammals disappeared.

Let us look at the question from another point of view. In the south of England the remains of the mammoth are abundant in the valley-gravels. They are found mixed through them, or more commonly at their base. Palæolithic implements are found in the same position, though usually in gravel higher up on the slopes of the valleys. When found in the gravel, the bones are broken and worn, and the flint implements have their angles rounded more or less as if by rolling. When, as has happened in a few cases, the bones and implements have been found below the gravels, they have been uninjured and unworn. Mr. Godwin Austen noticed the occurrence of bones of the mammoth in an old forest-bed beneath the valley-gravels, at Peasemarsh, in Surrey, uninjured and lying together, while in the overlying gravel the teeth of the mammoth were found singly and rolled.[1] And Colonel Lane Fox has recorded the discovery of flint implements at Acton in seams of white sand, nine feet from the surface, beneath deposits of gravel and brick-earth.[2] Their edges were as sharp as if just flaked off a core of flint; while those found in the gravel, on the contrary, have their edges worn and rounded just like those of the subangular pebbles of which the gravel is principally composed.

The position and the state of preservation of the bones and implements are such as might be expected if they had been deposited on an old land-surface before the outspread of the gravels, when the configuration of the country was much the same as now; and I have suggested that the occurrence of the implements, generally higher up the slopes of the valleys than the mammalian remains, is due to palæolithic man having frequented more elevated and drier localities than the great mammals. I have urged that the outspread of the gravels was due, as formerly supposed by Sedgewick, De la Beche, and Murchison, to the action of a great flood or debacle. I have advanced the theory that that debacle was caused by the breaking away of a barrier of ice that blocked up the English Channel, and with it all the drainage of Northern Europe, causing an immense lake of fresh or brackish water that was thus suddenly and tumultuously discharged.[3]

This great flood occurred, according to my theory, before the culmination of the Glacial period, and was primarily due to ice filling the bed of the North Atlantic as far south on the European side as latitude 49°. If the gravels in and below which the rude flint implements and the remains of the extinct mammals are found, were thus spread out, it follows that they were preglacial in the sense that they lived before the principal glaciation of the country.

We have seen that, in the north, such an excellent geologist as the late Prof. Phillips had arrived at this conclusion with regard to the age of the mammoth, the woolly rhinoceros, and the hippopota-

[1] *Quarterly Journal of the Geological Society*, vol. vii., p. 288.

[2] Ibid., vol. xxviii., p. 456.

[3] *Quarterly Journal of Science*, April, 1875. *Quarterly Journal of the Geological Society*, vol. xxxii., p. 84.

mus; and, in the south, Mr. Godwin Austen, from a study of the same remains in the valley-gravels. Direct evidence of great value has been added by Mr. Tiddiman in his reports on the exploration of the Victoria Cave, at Settle. He has shown that the cave-deposits lie beneath glacial clay, and, among the other remains, a human fibula has been found.[1] In the Cefn Cave, in Denbighshire, Mr. Mackintosh has also determined that the mammalian remains lie in and below a glacial clay.[2]

All the lines of inquiry thus far pursued in this paper point to the preglacial age of the remains in question, and some of the facts are directly opposed to the post-glacial theory. How, then, is it that the great majority of geologists write as if it had been clearly proved that palæolithic man was of post-glacial age? Principally because it is believed that Prof. Prestwich has proved that at Hoxne, in Suffolk, the implements and bones are found in deposits distinctly overlying bowlder-clay. This is spoken of as if it were a truism in most general treatises on geology;[3] and both in Europe and America the presumption is appealed to as being conclusive with regard to the age of the remains. The general opinion held is concisely given in the statement by Mr. John Evans in his presidential address to the Geological Society last year, that, at Hoxne, "the implement-bearing beds repose in a trough cut out in the upper glacial bowlder-clay, which itself rests on middle glacial sands and gravels."[4]

This opinion of the age of the Hoxne deposits is founded on the elaborate memoir by Prof. Prestwich, published in the "Philosophical Transactions of the Royal Society," for 1860. In this treatise the author gives a diagram showing the deposits in question lying in a trough cut out in the bowlder-clay. Though this section is confessedly only theoretical, it was accepted by Sir Charles Lyell and others as an actual one, and afterward the author himself wrote as if he had proved his theory to be true,[5] which he may well be excused for having done, when it had been accepted by so many eminent geologists.

The writings of Prof. Prestwich are admirable in this, as in other respects, that, although he indulges in wide-reaching theories, he invariably gives the evidence on which they are founded. Thus, in the memoir in question, in addition to the theoretical diagram he gives another, showing the actual facts observed, and also careful details of the various sections observed by him. It is, therefore, possible to check his theory by his facts, and in the present paper I shall do so,

[1] *Nature*, vol. ix., p. 14. "British Association Reports," for 1873, 1874, 1875.

[2] *Quarterly Journal of the Geological Society*, vol. xxxii., p. 91.

[3] Sir Charles Lyell, "Antiquity of Man," p. 166. J. Geikie, "Great Ice Age," p. 474. J. Croll, "Climate and Time," p. 241. W. Boyd Dawkins, "Cave-Hunting," p. 410. Jukes's "Students' Manual of Geology," p. 736.

[4] *Quarterly Journal of the Geological Society*, vol. xxxi., p. 74.

[5] "Philosophical Transactions," 1864, p. 253.

and also give the results of my own examination of the Hoxne district.

Mr. John Frere, so long ago as the first year of the present century, communicated to the Society of Antiquaries an "Account of Flint Weapons discovered at Hoxne, in Suffolk."[1] He stated that they were found in great numbers in a bed of gravel, which was overlaid by one foot of sand with shells, and containing the jawbone and teeth of an enormous animal; the sand being again covered by seven and a half feet of brick-clay. Mr. Frere noticed that the strata lay horizontally, and had been denuded to form the present valley, and therefore concluded that they belonged to a period when the configuration of the surface was different from what it is now, and he considered that their antiquity was possibly "even beyond that of the present world." The manner in which the flint implements lay, and their great abundance, led Mr. Frere to conclude that a manufactory of them had been carried on at the place where he found them.

The discovery does not appear to have excited any attention at the time, and for more than half a century remained unnoticed. In 1859, when the discovery of flint implements in the valley of the Somme, in France, in association with the remains of the mammoth and other extinct mammals, had at last aroused the attention of geologists, Mr. Frere's memoir was brought by Mr. John Evans before the notice of Mr. Prestwich, who had just returned from Amiens. He soon after visited Hoxne, and carefully examined into the facts of the case. He found that the bed of brick-clay was still being worked, and that flint implements were occasionally, though rarely, turned up; and on a subsequent visit with Mr. Evans they succeeded in disinterring one themselves.

The valleys of the Waveney and its tributaries are bounded by low hills of gravel and bowlder-clay. The bed-rock is not seen in any of the sections exposed, but it is supposed to be chalk. The gravels and sands (the middle glacial sands and gravels of Mr. Searles Wood, Jr.) are exposed in many gravel-pits on both sides of the Waveney. They are sometimes capped by the upper bowlder-clay; at others, by a more sandy bed with stones (the "trail" of Mr. Fisher), which in some of the sections graduates into the upper bowlder-clay, of which I believe it to be the modified representative. One of the deepest sections on the north bank of the Waveney is near the road from Diss to Harleston, at Billingford, where the series of beds shown in Fig. 1 are exposed.

Mr. Fisher some time ago called attention to the great importance of the upper bed, or "trail," in the study of the glacial beds,[2] but it has not yet received the notice it deserves. It is the most persistent of all the beds in the southeastern counties, and can be traced, in al-

[1] "Archæologia," 1800, vol. xiii., p. 206.

[2] *Quarterly Journal of the Geological Society*, vol. xxii., p. 553.

most every section, from Norfolk into Surrey. It is everywhere seen in the Thames Valley lying on the top of the lowland gravels, and is shown in great perfection in the long section now (March, 1876) exposed between Acton and Hanwell, on the Great Western Railway.

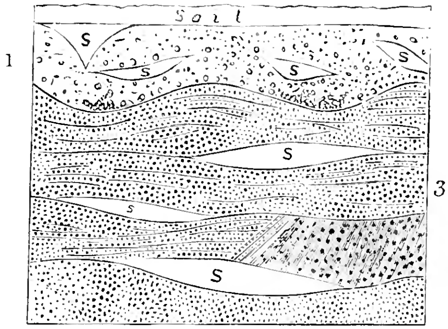


FIG. 1.—Scale twelve feet to one inch. 1. Sandy clay, or "trail," with patches of sand (S) and scattered flints, mostly in nests, at the irregular base of the deposit. 3. Sands and gravel, false-bedded with lenticular beds of sand (S), and in the lowest seams rounded pebbles of chalk.

It generally, if not always, rests upon an irregular surface of the beds below it, and contains stones derived from some other source.

On the south side of the Waveney, at Syleham, there are good sections on both sides of the turnpike, and these exhibit similar false-bedded sands and gravels, which are, however, covered by the upper bowlder-clay instead of by "trail." Fig. 2 shows a section exposed

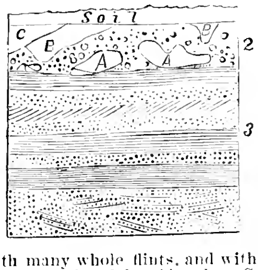


FIG. 2.—Brown bowlder-clay, with many whole flints, and with angular patches of red sand (B), marly clay with small stones (A), and red bowlder-clay (C). 3. Sands and subangular flint, gravel with rounded pebble of quartz, and (in the lowest seams) of chalk.

on the south side of the turnpike. A little farther west, on the north side of the turnpike, is another gravel-pit, showing a similar succession, but with the beds of sand and gravel strongly false-bedded. In all these sections small pebbles of chalk are very abundant in the lowest beds. The most remarkable feature in the upper bowlder-clay is the numerous angular patches of material quite different from the matrix of brown clay. The angular patches of red sand are very peculiar and difficult to explain.

In a large gravel-pit a little north of Oakley Church there is a long section exposed, and in it the upper bowlder-clay, similar to that shown in Fig. 2, at one end of the pit, gradually changes into a sandy loam with stones and angular patches of sand, not to be distinguished from the deposit named "trail" in Fig. 1.

At Hoxne itself, on the east side of Gold Brook, there is a gravel-pit showing seams of gravel and sand exactly similar to that at Syleham, but surmounted by sandy "trail" instead of by bowlder-clay. The gravel is not to be distinguished from the other, being composed like it of subangular flint-pebbles with rounded ones of quartz and quartzite, and with many small pebbles of chalk in the lowest seams. Notwithstanding this great similarity, Mr. Prestwich considers the beds at Hoxne to have been formed by river-action in post-glacial times; while those at Syleham, being capped by bowlder-clay, he of necessity classifies as middle glacial. Yet I could find no difference whatever in their appearance or composition. In both the pebbles are mostly small and subangular, with some rounded ones of quartz and quartzite. Both contain many small pebbles of chalk in their lowest seams, and both are false-bedded. That one is covered with bowlder-clay and the other by sandy "trail" does not suffice to prove them of different age, for at the Oakley gravel-pit we can trace the same gravels from one end, where the bowlder-clay overlies them, to the other, where the "trail" does so. The middle sands and gravels are generally supposed by geologists to be marine, and it is incredible that deposits due to such different agencies as that of the waves of the ocean beating on a beach and that of a flooded river should be absolutely identical in appearance and composition. But nowhere is either the ocean or any river known to be forming deposits of subangular pebbles, excepting where they are cutting into preëxisting beds of the middle glacial series. Both in sea and in river beaches the pebbles are smoothly rounded, and not, as in the gravels under consideration, broken and subangular. Even when we find in the latter rounded pebbles of tertiary age there is often a piece chipped out of them as if they had been dashed violently together. I have had a large number of the pebbles from the gravel at Ealing counted, and find that over eighty per cent. are broken or subangular. I ask where, in the whole world, is such a deposit being formed by existing agencies? Surely, if ordinary floods would produce them, they have had plenty of opportunities of doing so during the past pluvial year; yet where, on the banks of any of our rivers, have the great floods left deposits even approaching in character to those that geologists confidently ascribe to river-action? That they were caused by a great flood I fully believe, though not by that of any river, but by one that swept over the whole country, driving a huge mass of gravel and sand, and leaving them mantling both hills and valleys, holding or covering up the remains of palæolithic man and the great mammals that had lived before the waters were pent up by the Atlantic glacier.

A little above Hoxne, on the left side of the stream called the Gold Brook, is the Hoxne clay-pit. The clay is excavated along the slope of the shallow valley through which the brook runs. The road to Eye skirts the hill-side, having to the west the park of Sir Edward Kerrison; and to the east, between it and the stream, a narrow strip

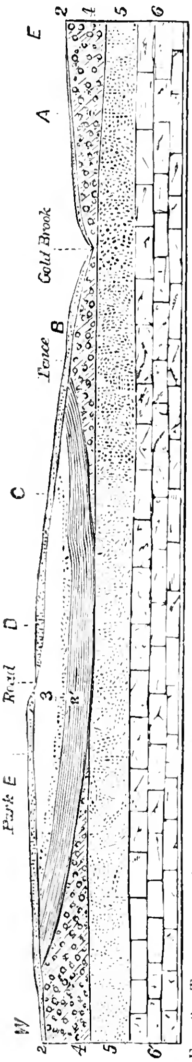


FIG. 3.—THEORETICAL SECTION ACCORDING TO PROF. PRESTWICH: 2. Surface gravels. 3. Brick, earth, and gravel, with flint implements, mammalian remains, and land and fresh-water shells. 3′. Peaty bed, with wood, and land and fresh-water shells. 4. Bowlder-clay. 5. Sands and gravels. 6. Chalk, probably.

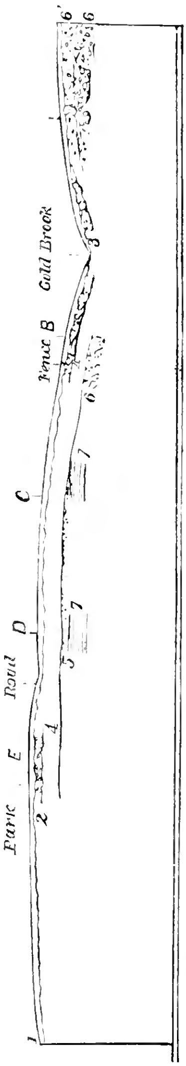


FIG. 4.—SECTION SHOWING THE ACTUAL FACTS OBSERVED: 1. Surface gravels, "trail." 2. Clay resembling "upper bowlder-clay." 3. False-bedded sands and gravel, flint. 3. Brick earth, flint implements scarce, land and fresh-water shells in lower part. 5. Gravel, many flint implements found by Mr. Frere. 6. Lower bowlder-clay and "till." 7. Peaty bed.

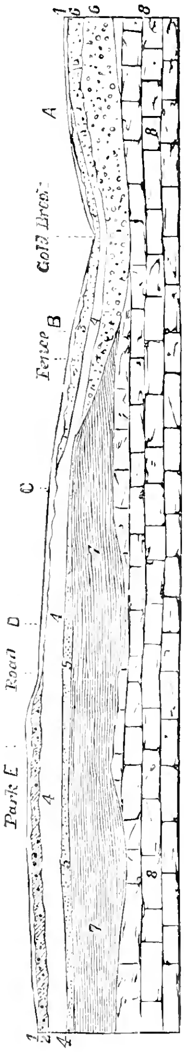


FIG. 5.—THEORETICAL SECTION BY THE AUTHOR: 1. Trail. 2. Upper bowlder-clay. 3. Middle glacial sands and gravel. 4. Brick-earth, "glacial." 5. Chalk gravel. 6′. Lower bowlder-clay. 6. "Till." 7. Preglacial peaty clay. 8. Chalk, probably.

of land from which the clay has been dug. The old workers had commenced near the village of Hoxne, and as they gradually exhausted the clay up to the road they moved farther southward, and the point at which it is now excavated is probably at least a quarter of a mile distant from that where Mr. Frere made his discoveries in 1800. The pit has now been worked up to some farm-buildings that interfere with its progress southward, and to get clay they have now crossed the road into the park, and thus made a most important addition to the section laid open.

I have in the accompanying plate given three sections of the ground. The first shows the theoretical relation of the beds according to Prof. Prestwich; the second exhibits the facts actually observed by Prof. Prestwich and myself; and the third is a theoretical section showing the relation that the beds hold to each other according to my own views. We shall in the first place confine our attention to the second section (Fig. 4), showing the facts actually observed.

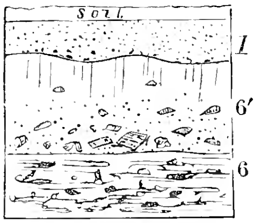


Fig. 6.—1. "Trail," three feet. 6′ and 6. Bowlder-clay, chalky in upper part: a slight line of division between it and the lower part, which is principally composed of crushed Kimmeridge clay with pieces of chalk.

On the east side of Gold Brook a cutting has been made into the bank, and a thick bed of bowlder-clay is exposed. At the point *A* in general section the beds are shown, as in Fig. 6. Near the line of division the upper and more chalky clay contains many large flints and transported bowlders. Some of these are smoothed, and strongly scratched and grooved. Two scratched blocks of septaria that I saw measured one and a half foot across. This bowlder-clay, both in its upper and lower division, is very distinct in appearance and composition from that lying above the gravels, as seen in other sections. Lower down toward the brook a seam of false-bedded sandy gravel comes in between the bowlder-clay and the "trail," and represents, I think, the gravels of Figs. 1 and 2.

Crossing the brook and ascending the opposite slope, we have, at the points *C* and *D* of general section, typical sections of the clay-pit, as shown in Fig. 7. The clay (4 in section) is called "red-brick earth" by the workmen, because it burns to a red color; while the lower, dark-colored clay (7 in section) is called "white-brick earth," because it burns to a white color. The bottom of the latter bed has not been reached, although Prof. Prestwich had a boring put down into it to a depth of seventeen feet. It is full of vegetable matter, and I found numerous pieces of wood in it. The men pointed out to me the gravel-seams (5 in section), as the horizon at which flint implements had been found; but, shortly before Prof. Prestwich visited the pit, two specimens had been taken from the lower part of the clay (4 in section). There can be little doubt, however, that they were found by Mr. Frere in the gravel below the "red-brick earth," as he says that "they lay in great numbers at the depth of about twelve feet in

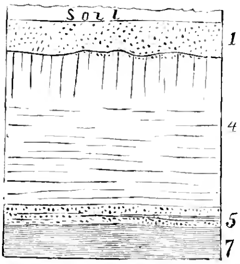


FIG. 7.—1. Sandy "trail" with flint-pebbles. 4. Yellowish-brown clay, unstratified at top and graduating downward into obscurely stratified chalky clay—ten feet. 5. Two thin bands of small chalky gravel, separated by eight inches of loam. 7. Dark calcareous clay, with fragments of wood and other vegetation.

a stratified soil, which was dug into for the purpose of raising clay for bricks. Under a foot and a half of vegetable earth was clay seven and a half feet thick, and beneath this one foot of sand with shells, and under this two feet of gravel, in which the shaped flints were found generally at the rate of five or six in a square yard. The manner in which the flint implements lay would lead to the persuasion that it was a place of their manufacture, and not of their accidental deposit. Their numbers were so great that the man who carried on the brickwork told me that, before he was aware of their being objects of curiosity, he had emptied baskets full of them into the ruts of the adjoining road."

As I have already mentioned, the place at which the clay is now excavated is some distance from that where Mr. Frere found the implements, and they are now very seldom met with—so seldom, that none of the men working at the clay-pit when I was there had ever seen one.

To the west of the road, in the pit that has been opened in Sir Edward Kerrison's park, a section of the beds has been exposed at the point marked *E* in general section, as shown in Fig. 8. The most remarkable feature in the section is the occurrence of the upper clay (2 in section), containing angular patches of red sand, like that seen in the "upper bowlder-clay" of other parts of the district. I cannot help thinking that, if this section had been open when Prof. Prestwich examined the deposits, he would have been led to modify his opinion respecting the relation of the deposits to the Glacial period. I myself believe this clay to be the upper bowlder-clay, and the sand with pebbles below it to be the "middle glacial sands and gravels."

To trace the "red-brick earth" (4 in section) down toward the lower bowlder-clay, I set some men to work, and had a shaft sunk—at the point marked *B* in general section—to a depth of seventeen feet from the top of the surface-soil, and obtained the section shown in Fig. 9. The most noticeable feature in this section is the thickening out of the false-bedded sands and gravels, their resemblance to the middle glacial series, and the absence of the "white-brick earth" (7 in section). In a pit a little east of this, Prof. Prestwich and Mr. John Evans found a flint implement in the gravel-bed (3 in section).

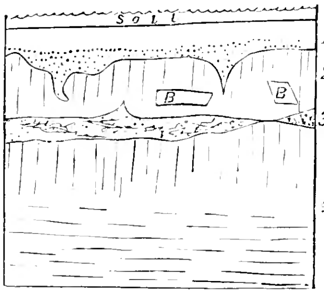


FIG. 8.—1. Sandy "trail" with flints graduating downward into sand, filling pipes in clay below. 2. Unstratified yellow clay, containing isolated angular patches of reddish sand. 3. Whitish sand with a few scattered pebbles, sometimes changing into reddish sand, like that of the patches in the clay above. 4. Yellowish-brown clay ("red-brick earth"), unstratified at top and graduating downward into laminated calcareous clay.

I have now given all the facts at present known respecting the relation of these beds to the Glacial period, and I proceed to the consideration of Prof. Prestwich's theoretical views, as shown in the general section (Fig. 3). In the first place, Prof. Prestwich identifies the bowlder-clay seen in the pit on the east side of the brook as the upper bowlder-clay. As I have already mentioned, it in no respect resembles the clay seen in other sections above the false-bedded sands and gravel, and the existence of the middle glacial beds below this particular deposit is entirely theoretical. Prof. Prestwich makes these sands and gravel to pass under the brick-clays; and I feel confident it will astonish many of those who appeal to this section, as proof of the post-glacial age of palæolithic man, to learn that they have never been seen in this position, and that their presence is an assumption only. The "red-brick earth" ought, according to Prof. Prestwich's views, to thin out eastward, and the dark clays or "red-brick earth" to crop up to the surface from underneath it. Instead of this, as shown in Fig. 8, at the point *B* in general section, the "red-brick earth" follows down the slope of the hill, and is not underlaid at all at that point by the dark clays. I do not, however, attach much importance to this, as the "red-brick earth" might mantle the hill, overlapping the edge of the dark clays, and yet Prof. Prestwich's general idea of the relation of the latter to the glacial beds be correct. What I do wish to point out is, that that relation is not proved by any of the facts known, and that an entirely different interpretation is not only possible, but more probable. That other interpretation I have indicated in the general section (Fig. 5), in which all the facts observed are incorporated. I consider that the dark clay with vegetable remains and bones of the large extinct mammals is preglacial, in the sense that it is older than any of the glacial beds of the district. The gravel below the "red brick earth," in which Mr. Frere found the flint implements, is probably of the same age, or that of the overlying gravel (5 in Figs. 4 and 5). That the implements, and also fragments of bones and wood, should be occasionally found in the overlying deposits, is what might be expected, as they were in great measure formed by the denudation of the older ones. The "red-brick earth" (4 in section) is, I believe, a true glacial clay, belonging to the latter part of the first European lake. It is a noticeable fact that, all over Northern Europe, the glacial clays burn to a red color—a point not without significance with regard to the red beds of Per-

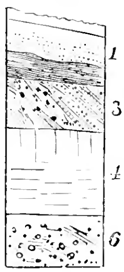


FIG. 9.—1. Sandy "trail" with flints—three feet. 3. False-bedded sand and subangular gravel—four feet six inches. 4. "Red-brick earth," yellow and unstratified at top, graduating downward into gray, laminated, calcareous clay; shells of *Bithinia tentaculata* and *Limnea palustris* abundant at its base, where there is about six inches of sandy clay—four feet six inches. 6. Clay similar at top to the lower part of the "red-brick earth," but with more chalk-grains, gradually more chalky downward, and with stones like the upper portion of the lower bowlder-clay at point *A* in general section.

mian or Triassic age. The false-bedded sands and gravels (3 in Figs. 4 and 5) belong, I think, to the middle glacial series, and the clay (2 in Figs. 4 and 5) is, I think, the upper bowlder-clay. These views are only theoretical, but I claim that they are based upon as sound a foundation, and are as much in accordance with the facts of the case, as those generally received.

Another interpretation is tenable, namely, that the lower bowlder-clay underlies the brick-clays, and that the upper bowlder-clay overlies them, while they themselves belong to a warm interglacial period, as held by Messrs. Croll and Geikie. I do not agree with this opinion, as I can nowhere find any evidence of a warm interglacial period, and am unwilling to believe that there were more post-tertiary glacial periods than one, when one will explain all the phenomena; but if it were to turn out that the lower bowlder-clay does exist beneath the brick-clays at Hoxne, it would be one of the strongest facts in its favor yet brought forward.

I now come to the real point and object of this paper. We have in England, at Hoxne, one of the finest opportunities known to exist anywhere in Europe of determining the true relation that the beds containing remains of palæolithic man and the great extinct Mammalia bear to the Glacial period; yet we have been content for more than a dozen years to allow the age of the beds that underlie these deposits to remain a conjecture, and to accept a theory instead of ascertaining what are the true facts of the case. The geological world has been taught to believe that a question was settled that is not settled. We do know the age of the Hoxne deposits: they may, as held by Prof. Prestwich, be post-glacial; or they may, as held by Messrs. Croll and Geikie, be interglacial; or, lastly, they may, as I hold, be preglacial.

It is not creditable that this uncertainty should remain when it can easily be cleared up. A few shafts or bore-holes put down would soon determine whether or not glacial beds underlie the dark clays of the brick-pit, or sands and gravel underlie the bowlder-clay on the other side of the brook. Excavations should also be made around the spot where Mr. Frere made his discoveries, to ascertain the exact position in which the flint implements were found so abundantly. I feel satisfied that, if Sir Edward Kerrison, to whom the property belongs, were applied to by any of our learned societies, he would willingly allow the necessary excavations to be made. Probably the expenditure of two hundred pounds would be amply sufficient, and I submit that it is a work that should be undertaken by the Royal Society or the British Association, who make grants for scientific inquiry.—*Quarterly Journal of Science.*

EFFECTS OF STUDY ON THE EYESIGHT.[1]

By WARD McLEAN.

A POPULAR error has long existed as to the real character of short-sightedness; and even medical men have to some extent participated in it. It is *not* an indication of strength of vision. It is *a disease*, always inconvenient, and sometimes dangerous. Its char-

[1] The circumstance that one of the children of the writer is temporarily withdrawn from school because of injury to his sight contracted in study, has led him to look into this subject, and this paper is the result. The startling extent, the rapid increase, and the serious character, of these visual defects in our schools, and the fact that the greater part of them originated there, and might have been prevented, should awaken universal interest, that the proper remedies may be applied to arrest the evil as speedily and effectually as possible.

The writer having submitted this paper to Dr. David Webster, of this city, takes this occasion to acknowledge, with great pleasure, his obligation to him for important suggestions.

acter, cause, and progress, have enlisted the earnest attention of the most eminent oculists, especially during the last decade. The movement received its first impulse from a suggestion of Prof. Donders, made in 1864. It originated, therefore, at the very fountain-head of influence and authority in ophthalmology; for Donders was one of the three men who led in what is now styled "The Great Reformation," wrought some twenty-five years ago, in the treatment of defects and diseases of the eye. To illustrate the character of this change, Dr. Agnew, of New York, in his analysis of 1,065 cases of asthenopia (weak sight), thus describes the standard treatment for this disease only thirty years ago:

"Blisters, mercury, low diet, tartar-emetic, bloodletting, applications of irritating alkaloids, such as veratria, to the circum-ocular parts, and setons, were freely employed. Sometimes the sufferers were so subdued or silenced by the treatment that they ceased to complain of their eyes, preferring to endure the ills they had, rather than to endure those which the attempts to relieve their asthenopia led them to. So common was this treatment," he continues, "that more than one clever irregular practitioner made his fame and fortune in putting the exhausted subjects of it under hygienic rules, and giving them new life and hope by a generous dietary and free out-of-door life; thus showing how so-called quackery is often the natural offspring of our ignorance."

The suggestion of Prof. Donders is found in his work, "Accommodation and Refraction of the Eye," and is as follows:

"It would be of great importance to possess accurate statistics of the near-sight and far-sight occurring at a given time in a particular category of men, especially, for example, among the students of a university, in order to be able to compare them with the results of repeated investigations at subsequent periods. If it were thus found—and I can scarcely doubt that it would be so—that near-sight is progressive in cultivated society, this would be a very serious phenomenon, and we should earnestly think of means of arresting this progression. Not only is the near-sighted person not in a condition to discharge all civil duties, not only is he limited in the choice of his position in society, but in the higher degrees near-sight leads to disturbance of the power of vision, and threatens its subject with incurable blindness."

About two years after this, Dr. Cohn, of Breslau, published the startling result of his investigations, which had táken the form of an inquiry into the effects of study on the eyesight. Similar investigations followed in various parts of Europe.

A like movement is progressing in this country, which was initiated by Dr. Cornelius R. Agnew, of New York. Under his auspices, examinations have been made in New York, Brooklyn, and Cincinnati. Dr. Edward G. Loring, Jr., and Dr. Peter A. Callan, of New York; Dr. Lucien Howe, of Buffalo; and Dr. Hasket Derby, of Boston, have reported investigations in the same direction.

In some of these investigations the suggestion of Donders has been literally followed; while in most of them the effect of several successive examinations of "a particular category of men" has been sought to be realized by one examination of several classes of students in the various stages of advancement in study.

In the thirty-three schools of Breslau, including its university, Dr. Cohn examined 10,060 pupils of all grades, and found that 1,004 of the number, distributed among all the schools, were near-sighted; and that only twenty-eight of these had near-sighted parents. Of the children who were yet in their first half-year of school-life, only 0.4 per cent. were near-sighted. Thence, upward, through seven biennial grades, the percentage increased till it reached 63.6 per cent. of those who had been fourteen years at school. The disease was found also to be progressive in degree.

Results bearing a striking correspondence with these have since been reported by various eminent European oculists, chiefly the following: Of 4,358 examinations by Dr. Erismann, of St. Petersburg, in 1871; of 1,058 by Dr. Reusse, of Vienna, in 1872, '73, '75; of 3,036 by Dr. Conrad, of Königsberg, in 1874-'75; and of 1,846 by Dr. Pflüger, of Lucerne, in 1876.

The interest excited by these reports was not confined to European circles. But the conditions of school-life in this country were believed to be so much more favorable than in Europe, that these deplorable statistics, it was thought, could have no parallel here. Nevertheless, the examinations which have been made, as we shall show, furnish occasion for the deepest solicitude.

In New York the examinations were made by Dr. W. Cheatham; in Brooklyn, by Drs. Prout and Matthewson; and in Cincinnati, by Drs. Ayers and E. Williams. They had been furnished by Dr. Agnew with elaborate tables or forms, arranged like Cohn's, which they returned to him filled for summing up and comparison. In this he was assisted by Dr. Webster. The results are as follows:

New York College, 549 students: introductory class—near-sighted, twenty-nine per cent.; freshman class, forty per cent.; sophomore class, thirty-five per cent.; junior, fifty-three per cent.; senior, thirty-seven per cent.

Brooklyn Polytechnic, 300 students: Academic Department, ten per cent.; collegiate, twenty-eight per cent.

Cincinnati, 630 students: district schools, ten per cent.; intermediate, fourteen per cent.; normal high, sixteen per cent.

This report was read by Dr. Webster before the Social Science Congress at Detroit in 1875, and again by Dr. Agnew at the Medical Congress in Philadelphia, September, 1876. In the report of the proceedings of the latter body, for the *Medical Record*, October 14th, it is stated that "the section unanimously recommended to the Congress that the paper be published, with the statistical tables in full." Nevertheless, the paper has not yet been printed; but some of its conclusions may be found in the *Medical Record*, January 20th.

In February last, Dr. Lucien Howe was appointed, by the Buffalo

Medical Association, to examine and report upon the effects of study upon the eyes of pupils of the public schools of Buffalo. In March he reported that he had examined 1,003 scholars, of whom he found twenty per cent. to be near-sighted, and twelve per cent. over sighted; that not a single case of near-sight was found among the children six years old and under; but that at seven years of age five per cent. had acquired near-sight; at eleven there were eleven per cent.; at thirteen there were nineteen per cent.; and at eighteen twenty-six per cent. Among those who had continued in the schools beyond the age of twenty-one years, he found no less than forty-three per cent. with near-sight. He says that Dr. Agnew had sent him blanks for the name, age, sex, and height; for the exact size of desks and seats; also, for each room, the color of the walls, number of windows, and whether to the right, left, front, or rear; the number of square feet in each window, and the distance of adjoining buildings which might obstruct the light. Also, for methods of teaching by large objects, the hours of study, number of recesses, methods of heating and ventilation, and for the cubic feet of air to each individual. The greatest care was exercised to record: 1. The precise condition of the pupils' vision, whether healthy or not; and, if abnormal, to what degree. 2. The usual position of the body when studying. 3. Illumination of the school-room. 4. The relaxation given to the eye alone, or to the whole body. 5. The general hygienic surroundings of the pupil.

He then describes the process of individual examination: Half a dozen scholars at a time were sent into a class-room, on one of the walls of which had been hung a card of letters known to oculists as "Snellen's test-types." The scholars were placed at a distance of twenty feet from these letters, and asked to read the lowest line, the letters being $\frac{3}{8}$-inch Gothic. *Those who can pass this test are not near-sighted.* Then there is held before the eye of each a weak convex glass, such as old people are accustomed to wear. *If he cannot see so well as without it, he is not far-sighted.*[1] In some cases of unusually imperfect vision, the ophthalmoscope was employed.

During the summer of 1876, Dr. E. G. Loring, Jr., of New York, assisted by Dr. R. H. Derby, examined the sight of 2,000 pupils of the Twelfth Street public school and the normal school in Sixty-sixth Street, New York. Their ages ranged from six to twenty-one years. As in the other examinations cited, myopia was found to affect a very small percentage of the pupils in their first year, and to increase yearly and largely thereafter, to the close of school-life; and that the average *degree* of near-sight increases with the age up to twenty-seven years. His report was read before the Medical Congress in Philadelphia, in September, 1876.

In the fall of 1875, Dr. Hasket Derby, of Boston, commenced a

[1] These are approximate tests.

series of examinations at Amherst College, with the purpose of noting the progress of near-sight in the same class and in the same individuals. The freshman and sophomore classes—1,880 and 1,879—were required to report to him; and twenty-seven per cent. of the former and twenty-eight per cent. of the latter were found to be near-sighted. In the fall of 1876 they were again examined, when the disease was found to have progressed in one-half the number of those previously found to be myopic. In January, 1877, he examined the eyes of 122 volunteers from the freshman class of Harvard College—a little more than half the class—of whom 29.5 per cent. were found to be near-sighted. Of these, twenty-two per cent. had supposed their sight to be normal. He describes his blank-printed forms as—

"filled in with the name and age of each individual, the state of each of his eyes as separately tested by glasses and the ophthalmoscope, the amount of his vision, and remarks on his previous history and family peculiarities in this regard. Blanks are left for a similar examination at the close of the senior year."

In his report to President Eliot,[1] he urges the advantages to the student of—

"reliable information at the outset of his collegiate career as to the state of his eyes, their availability for study, and the course he must pursue to maintain their integrity, or keep existing evils from increasing. At the termination of his undergraduate course he learns the effect of his four years of study, and is thereby enabled to form or modify his future plans."

His report closes with an illustration of the development of near-sight in a person born free from it, but inheriting a strong tendency to it. During nine years—from the age of ten to nineteen—suggestions several times offered with regard to rest and treatment having been unheeded, a progressive change had occurred, ranging from perfect soundness in one eye, and a very slight degree—represented by "0.75"—of near-sight in the other, to a high degree of near-sight, represented by "5.50" in each. If advice and warning are still unheeded, he thinks "an amount of structural change may be brought about incompatible with the integrity of the eye through life."

But while it appears to be conceded that near-sight is of infrequent occurrence among the illiterate classes, the question is a very natural one, "Have examinations been made, for comparison, of the eyes of any classes of young persons other than those engaged in study?" Dr. Cohn examined the eyes of many peasant-children, living in a state of comparative simplicity, and having little or no occasion to tax or strain the sight, and found that hardly two in a hundred of them were near-sighted. Examinations have been made also of the sight of young factory-operatives in large manufacturing towns in Europe, and the results exhibit a low percentage of myopia, corresponding to that of the peasant-children here cited. Dr. Howe says:

[1] *Boston Medical and Surgical Journal*, March 22, 1877.

"Of 213 cases of eye-disease seen during the last year among the paupers of Buffalo, the record shows only three and one-half per cent. to have been near-sighted."

Donders remarked this difference between his private patients—representing the wealthy and cultivated class—and his hospital patients: that while over-sight was distributed between the two classes in nearly equal proportion, near-sight occurred much more frequently among his private patients.

The investigations of Dr. Peter A. Callan belong in this category, with a qualification. He examined the sight of 457 colored-school pupils, aged from five to nineteen years, of the New York public schools, Nos. 3 and 4, and he found but 2.6 per cent. of them near-sighted. This field was selected because it was thought to furnish the nearest approach to the normal eye to be found in this locality. The Southern freedmen, he thinks, would afford the best possible field for this special line of investigation. As a class, the colored people of New York, prior to this generation, had very limited educational advantages, and the occupations which tax the sight, like engraving, etc., have never been known among them. But as these 457 subjects are now receiving the best school-training that the city affords, the superior condition of their sight must be referred to their freedom from hereditary tendency to myopia. The conscientious painstaking and thoroughness of Dr. Callan's work, as exhibited in his report, are manifest and noteworthy.

The uniform drift of results in all the examinations here referred to, and relating to over 26,000 individuals, may be regarded as sufficiently establishing the following propositions:

1. That, as a rule, near-sight originates in school-life.

2. That a large percentage of the scholars are thus afflicted—the percentage progressing with the stage of advancement in study.

3. That near-sight is progressive *in degree*, according to the length of school-experience.

But, though the demonstration of these points is now complete, further and successive examinations will still be useful to determine the improvement consequent upon the adoption of means to that end, and to furnish a standard of comparison between different schools in respect to material or methods, or both—that is, first, in respect to arrangement of building, amount and direction of light, character and position of desks, seats, etc.; and, second, in respect to methods of teaching, especially in the earlier years, and generally to the intelligent observance and enforcement by the teachers of hygienic conditions. Dr. Howe's report is interesting in this feature, showing that "in schools where the hygienic conditions relating to the position of the pupils and the amount of light are disregarded, the proportion of near-sighted pupils grows larger; and conversely, where these relations are observed, the number diminishes;" and he gives numerical rank "from an ophthalmic point of view" to the different schools examined by him.

Here arise two questions: 1. Can near-sight be cured? 2. Can it be prevented?

All authorities agree that it is incurable, and all agree that it may be prevented.

How?

The answer to this may be made more satisfactory if first we rapidly sketch a few well-known physiological facts, and get an understanding, approximately correct at least, of what near-sight is, and what causes it. Incidentally we shall have occasion to notice some of the methods and appliances for detecting both near-sight and over-sight.

When we see any object clearly, it is because the rays of light reflected or radiated from it enter the eye and produce a perfect picture of the object upon the retina. But the perfection of the picture depends upon the distance, size, and illumination of the object relatively to the powers and condition of the eye. The distance determines the angle at which the rays enter the eye. Whatever this angle, the rays must converge upon the retina, or the picture will be defective. This convergence it is the office of the lens to effect. From remote objects the rays are parallel, or nearly so. These, passing through the lens, are converged by it upon the retina. As the distance diminishes, rays entering the eye from any given point of the object become more and more divergent. Now, unless there be a corresponding increase in the convexity of the lens, these divergent rays will not be focalized at the same point as were the parallel rays; because, with the same power of lens, the focal distance must increase as the rays diverge; they will not, therefore, have converged when they reach the retina. A perfect picture will not be formed, and distinct vision will not be realized. But a change does take place in the lens corresponding to the change in the angle of the rays which enter the eye. As they diverge, its convexity increases. This is effected by the contraction of a muscle called, sometimes, *the muscle of accommodation*, which encircles the lens. Thus, the point of convergence is maintained upon the retina, in spite of the varying angle of the entering rays.

The normal location of the retina is that point at which parallel rays are converged, the lens being at rest. But if the eyeball loses its normal shape, and becomes elongated in the direction of its visual axis, the retina is thereby set back beyond the focal point. Convergence may be effected within the normal distance, but never beyond it; for, while the lens may become changed from its passive state to one of greater convexity, it cannot assume a convexity less than that of its passive state. Consequently, when the eyeball becomes elongated from front to back, the convergence will be at a point *in front* *of*, instead of *upon*, the retina. This is near-sight, as it may be recognized by object-tests or trial-glasses. But near-sight is sometimes simulated. This is caused by a spasmodic action of the muscle of accommodation. To determine absolutely, therefore, whether or not the eyeball has taken this abnormal shape, or whether the apparent near-sight is due to this spasmodic action of the focalizing muscle, the oculist must paralyze that muscle. He does this by a simple and, in his hands, a harmless application of a weak solution of sulphate of atropia.[1] Then the object-tests and trial-glasses will determine the question with certainty. But, if it be impracticable to apply the atropia, then the ophthalmoscope[2] must be resorted to, as offering the nearest approach to certainty of results when the accommodating muscle cannot be paralyzed, because its contraction is not very likely to occur under the operation of that instrument. Thus provided, the oculist proceeds to examine the interior of the eye, and, his own eye being normal, and his own accommodation relaxed, if he sees the retina of the examined eye perfectly, he pronounces the refraction to be correct; or, technically, the eye is *emmetropic*. But, if he finds the retina is not clearly visible, there being no opacity of the refracting media, he knows it can only be because the rays reflected from the ophthalmoscope have not converged upon it. Assuming it to be a case of anterior convergence, he interposes a concave glass, which lengthens the focus and removes the point of convergence back upon the retina. Thereupon he pronounces the eye *near-sighted;* or, technically, *myopic*, of a degree indicated by the strength of the glass.

Near-sight, then, is that condition of the eye in which the rays from distant objects reach the retina AFTER *convergence.*

On the other hand, if, instead of the eyeball becoming elongated, it is flattened, then the visual axis is too short; that is, the retina is brought too near the lens, which consequently requires the contraction of the accommodating muscle to focalize the parallel rays upon the retina; whereas, had the eye been normal, the lens would have performed this function while in a state of rest, and would have required the contraction only for divergent rays.

[1] Though this is frequently done with individual patients, yet schools have generally objected to it. Dr. Cohn enjoyed an exceptional opportunity to examine the eyes of 240 scholars after the application of sulphate of atropia. Dr. Callan's colored subjects, he relates, refused to permit this application. Therefore, wishing "to place the results of his examination beyond dispute" in point of accuracy, he adopted the alternative course, and "kept both of his own eyes under the influence of a four-grain solution of sulphate of atropia, applied three times daily during a period of five weeks, so that the accommodation was completely paralyzed for that length of time." Sometimes the examining oculist has acquired the power to perfectly relax his accommodation at will. But the relaxation of the accommodation of *the subject*, as well as that of the examiner, is essential to entire accuracy.

[2] A small mirror with a hole in the centre. The mirror is held close to the patient's eye, so as to reflect into it the light of a gas-jet back of him. The oculist then places his eye close to the hole, and looks into the illuminated interior of the eyeball.

This condition is known as *over-sight*,[1] technically, *hypermetropia*. When it exists in a degree beyond the adjustability of the lens, it may be recognized by object-tests and trial-glasses; but in less degrees it may escape detection by these means, because of the accommodating action of the lens. As in the case of near-sight, therefore, atropia must be employed for its exact observation.

Over-sight may, then, be defined as that condition of the eye in which parallel rays, passively transmitted by the lens, reach the retina BEFORE *convergence, because of the shortened axis.*

While the subjects of this malformation are numerous, some investigators finding them even to exceed largely those of the opposite condition,[2] and while the eyes so malformed are usually *not diseased, as in myopia*, yet numerous local and general disturbances are found to exist in very many of the cases. These are the result of over-use, or straining of the muscle of accommodation. A special interest has recently been excited in reference to them by an address of Dr. George T. Stevens, of Albany, read last December before the Albany Institute,[3] in which the relation of cause and effect is claimed to have been established by the author, between certain visual defects, particularly over-sight, and such functional nervous affections as neuralgia, the more common forms of headache, epilepsy, St. Vitus's dance, hysteria, and insanity. About six months previously he had presented this theory to the New York Academy of Medicine, but he then limited its application to St. Vitus's dance. These views were "new and unexpected to the profession," and were controverted by Dr. Charles S. Bull, of New York, in a paper read before the New York Medical Journal Association, in April last.[4] He reports thirty-one cases of St. Vitus's dance in his own recent practice, in which special attention was given to the discovery of any such relation as Dr. Stevens affirms to exist. Fifteen of the thirty-one had correct and sixteen had defective vision (over-sight). Of the latter only five could be induced to purchase and wear the necessary correcting glasses. But in these five cases there should have been some improvement, at least, in the nervous symptoms consequent upon their wearing the glasses; this being, by the admission of Dr.

[1] This is not a disease, like near-sight, but a condition; and it is not acquired, but is congenital, always. It is also called *far-sight* and *long-sight;* but it is thus liable to be confused with an acquired condition—producing a similar result, as in the sight of old people—which is not a flattening of the eyeball itself, nor of the cornea and the lens, but it is an impairment of the power of accommodation due to the hardening of the lens, which usually occurs at about the age of forty-five years, and is often called *old sight*, but is technically known as *presbyopia*.

[2] *See* "A Preliminary Analysis of 1,060 Cases of Asthenopia occurring in the Practice of C. R. Agnew, M. D.," which shows hypermetropia 359 to myopia 121, or nearly three to one.

[3] New York Medical Journal for June.

[4] *Medical Record*, June 2d.

Stevens himself, "the crucial test" of the correctness of his theory. *Yet no such result was observed.* Nevertheless, in his later essay, he insists that "correction of the eyes of the patients does relieve their nervous symptoms. . . . This is no place," he says, before the Albany Institute, "to relate cures in medical practice; but, after a sufficiently extended and careful series of observations, continued during more than four years, I can safely prophesy that this principle will be found of more universal application, and more successful in its workings, than any which has been advanced for the mitigation of this class of affections."

The distressing confusion and disappointment resulting from the unbalanced action, in the over-sighted eye, between the arrangement for adjusting the lens and that for converging the eyeballs, is very clearly explained by Dr. Stevens in the same paper. Referring to its effect upon school-children he says:

> "How often do we see children of our schools, frequently the brightest and most ambitious of their class, struggling with irritable nerves, at a disadvantage in their studies, laying the seeds of future trouble, and often, as the time comes for selecting a pursuit in life, forced to abandon a chosen course of studies, because the confinement at such work is too great a strain upon them! I look forward to the time when these children, who from this single peculiarity are placed at so serious a disadvantage in the struggle for life, shall find the relief that science is ready to afford them, and which would remove the weight that would otherwise prove a serious hinderance in their course."

Resuming now the consideration of near-sight, we proceed to suggest some of its principal causes, as follows:

1. Too early use by school-children of books, slates, and writing-paper, or copy-books, when blackboards and models would be better. Type and script letters and figures, and their primary combinations, at least, should never be taught from books, but from large and perfectly-formed models, printed on cards and hung on the wall. When the eye and the memory are sufficiently trained to easily recognize and name each letter and figure at sight, and when some knowledge has been gained of the power of letters and figures in combination, then the same forms in books will be at once familiar as old acquaintances, and may be studied without straining the sight. *To train the hand* without straining the sight presents a greater practical difficulty. In the large schools, of course, all the children cannot go to the blackboard. But a considerable practice in drawing large lines and simple objects on good-sized slates, in a sort of free-hand style, should precede the formation of letters and figures; and, when these are begun, they should be made of generous size. A correct position, meanwhile, should be an imperative requirement; and, until it becomes habitual and easy, good work should be held to be of secondary importance. Hard slate-pencils and greasy slate-surfaces should not be permitted; both should be subject to systematic inspection.

2. Ignorance or laxity on the part of parents and primary teachers, in permitting faulty positions of the head, body, and book, during reading, study, and writing; and in not seeking early to secure the intelligent coöperation of the pupil by simple and appropriate physiological instruction.

3. A prolonged and steady looking at an object or at objects near the eye, though at proper distance, without rest or frequent change of the visual focus, as in long and absorbed novel-reading, intense study, or persistent diligence in needlework.

4. The practice of reading or otherwise using the sight at too short range. This results in part from insufficient light; or from its faulty direction, so that the hand or body throws a shadow on the page; or so that the direct rays fall upon the eye, causing undue contraction of the pupil, while the page is in shadow. It results also from improperly graded desks, from small and poor type and inferior printing-ink, and from faulty color and quality of printing-paper; also from pale writing-ink—pale when used—and from the substitution of the lead-pencil for the pen, especially in the evening.

5. A prone or forward position of the head too long maintained, or frequently repeated, and becoming a habit. This results from reading or studying with the book in the lap, and from the use of desks not graded to the height of the pupil. Dr. Howe reports pupils varying eighteen inches in height seated at the same grade of desks. The distance of the eye from the page should not be less than twelve nor more than eighteen inches. Having the desks set too far from the seats also induces this faulty position. The front of the desk should overlap the seat one or two inches.

Donders says,[1] "In the hygiene of myopia the very first point is to guard against working in a stooping position." He favors high, sloping desks, and indicates "rectilinear drawing on a flat surface" as a class of work which is especially objectionable.

6. Since a vitiated atmosphere is a frequent feature of the school-room, it may not be amiss to add here that the effect of bad air is indirectly to injure, if not to destroy, the sight.

7. Allowing a sun-glare on the page while reading; also transitions from cloud-shadow to sunshine.

8. Reading and studying in railroad-cars is known to be a fruitful source of injury.

9. But insufficient light, perhaps more than any other cause, produces disease of the eye and derangement of the vision. This is not confined to the schools. Sadly frequent as it is found to be there, it is believed to be yet oftener illustrated at home, both by daylight and in the evening, in preparation for the school and otherwise. Artificial illumination is faulty at best, but, even in the most favored homes, the elder group is apt to monopolize the shaded drop-light or student-

[1] "Accommodation and Refraction," p. 419.

lamp, while the schoolboy with his text-books is found somewhere in the outer circle.

Twilight-reading is much practised, and is especially pernicious—that is, prolonging the study or reading after daylight has begun to decline. The change is so stealthy that, when the interest is excited, and the mind absorbed, the growing darkness is unheeded or unobserved, till serious mischief is done.

A curious and interesting case of injury to the sight by study is that of Prof. John Nott, late of Union College, Schenectady. Over thirty years ago his sight was permanently destroyed for all literary purposes, "by attempting," as he says in a recent letter to the writer of this, "too much study without thought of the necessity of care for the eyes." How many are following after him! In the same letter he thus describes his case as diagnosed by Dr. Alexander, of London, who alone of all whom he consulted was able to afford him even temporary and partial relief: "Thirty-six very small glands in the eyelids make *oil* for the eye, the same as oil for your lamp. When these glands become dry, reading is impossible, although in other respects the eye may be perfect. This was my disease—no oil was supplied to the eye." He makes or implies this noteworthy suggestion, which is hereby commended to authors, publishers, and school-boards: *that a brief and appropriate caution be conspicuously printed or pasted in the front of every school and college text-book, by authority of commissioners, superintendent, trustees, or faculty.* Something like the following would perhaps realize his idea:

Caution.—Reader, *your eyesight* is worth more to you than any information you are likely to gain from this book, however valuable that may be. You are therefore *earnestly cautioned*—

1. To be sure that you have sufficient light, and that your position be such that you not only avoid the direct rays upon your eyes, but that you also avoid the angle of reflection. In writing, the light should be received over the left shoulder.

2. That you avoid a stooping position and a forward inclination of the head. Hold the book up. Sit erect also when you write.

3. That at brief intervals you rest the eyes by looking off and away from the book for a few moments.

And you are *further cautioned* to avoid as much as possible books and papers printed in small type, and especially such as are poorly printed; also to avoid straining or overtaxing the sight *in any way.*

Boys may need to be reminded of the great importance of thoroughly cleansing the eyes with soft, pure water both morning and evening.

To many readers it would no doubt be interesting to consider how each of the practices and conditions we have pointed out as producing near-sight tends to effect the elongation of the visual axis. But while there might be no disagreement among oculists as to the fact that the practices and conditions named do thus tend, there may not be a consonance so general as to the precise process in every case A few general suggestions, however, are submitted:

1. The *rationale* of the effect of the premature use of books, etc., during the more plastic condition of the eye is sufficiently obvious.

2. A prolonged tension of the sight lessens the muscular elasticity.

3. The contraction and consequent thickening of the muscles which pull the two eyes inward, so as to focalize the sight upon a near object, causes a side-pressure, and a corresponding transverse or lengthwise protrusion. The nearer the object, the stronger must be this action of the muscles, and the more marked the effect.

4. The prone position of the head causes the blood to settle in the eyeballs, increasing the tension of the fluids, exciting inflammation and consequent softening of the coatings, and resulting in permanent distention.

The attentive reader cannot have failed to observe that we have enumerated causes of injury to the eyes from study, other than those which produce near-sight. Of these, only one seems to require reference—the effect of bad air in the school-room.

Dr. Loring read a paper in February last before the Medico-Legal Society of New York, answering four questions relating to the care of the eyesight, which had been submitted to him by that Society. The first of the series inquires the effect of bad air on the sight.[1] His reply, given at some length, supports the statement herein made.

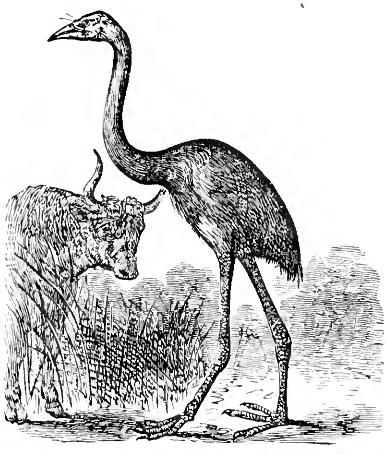
In a recent conversation with the writer, Dr. Loring advocated examinations of the sight of all children when they first enter school, and at such subsequent stages of their education as might seem desirable. The position of a child's seat relatively to the blackboard, etc., would often be governed by such an examination. He thought, too, that glasses would be recommended in some cases by the examining oculist—a permanent official he would have him to be—and that, if necessary, they should be furnished at the public expense, or out of some special fund; the glasses to be worn during school-hours at least, if not continuously. He related the circumstance of a lad having been recently brought to him by his father from the West. An examination verified the boy's statement that he could see to read usually very well; but that sometimes, in a moment, his sight would be so affected that reading became impossible. This had led to his repeated punishment at school, his averment of inability not being credited by his teacher.

[1] *Medical Record*, April 14th.

THE GIGANTIC MOA-BIRD.

THE extinction of many animals that are known to have formerly existed on the earth is a subject which cannot very easily be explained, while the number of them is greater than at first sight would be supposed. Various species no doubt undergo gradual extinction by changes which deprive them of their accustomed food; but others seem to die out from unknown causes. During the historic period a considerable number of animals have been swept off the British Islands, among which are the bear, the wolf, the Irish elk, etc. In America, during the comparatively short period of its history, various species have vanished, and others are following them. The beaver, formerly so generally spread over the whole of that country, is now only to be found in remote regions. The deer and the moose are disappearing in the same manner. The bison is very much diminished in numbers, and must ere long be extirpated. The mastodon, a creature of enormous bulk, has totally disappeared, although, along with the skeletons of them which have been discovered, there are evidences of their having lived on food derived from plants which are still existing. In other parts of the world, the dodo and the moa have perished within the last few centuries; and the apteryx is undergoing the same fate.

The moa or dinornis was a huge bird, of which the remains are plentifully found in New Zealand. Within recent historic times, this colony was tenanted, to the almost entire exclusion of mammalia, by countless numbers of gigantic wingless birds of various genera and species, the *Dinornis gigantea*, the largest, attaining a size nearly thrice that of a full-grown ostrich. From traditions which are current among the Maoris, they were fat, stupid, indolent birds, living in forests and feeding on vegetables; while the name *moa* seems to have been given to them from their peculiar cry. Since remains have been found in great plenty, the investigation of this singular bird is of the greatest interest to students of natural history.



DINORNIS GIGANTEA.

It is to the Rev. Richard Taylor that the first discovery of moa remains is due, which he thus describes:

"In the beginning of 1839 I took my first journey in New Zealand to Poverty Bay with the Rev. W. Williams, Bishop of Waiapu. When we reached Waiapu, near the East Cape, we took up our abode in a native house, and there I noticed the fragment of a large bone stuck in the ceiling. I took it down, supposing at first that it was human; but, when I saw its cancellated structure, I handed it over to my companion, who had been brought up to the medical profession, asking him if he did not think it was a bird's bone. He laughed at the idea, and said, 'What kind of a bird could there be to have so large a bone?' I pointed out its structure, and, when the natives came, requested him to ask them what it belonged to. They said it was a bone of the *tarepo*, a very large bird, that lived on the top of Hikurangi, the highest mountain on the east coast, and that they made their largest fish-hooks from its bones. I then inquired whether the bird was still to be met with; and was told that there was one of an immense size which lived in a cave, and was guarded by a large lizard, and that the bird was always standing on one leg. The chief readily gave me the bone for a little tobacco; and I afterward sent it to Prof. Owen by Sir Everard Home in 1839; and I think I may justly claim to have been the first discoverer of the moa."

Mr. Taylor continued his inquiries among the natives, who informed him that the moa was quite as large as a horse; that these birds had nests made of the refuse of fern-root, on which they fed; and that they used to conceal themselves in the veronica-thickets, from which, by setting them on fire, the natives drove them out, and killed them; hence originated the Maori saying, "The veronica was the tree which roasted the moa." The natives further mentioned that when a moa-hunt was to take place notice was given inviting all to the battue. The party then spread out to inclose as large a space as possible, and drive the birds from their haunts; then, gradually contracting the line as they approached some lake, they at last rushed forward with loud yells, and drove the frightened birds into the water, where they could be easily approached in canoes and dispatched without their being able to make any resistance. These moa-hunts must thus have been very destructive; as, from the number of men employed, and the traces of long lines of ovens in which the natives cooked the birds, and the large quantity of egg-shells found on the western shores of New Zealand, a clear proof is given that these birds were eagerly sought for and feasted upon. Thus the poor moas had very little chance of continuing their race.

From a very interesting communication of the Rev. W. Williams, dated May 17, 1872, it would appear that the moa may not yet be entirely extirpated. He remarks:

"Within the past few days I have obtained a piece of information worthy of notice. Happening to speak to an American about these bones, he told me that the bird is still in existence in the neighborhood of Cloudy Bay, in Cook's Strait. He said that the natives there had mentioned to an Englishman, belonging to a whaling-party, that there was a bird of extraordinary size to be seen only at night on the side of a hill near the place; and that he with a native and a second Englishman went to the spot; that after waiting some time they saw the creature at a little distance, which they describe as being about fourteen or sixteen feet high. One of the men proposed to go nearer and shoot; but his companion was so exceedingly terrified, or perhaps both of them, that they were satisfied with looking at the bird; when after a little time it took the alarm and strode off up the side of the mountain."

In the *Greymouth Weekly Argus*, published in New Zealand in 1876, there appeared a letter signed R. K. M. Smythe, Browning's Pass, Otago, describing in a very detailed manner the capture of two living moas, a female eight feet high, and a younger one three feet shorter. The writer finishes his account of their capture by remarking that he has little doubt that he will be able to bring them both alive to Christchurch. It is therefore to be hoped that living representatives of the genus *Dinornis* still survive. Feathers of the bird have been also found in a state of preservation sufficiently good to show that they possessed an after-shaft of a large size; and at the same time tradition and the condition in which the bones are found, retaining much of their animal matter, tend to show how lately the bird formed part of the existing fauna of the country. If the letter be genuine, it cannot be long before ornithologists, of whom there are several of no mean repute in New Zealand, will be able to satisfy themselves on the subject.

An additional reason for supposing that these magnificent birds existed not long ago is found in the fact that specimens of their eggs have been preserved. In the volcanic sand of New Zealand, Mr. Walter Mantell found a gigantic egg, of the magnitude of which he gives us a familiar idea by saying that his hat would have been just large enough to have served as an egg-cup for it. This egg must have been one of a dinornis or a palapteryx, and, although its dimensions are considerably greater than the egg of the ostrich, still it is smaller than might have been expected from a bird from twelve to fourteen feet high. It is well known that the egg of the New Zealand apteryx, to which the moa bears a very close affinity, is one of dimensions that are quite surprising in proportion to the bulk of the bird. The apteryx is about as big as a turkey, standing two feet in height; but its egg measures four inches ten lines by three inches two lines in the respective diameters. To bear the same ratio to the bird as this, the egg of the *Dinornis gigantea* would be of the incredible length of two feet and a half, by a breadth of one and three-quarters!

In the museum at York there is a complete skeleton of a moa, which, besides feathers, has the integuments of the feet partly preserved; from which it is evident that the toes were covered with small hexagonal scales. A specimen has also been sent by Dr. Haast, of New Zealand, to Prof. Milne-Edwards, which is to be seen in the Museum of Natural History at Paris.—*Chambers's Journal.*

TO THE "RING NEBULA."

By J. L. STODDARD.

O PALLID spectre of the midnight skies!
Whose phantom features in the dome of Night
Elude the keenest gaze of wistful eyes
Till amplest lenses aid the failing sight,
On heaven's blue sea the farthest isle of fire,
From thee, whose glories it would fain admire,
Must vision, baffled, in despair retire!

What art thou, ghostly visitant of flame?
Wouldst thou 'neath closer scrutiny dissolve
In myriad suns that constellations frame,
Round which life-freighted satellites revolve,
Like those unnumbered orbs which nightly creep
In dim procession o'er the azure steep,
As white-winged caravans the desert sweep?

Or art thou still an incandescent mass,
Acquiring form as hostile forces urge,
Through whose vast length a million lightnings pass
As to and fro its fiery billows surge—
Whose glowing atoms, whirled in ceaseless strife
Where now chaotic anarchy is rife,
Shall yet become the fair abodes of life?

We know not; for the faint, exhausted rays
Which hither on Light's wingèd coursers come,
From fires which ages since first lit their blaze,
One instant gleam, then perish, spent and dumb!
How strange the thought that, whatsoe'er we learn,
Our tiny globe no answer can return,
Since with but dull, reflected beams we burn!

Yet this we know: yon ring of spectral light,
Whose distance thrills the soul with solemn awe,
Can ne'er escape in its majestic might
The firm control of omnipresent law.
This mote descending to its bounden place,
Those suns whose radiance we can scarcely trace,
Alike obey the Power pervading space

SKETCH OF MICHAEL SERVETUS.[1]

BY M. MAURIS.

THE publication of an elaborate life of Servetus in English at the present time will be welcome to many readers, who at present know little more of the man than that he was burned at the stake at Geneva, at the instigation of John Calvin, three hundred and twenty-five years ago. The progress of the world from polytheism to monotheism has had many tragic passages, but perhaps the most unique was this roasting alive of the Unitarian Servetus with green wood by a leader of the Protestant Reformation.

Dr. Willis, the author of the work, had edited an edition of the writings of William Harvey, accompanied by a biography of the great demonstrator of the circulation of the blood. His researches into this interesting subject led him to investigate the claims of Servetus to a share in this grand discovery, when it was established that he was "the first who proclaimed the true way in which the blood from the right reaches the left chambers of the heart by passing through the lungs, and even hinted at its further course by the arteries to the body at large." His study of the subject deepened the interest of Dr. Willis in the character of Servetus, not only as a physiologist, but as a philosopher and scholar; as a practical physician, freed from the fetters of mediæval routine; an eminent geographer and astronomer, and a liberal Biblical critic in days when criticism, as we understand the term, was unimagined.

Servetus was a Spaniard, born at Villanueva, in Aragon, in 1509, of an old family in independent circumstances. He entered the University of Saragossa when about fourteen years old, and there perfected himself in the study of the classics, in the Greek and Hebrew tongues, as well as in the ethics of Aristotle, scholastic philosophy, mathematics, astronomy, and geography. From Saragossa he appears to have passed to the law-school of Toulouse, but theology had more attractions for him than law. A rational exposition of God's revelation of himself in Nature seems to have been a craving in the ardent and religious temperament of the thoughtful young Spaniard. While at Toulouse he read the Bible, the writings of Luther, the rational theology of Rymund de Sabunde, and the works of Erasmus. The effect of these studies was that, at eighteen years of age, he had already framed a theological system of his own, far in advance of the ideas of his time. Leaving Toulouse, Servetus entered the service of Juan Quintana, a Franciscan friar, and confessor of the Emperor Charles V., whose coronation he attended in Aix-la-Chapelle, and also

[1] "Servetus and Calvin: A Study of an Important Epoch in the Early History of the Reformation." By R. Willis, M. D. 541 pages. London: Henry S. King & Co.

the Diet of Augsburg, which closely followed it. Servetus was in sympathy with the Reformers of the Lutheran Reformation, and, in fact, came into conflict with them, because he did not think they were sufficiently rational and thorough-going, and what he saw of the pomp and tyranny of princes and bishops was not calculated to quiet the spirit of protest that early took a powerful hold upon his mind. At the age of twenty he writes: "For my own part, I neither agree nor disagree in every particular with either Catholics or Reformers. It would be easy enough, indeed, to judge dispassionately of everything, were we but suffered without molestation by the churches freely to speak our minds; the older exponents of doctrine, in obedience to the recommendation of St. Paul, giving place to younger men, and these, in their turn, making way for teachers of the day, who had aught to impart that has been revealed to them. But our doctors now contend for nothing but power. The Lord confound all tyrants of the Church! Amen."

With such views, and a constitutional temperament that knew no fear, and led him to the free expression of his opinions, he was, of course, soon dismissed from the service of Quintana. He then threw himself, body and soul, into the study of theology, and in 1530 we find him at Basle, Switzerland, disputing with Œcolampadius and other theologians on the consubstantiality and coeternity of the Son with the Father, and other points in connection with the idea of the Trinity then prevailing among Catholics as well as Reformers. Being unable to make his views acceptable to the Reformer of Basle, he proceeded to Strasburg to propound his docrines to Martin Bucer and W. F. Capito, but with no better results. Meanwhile, he had not been otherwise idle; he had written a book in which his new opinions concerning Christianity were fully explained, and he resolved upon having it printed, to make the world judge between him and the other Reformers. He was in Germany, the land of free thought, as he imagined, and among men who had thought freely: why should he not avail himself of the same right? The names of Luther, Calvin, etc., appeared on the title-pages of their works: why should his name be withheld from the world? Accordingly, the "Seven Books on Mistaken Conceptions of the Trinity" appeared with the author's full family name, and the name of the country that called him son.

As he appears in this book, Servetus may be considered as the founder of the doctrine of real monotheism, as it was possible to conceive it in the sixteenth century. We are sorry to be unable to give more than a passing notice of the chief points discussed in this work. He believed in a kind of Trinity, but modal and formal, not real and personal in the usual sense of the word. "God cannot be conceived as divisible," he says; he acknowledges a Son of God and a Holy Ghost, finding them in the Scriptures, no word of which he would overlook, though putting his own interpretation on all they say.

"The word Trinity," he writes, "is not to be found in Scriptures. The Son and the Holy Ghost are no more than so many forms or aspects of Deity. . . . To believe," he continues, "suffices, it is said (to salvation); but what folly to believe aught that cannot be understood, that is impossible in the nature of things, and that may even be looked on as blasphemous! Can it be that mere confusion of mind is to be deemed an adequate object of faith?" Speaking of the Holy Ghost, Servetus forgot what is due to a subject that has engaged the serious thoughts of so many pious and learned men. He saw some portions of the Catholic Christian dogma so unreasonable as to be unable to refrain from ridiculing them. Yet the idea of God to which Servetus had attained is unquestionably pure and grand—the only one, in fact, as we see the subject, that can be reasonably held by a true idealist. He also deals heavy blows at the doctrine of justification by faith, the leading feature of Luther's theology, in terms neither complimentary nor respectful to its author; nor less roughly dealt with is the leading Calvinistic theory of predestination and election.

The book seems to have caused a considerable stir both in Germany and Switzerland, to have found proselytes in Italy, and to have been read by every one of liberal education. Some of the antagonistic Reformers themselves could not forbear being strongly impressed with it. Œcolampadius, writing to Martin Bucer, July 18, 1531, says: "Read the book, and tell me what you think of it; as the writer does not acknowledge the coeternity of the Son, I can in no wise approve of it as a whole, although it contains much that is good." Melanchthon writes to a friend, "I read Servetus a great deal." He does not agree with the author, but "I have little doubt," he continues, "that great controversies will one day arise on this subject as well as on the distinction of the two natures in Christ."

"The Reformers of the sixteenth century," Dr. Willis says, "went little way in freeing the religion of Jesus of Nazareth from the accretions which metaphysical subtilty, superstition, and ignorance of the laws of Nature, had gathered around it in the course of ages. Their business, as they apprehended it, was to reform the Church—the task Servetus had set himself, in the end, was to reform *religion*, with little thought of a church, in any sense as it was conceived in his day either by papists or Protestants." How could a book in this direction be welcome to the Reformers? It was too far in advance of their ideas; Servetus's dialectics were too stringent, and his arguments too conclusive against them.

After writing a splendid letter to Œcolampadius, for which we regret to have no room, he quitted Switzerland, whither he had returned after the publication of his book at Hagenau; and here he seems to have again taken up his quarters for some weeks or months, to write and superintend the printing of the "Two Dialogues on the

Trinity." Under color of modifying some of the views enunciated in his first work, he now cast the concluding anathema against all tyrants of the Church, as a parting shot, and off he went to France, reaching Paris toward the end of 1532.

If Switzerland and Germany "were too hot for him," Roman Catholic France would have proved still hotter; but during the time he lived in that country he never made himself known save as "Monsieur Michel Villeneuve," from the town of his nativity. He entered as a student of mathematics and physics at one of the colleges of Paris, and lived very quietly. At a later period he took his degree of M. A. in the University of Paris.

But the study of mathematics had soon to be abandoned for present means of subsistence. After a short stay at Avignon and Orleans, Villeneuve betook himself to Lyons, then a great centre of learning. There he seems to have found ready employment as reader and corrector of the press, first, and afterward as editor in the celebrated printing-establishment of Trechsel Brothers. Among the works he edited for them, the "Geography of Ptolemy," enriched by extensive comments from him, can by no means be overlooked, connected as it is with the charges imputed to its editor, later on, in his trial at Geneva.

The reading-room of the printers of Lyons, and the acquaintance Servetus formed there with the great physician and naturalist, Dr. Champier, brought the former back from the empyrean of metaphysics to the earth, and put him in the way of becoming the geographer, astrologian, Biblical critic, physiologist, and physician, with whom we are made familiar in his subsequent life and writings. With the money he had saved in the two years spent with Trechsel, he went back to Paris (1536), and gave himself to the study of medicine. He became at once associated with scientists as distinguished as Andreas Vesalius, the creator of modern anatomy, and Joannes Guinterus; and in a singularly short time he obtained the degree of M. D. With the stimulus of necessity upon him, for he was poor, and the excitement of ambition, with which he was largely endowed, as he found it hard to earn a living by his profession, Servetus appeared before the world as lecturer on geography and astrology—which then embraced the true doctrine of the heavenly bodies, as well as the false one of their influence on the life of man; and in this capacity he achieved an enormous success. Next he came forward in connection with his profession by writing a book on "Medicinal Sirups and their Use," thus winning fame also as a physician. A fiery struggle was going on during the early part of the sixteenth century between the Averrhoists and the Galenists. Like his initiator into medical matters, Dr. Champier, Servetus was himself a Galenist; but in this character, too, he showed the independence of his nature, by having open eyes for any truth which the Arabian writers and their followers might present.

Servetus's fate on starting in life was opposition. Through superior endowment and culture, he found himself antagonistic to almost all around him; his convictions were deep, and the haughtiness and violence of his disposition made it impossible to suppress them. The physician, therefore, met the fate of the theologian. It seems that he had gone out of the way, in his lectures, to accuse his fellows of ignorance, at least, of astronomy. The doctors of the faculty retaliated by denouncing him from their chairs as an impostor and a windbag. Servetus then wrote a pamphlet, in which he laid bare the sore places in the characters of his adversaries, even holding them up, in their ignorance, as the pests of society. His intentions being made known, the Senate of the University and the Parliament of Paris were petitioned to forbid the publication of the pamphlet; but Servetus outwitted them—before the day of citation came, the dreaded pamphlet was distributed to the public. The faculty of medicine had him summoned before the inquisitor of the king as an enemy of the Church, on the score of heresy, implied in the practice of judicial astrology. So thoroughly, however, did he satisfy the inquisitor that he was a good Christian, that he left the court with flying colors, absolved even of all suspicion of heresy. The doctors, however, in the end, won the day. The award of the Parliament ordered Michael Villanovanus to call in his pamphlet and deposit the copies in the court; to pay all honor to the faculty and its members; and he was expressly forbidden to appear in public or in any other way as a professor of astrology.

Villeneuve now moved to Charlieu, near Lyons, where he resumed the practice of medicine. While at Charlieu (1539), having attained his thirtieth year, according to the religious tenets he professed, he had himself baptized.

Pierre Paumier, one of his Paris admirers and friends, and now Archbishop of Vienne, hearing of his whereabouts, invited him to quit the narrow field of his practice for a wider one. Villeneuve accepted, and for the next twelve years he lived in Vienne, under the immediate patronage of the eminent prelate.

Besides practising medicine, he resumed his connection with the publishers of Lyons, and among other works edited the Latin Bible for Trechsel, with comments of his own. From his long studies in the Scriptures he had come to the conclusion that, while the usual prophetical bearing ascribed to the Old Testament was ever to be kept in view, the text had a primary, literal, and immediate reference to the age in which it was composed and to personages, events, and circumstances, among which the writers lived; and, according to this plan, he carried out the work. Yet Spinoza, Astruc, and others, who lived a century later, are called the founders of the modern school of Biblical exegesis, and Servetus is not even named as a Biblical critic and expositor!

We have now arrived at a momentous event in the life of Servetus

—his theological correspondence with John Calvin. It seems to have been entered upon at the suggestion of John Frelon, one of the Lyons publishers.

Servetus has been accused of having provoked the Genevese Reformer by addressing him in a style calculated to wound, if not to insult, him; and the character of the man gives likelihood to the charge. But, had Calvin's letters been preserved, we doubt whether the accusation would hold good; we know for a certainty that the great Reformer applied very freely the lowest epithets to his opponents—"rascal, dog, ass, and swine, being found of constant occurrence among them—had there been any stronger than scoundrel and blasphemer, they would have been hurled at Servetus." Calvin's own letter to Frelon, their go-between, throws a great light on the subject. Among other things, he writes: "I have been led to write to him more sharply than is my wont, being minded to take him down a little in his presumption; and, I assure you, there is no lesson he needs so much to learn as humility." At any rate, Villeneuve approached the Reformer, at first, as one seeking aid and information from another presumed most capable of giving both. Calvin replied in a concise, dogmatic way which, indeed, could not satisfy a mind as thoroughly made up as that of Servetus. Moreover, the Reformer soon grew weary of the correspondence, so that Frelon had to interpose in behalf of the Spaniard in order to make the former answer his letters. Nor is this all: thinking he might escape further molestation, Calvin referred Servetus to his book, "Institutions of the Christian Religion," as though he had been a schoolboy who had entered upon a discussion with the Reformer, with no knowledge of his doctrines. Villeneuve now became his critic. The copy of the "Institutions" was sent back, copiously annotated in the margin. There was hardly a proposition in the text that was not taken to pieces by him and found untenable on the ground of Scriptures and patristic authority, and this he did with the freedom of expression in which Villeneuve indulged. Calvin, in writing to a friend, indignantly says, "There is hardly a page that is not defiled by his vomit." "The liberties taken with the 'Institutions,'" Dr. Willis says, "were looked on as a crowning personal insult by Calvin; and reading, as we do, the nature of the man, it is not difficult to conclude that it was this offense, superadded to the letters, which put such rancor into his soul as made him think of the life of his critic as no more than a fair forfeit for the offense done." As a matter of course, the correspondence was soon dropped by Calvin, but not so by Servetus, who seemingly could not bear his opponent's neglect; over thirty letters of his, embracing a period of more than two years, are still extant.

Servetus meanwhile had prepared another book, "Christianismi Restitutio" (The Restoration of Christianity)[1] with which he intended

[1] The "Christianismi Restitutio" of Servetus is one of the rarest books in the world.

to bring religion back to more winning simplicity and purity. Having made a MS. copy of it, he sent it to Calvin, requesting an opinion on its merits. It was on its reception that, writing to his friend Farel, Calvin made use of the following language: "Servetus wrote to me lately, and besides his letter sent me a great volume full of his ravings, telling me with audacious arrogance that I should there find things stupendous and unheard of until now. He offers to come hither if I approve; but I will not pledge my faith to him: for, did he come, if I have any authority here, *I should never suffer him to go away alive.*" We see already by what feeling Calvin was animated: he hates the man who did not acknowledge his superiority, as he was accustomed to see others do, and who dared to criticise his opinions. Not only did he not even condescend to offer any strictures upon Servetus's work, but he never sent back the MS., although repeatedly asked for it.

Servetus, who had kept another copy for himself, determined to have the book printed anonymously. Arrangements were made with Balthasar Arnoullet, printer at Vienne, and, as secrecy was of capital importance, a small house away from the known printing-establishment was taken; type, cases, and a press, were there set up, and in a period of between three and four months an edition of 1,000 copies was successfully worked off. The whole impression was then made up into bales of 100 copies each, and confided to friends at Lyons, Frankfort, etc., for safe-keeping, until the moment of putting them in the market abroad had come.

The book on "The Restoration of Christianity" comprises a series of disquisitions on the speculative and practical principles of Christianity as apprehended by the author; thirty of the letters he had written to Calvin; and other writings of minor importance. It is in this book that Servetus shows himself the most far-sighted physiologist of his age, by anticipating the discovery of the circulation of the blood.

Through Frelon a copy of the book, "hot from the press," was especially addressed to "Monsieur Johann Calvin, minister of Geneva." We leave for the reader to imagine what additional anger must now have entered the Reformer's heart, when, besides the offensive and, as he regarded it, heretical matter of the book, he found the letters written to him made public, himself publicly schooled, his most cherished doctrines proclaimed derogatory to God, and some of them as barring the gates of heaven! What the reader, perhaps, could not imagine is, that the "high-minded" man who had emphatically denounced the "right of the sword" in dealing with heresy, was now ready to become instrumental in having it applied to Servetus. He became the denunciator of Servetus to the Catholic authorities of Vienne; he betrayed friendship and trust by furnishing them with

Of the thousand copies printed, two only are now known to survive: one among the treasures of the National Library of Paris, the other among those of the Imperial Library of Vienna.

the documents (letters and leaves from the printed book as well as the MS. copy which he had kept) that would bring about his conviction, and consequently his death. And this was not done openly. Calvin sent the wanted information through a convert to the Reform, a young man by the name of William Trie. Did not the style of Trie's letters and the documents show plainly the part played by the Reformer in the treason, he might be easily absolved from the charge —so cautiously had he worked to keep his treachery a mystery. Servetus was arrested and tried; he only avoided being burned alive by making good his escape from prison (April 17, 1553), in which he seems to have been aided by some devoted friend. All the books, however, that could be found, were seized and burned, together with his effigy.

Escaped from the prison of Vienne, after rambling some weeks through Southern France, he fled to Geneva. His choice of this place can hardly be accounted for. Perhaps, though he knew that Calvin had been his denunciator, it never entered his mind that the Reformer would now take the knife in hand himself. In the early morning of some day after the middle of July, he entered Geneva and put up at a small hostelry on the banks of the lake, where he seems to have lived very privately for nearly a month. On Sunday, August 13th, he ventured imprudently to show himself at the evening service of a neighboring church. Being recognized, Calvin was informed of his presence, and without a moment's delay he again denounced him, and demanded his arrest. Servetus was at once thrown into the common jail of the town.

According to the laws of Geneva, grounds for an arrest on a criminal charge were to be delivered within twenty-four hours thereafter. Calvin worked all night, and thirty-eight articles drawn from the "Christianismi Restitutio" were in due time presented in support of the charge. Another law prescribed that criminal charges should be made by some one who avowed himself aggrieved, and was contented to go to prison with the party he accused, the law of retaliation disposing of him in case his charges were not made good; and Calvin complied with this law, too, by means of a substitute. His cook, Nicolas La Fontaine, was the man who now came forth as "personally aggrieved by," and prosecutor of, Michael Servetus!

The main charges against the Spaniard were: his having troubled the churches of Germany, about twenty-four years previously, with his heresies and with an execrably heretical book, by which he had infected many; having continued to spread poison abroad with his "Comments to the Bible," the "Geography of Ptolemy," and lately with his "Restoration of Christianity;" having blasphemed against the Trinity, the Sonship of Christ, his consubstantiality with the Father, and proclaimed infant baptism a diabolic invention; having escaped from the prison of Vienne; and, finally, "of having in his printed books made use of scurrilous and *blasphemous* terms of reproach in speaking of Monsieur John Calvin and his doctrines."

Servetus's reply in his preliminary interrogatory was: that he was not conscious of having caused any trouble to the churches of Germany, and defied any one to prove it; that he was unaware that the book he owned to have had printed at Hagenau had produced any evil; that it was true he had commented on the above-mentioned books, but he had said nothing in them that was not the truth; and in the book lately printed he did not believe that he blasphemed, but if it were shown that he had said anything amiss, he was ready to amend it; that in the book he wrote on the Trinity he had followed the teaching of the doctors who lived immediately after Christ and the apostles; that previous to the Council of Nicæa no doctor of the Church had used the word *Trinity;* that his strong language against the Trinity, as apprehended by the modern doctors, was suggested by the belief that the unity of God was by them denied or annulled; that as regards infant baptism it was his belief that none should be baptized who had not attained the years of discretion; but he added, as ever, that if he were shown to be mistaken, he was ready to submit to correction; that Calvin had no right to complain of the respondent's abusive language, as he had been himself publicly abused by Calvin: he had but retaliated, and shown him from his writings that he was mistaken in many things.

On August 15th the council was formally installed as a court of criminal judicature, and the trial commenced; the answers of the prisoner to the articles being generally in the terms of his previous examination. The court closed the meeting with making good a petition of Nicolas La Fontaine to be discharged from prison, Servetus himself having given sufficient *prima-facie* evidence of his guilt. Bail was, however, required; and this was immediately forthcoming in the person of Monsieur Antoine Calvin, brother of the Reformer. The *chef de cuisine* was discharged, while Servetus was remanded to jail. About this time, in a letter to his bosom friend Farel, after relating the events of Servetus's arrest and of the proceedings against him, Calvin wrote, "I hope the sentence will be capital *at least.*"

It would be most interesting to follow this unprecedented sham-trial in all its details, as Dr. Willis has done; but want of space limits us to mere outlines of it. The party of free thought, or Libertines, showing sympathy for the prisoner, the trial assumed the character of a struggle between the two factions in Geneva. It was necessary for Calvin to nip in the bud the new growth of rebellion against his authority; and, throwing aside disguise, he now came forward as prosecutor of Servetus. The Spaniard's opinions differed so obviously from all they had ever been led to believe, that it was easy for Calvin to satisfy the majority of the judges of Servetus's culpability on theological grounds. It seems, however, that a feeling in favor of the prisoner prevailed in the court; the Swiss churches, which on a similar occasion had decided against Calvin, were appealed to for advice, and the proceedings were postponed. It is pitiful to see how Calvin had set his heart on the condemnation of Servetus. He interfered with the course of justice by threatening the weakest among the judges, by stirring the feelings of his party in the council; he denounced and vilified his opponent from the pulpit in no measured terms, exposing his opinions in their most glaring and repulsive aspects; he tampered with the ministers of the Swiss churches; he formulated new and more elaborate articles of accusation, and to these, besides his own, had the signatures of thirteen of his fellow-ministers appended—in one word, he left no stone unturned to wreak his revenge. He wanted Servetus's death! The arguments and authorities piled against him by Calvin were so many, and the proceedings became so intricate, that Servetus was forced to request that he might be furnished with books, and have pen, ink, and paper, supplied, in which to epitomize his defense. The jailer was directed to give him the books he wanted, and a *single sheet* of paper!

On this "famous" sheet, Servetus, after demonstrating that civil tribunals are incompetent to decide on questions bearing on religion only, and that heretics were either to be brought to reason by argument, or punished by banishment, and not by prison, concludes:

"Secondly, my lords, I entreat you to consider that I have committed no offense within your territory; neither, indeed, have I been guilty of any elsewhere: I have never been seditious, and am no disturber of the peace. During all the time I passed in Germany, I never spoke on such subjects" (his theological views), "save with Œcolampadius, Bucer, and Capito; neither in France did I ever enter on them with any one. I have always disavowed the opinions of the Anabaptists, seditious against the magistrate, and preaching community of goods. Wherefore, as I have been guilty of no sort of sedition, but have only brought up for discussion certain ancient doctrines of the Church, I think I ought not to be detained a prisoner, and made the subject of a criminal prosecution.

"In conclusion, my lords, inasmuch as I am a stranger, ignorant of the customs of this country, not knowing either how to speak or to comport myself in the circumstances under which I am placed, I humbly beseech you to assign me an advocate to speak for me in my defense."

If a shadow of justice had ruled the trial, this petition would have met with success; but the court took no notice of it. "Skilled in lying as he is," said the attorney-general, Calvin's tool, "there is no reason why he should now demand an advocate."

After the sitting of September 1st, in compliance with a wish previously expressed by the court, Calvin, surrounded by a staff of ministers, proceeded to the jail to visit the prisoner. Calvin having then opened upon him with a bigoted lecture, the consequences are easily imagined: the interview ended as it could only end—with increased irritation on both sides. From this time (and we cannot but excuse the man), Servetus became more intemperate and aggressive on Calvin; not only indisposed to yield one jot or tittle, but negligent also of opportunities to defend his conclusions. Perhaps he knew it was useless to argue, for, as a Spanish proverb says, "No man is so deaf as he who *will not* hear." Perhaps Perrin and Berthelier, the leaders of the Libertines, too, had fed his brain with false hopes and promises.

The trial was now interrupted through differences between Calvin and the city fathers about municipal affairs. On September 15th Servetus wrote to the council a letter, from which we quote the first paragraph:

"My most Honored Lords: I humbly entreat of you to put an end to these great delays, or to exonerate me of the criminal charge. You must see that Calvin is at his wit's end, and knows not what more to say, but for his pleasure would have me rot here in prison. The lice eat me up alive; my breeches are in rags, and I have no change—no doublet, and but a single shirt in tatters. I have also demanded to have a counsel assigned me. This would have been granted me in my native country; and here I am a stranger, and ignorant of the laws and customs of the land. Yet you have given counsel to my accuser,[1] refusing it to me."

On the 22d of September, perhaps instigated by Berthelier, Servetus took a bold step: he accused Calvin as his calumniator, and asked him to be declared subject to the law of retaliation; but the council took no more notice of this than they had of the previous petition. The appeal to the churches of Switzerland caused another pause in the proceedings, and Michael Servetus, October 10th, forwarded the following letter to the council:

"Most Noble Lords: It is now about three weeks since I petitioned for an audience, and still I have no reply. I entreat you for the love of Jesus Christ not to refuse me that you would grant to a Turk, when I ask for justice at your hands. As to what you may have commanded to be done for me in the way of cleanliness, I have to inform you that nothing has been done, and that I am in a more filthy plight than ever. In addition, I suffer terribly from the cold, and from colic, and my rupture, which causes me miseries of other kinds, I should feel shame in writing about more particularly. It is very cruel that I am neither allowed to speak nor to have my most pressing wants supplied; for the love of God, sirs, in pity or in duty, give orders in my behalf!"

This appeal of the prisoner, as far as his needs were concerned, met with an immediate response; but the audience was never granted. The answers of the Swiss churches arrived at last, and as Calvin had been their inspirer, and they had been taken in concert, they unanimously condemned Servetus's theological views. On the 26th of October the council solemnly assembled and condemned Servetus to be burned alive with his books; the sentence to be carried into effect on the morrow! In a letter to Farel, alluding to the vain attempts made by Perrin, the first syndic, by delay and entreaty, to save the prisoner's life, Calvin speaks of the merciful man by the nickname under

[1] Germain Colladon was introduced as counsel for Nicolas La Fontaine, and continued all through the trial as Calvin's champion.

which he was wont to characterize his great Libertine opponent, and says:

"Our comical Cæsar (Perrin), having feigned illness for three days, mounted the tribune at length, with a view to aid the 'wicked scoundrel' to escape punishment. Nor did he blush to demand that the cause might be remitted to the Council of the Two Hundred. But in vain; all was refused, the prisoner was condemned, and to-morrow he will suffer death."

The sentence was imparted to Servetus in the early morning of the following day—his last. Encouraged by the Libertines, and knowing himself guilty of no intentional blasphemy, he had never thought it possible that he would be condemned to death. He was at first as if struck dumb by the intelligence. He did but groan and sigh, as though his heart would burst, and cry, in his native language, "Misericordia!" Having by degrees recovered self-possession, he requested to see Calvin. Accompanied by two councilors, Calvin entered the prison and asked what he wanted of him. Servetus had the heroic virtue to ask pardon of him—the man who had brought him to his death! Hard to say: the intolerant despot of Geneva, devoid of all humanity, had not a word of mercy for his victim, when a word of his would have saved him!

An hour before noon of October 27, 1553, Servetus was taken from his jail to receive his sentence from my lords the councilors and justices of Geneva. The tribunal, in conformity with custom, assembled before the porch of the Hôtel-de-Ville, and received the prisoner, all standing. The proper officer then proceeded to recapitulate the heads of the process against him, "Michael Servetus, of Villanova, in the kingdom of Aragon, in Spain," in which he is charged—

"First, with having, between twenty-three and twenty-four years ago, caused to be printed at Hagenau, in Germany, a book against the Holy Trinity, full of blasphemies, to the great scandal of the churches of Germany, the book having been condemned by all their doctors, and he, the writer, forced to fly that country. *Item.* With having, in spite of this, not only persisted in his errors and infected many with them, but with having lately had another book clandestinely printed at Vienne, in Dauphiny, filled with the like heresies and execrable blasphemies against the Holy Trinity, the Son of God, the baptism of infants, and other sacred doctrines, the foundation of the Christian religion. *Item.* With having in the said book called all who believe in a Trinity, tritheists, and even atheists, and the Trinity itself a demon or monster having three heads. *Item.* With having blasphemed horribly, and said that Jesus Christ was not the Son of God from all eternity, but only became so from his incarnation; that he is not the son of David according to the flesh, but was created of the substance of God, having received three of his constituent elements from God, and one only from the Virgin Mary, whereby he wickedly proposed to abolish the true and entire humanity of Jesus Christ. *Item.* With declaring the baptism of infants to be sorcery and a diabolical invention. *Item.* With having uttered other blasphemies, with which the book in question is full, all alike against the majesty of God, the Son of God, and the Holy Ghost, to the ruin of many poor souls, betrayed and desolated by such detestable doctrines. *Item.* With having, full of malice, entitled the said book, though crammed with heresies, against the holy evangelical doctrine, 'Christianismi Restitutio'—'The Restoration of Christianity'—the better to deceive and seduce poor, ignorant folks, poisoning them all the while they fancied they were sitting in the shadow of sound doctrine. *Item.* With attacking our faith by letters as well as by his book, and saying to one of the ministers of this city that our holy evangelical doctrine is a religion without faith, and, indeed, without God, we having a Cerberus with three heads for our God. *Item.* For having perfidiously broken and escaped from the prison of Vienne, where he had been confined because of the wicked and abominable opinions confessed in his book. *Item.* For continuing obstinate in his opinions, not only against the true Christian religion, but as an arrogant innovator and inventor of heresies against popery, which led to his being burned in effigy at Vienne, along with five bales of his books. *Item.* And in addition to all of which, being confined in the jail of this city, he has not ceased maliciously to persist in the aforesaid wicked and detestable errors, attempting to maintain them, with calumnious abuse of all true Christians, faithful followers of the immaculate Christian religion, calling them tritheists, atheists, and sorcerers, in spite of the remonstrances made to him in Germany, as said, and in contempt of the reprehensions and corrections he has received, and the imprisonment he has undergone as well here as elsewhere.

"Now we, the syndics and judges in criminal cases within this city, having reviewed the process carried on before us, at the instance of our lieutenant having charge of such cases, against thee, Michael Servetus, of Villanova, in the kingdom of Aragon, in Spain, whereby guided, and by the voluntary confessions made before us, many times repeated, as well as by thy books produced before us, we decree and determine that thou, Michael Servetus, hast, for a long time, promulgated false and heretical doctrine, and, rejecting all remonstrance and correction, hast maliciously, perversely, and obstinately, continued disseminating and divulging, even by the printing of books, blasphemies against God the Father, the Son, and the Holy Ghost, in a word, against the whole foundations of the Christian religion, thereby seeking to create schism and trouble in the Church of God, many souls, members of which, may have been ruined and lost—horrible and dreadful thing, scandalous and contaminating in thee, thou, having no shame nor horror in setting thyself up in all against the Divine Majesty and the Holy Trinity, and having further taken pains to infect, and given thyself up obstinately to continue infecting, the world with thy heresies and stinking heretical poison—case and crime of heresy grievous and detestable, deserving of severe corporal punishment.

"These and other just causes moving us, desiring to purge the Church of God of such infection, and to cut off from it so rotten a member, we, sitting as a judicial tribunal in the seat of our ancestors, with the entire assent of the General Council of the state, and our fellow-citizens, calling on the name of God to deliver true judgment, having the Holy Scriptures before us, and saying, In the name of the Father, Son, and Holy Ghost, we now pronounce our final sentence, and condemn thee, Michael Servetus, to be bound and taken to Champel, and there bound to a stake, to be burned alive, along with thy books, printed as well as written by thy hand, until thy body be reduced to ashes. So shall thy days end, and thou be made an example to others who would do as thou hast done. And we command you, our lieutenant, to see this our sentence carried forthwith into execution."

The staff, according to custom, was then broken over the prisoner, and there was silence for a moment. The terrible sentence pronounced, the silence that followed was first broken by Servetus; not to sue for mercy, for he knew there was no appeal, but to entreat that the manner of carrying it out might be commuted for one less dreadful. "He feared," he said, "that, through excess of pain, he might prove faithless to himself, and belie the convictions of his life. If he had erred, it was in ignorance; he was so constituted, mentally and morally, as to desire the glory of God, and had always striven to abide by the teachings of the Scriptures." His appeal to the humanity of the judges, however, met with no response. He prayed God to forgive his enemies and persecutors, and then exclaimed: "O God, save my soul! O Jesus, Son of the Eternal God, have compassion upon me!" From the Hôtel-de-Ville he was taken to Champel. While on the way thither, Farel, the minister who accompanied him, tried to wring from him an avowal of his error, and the prayer, "Jesus, thou Eternal Son of God!" The unhappy Servetus, with a martyr's faith, only replied in broken invocation, "Jesus, thou Son of the Eternal God, have compassion upon me!"

"When he came in sight of the fatal pile, the wretched Servetus prostrated himself on the ground, and for a while was absorbed in prayer. Rising and advancing a few steps, he found himself in the hands of the executioner, by whom he was made to sit on a block, his feet just reaching the ground. His body was then bound to the stake behind him by several turns of an iron chain, while his neck was secured in like manner by the coils of a hempen rope. His two books—the one in manuscript sent to Calvin in confidence six or eight years before for his strictures, and a copy of the one lately printed at Vienne—were then fastened to his waist, and his head was encircled in mockery with a chaplet of straw and green twigs bestrewed with brimstone. The deadly torch was then applied to the fagots and flashed in his face; and the brimstone catching, and the flames rising, wrung from the victim such a cry of anguish as struck terror into the surrounding crowd. After this he was bravely silent; but the wood being purposely green, a long half-hour elapsed before he ceased to show signs of life and suffering. Immediately before giving up the ghost, with a last expiring effort, he cried aloud, 'Jesus, thou Son of the Eternal God, have compassion upon me!' All was then hushed save the crackling of the green wood; and by-and-by there remained no more of what had been Michael Servetus but a charred and blackened trunk, and a handful of ashes."

Thus perished a noble man of whom his age was not worthy—the victim of murderous religious bigotry. But the crime that had been committed shocked the humanity of Geneva, even in that dark period, and, before the year was out, Calvin was driven to self-defense, and displayed the remorseless traits of his character by libeling the man whom he had slain. It is said that, in this persecution unto death, he only manifested the spirit of his age, and must be judged by that standard. While this may be true, it is also happily true that in the lapse of centuries better standards have arisen, by which the character of Calvin will be given over to execration, while that of Servetus will be increasingly honored as that of an heroic Christian martyr.

CORRESPONDENCE.

"THE TIDES."

To the Editor of the Popular Science Monthly.

SIR: Returning a day or two ago to Columbus at the end of our vacation, I last night took up the September number of THE POPULAR SCIENCE MONTHLY. Therein is a letter from Evanston, Illinois, in which some of Prof. Schneider's mistakes, in his article on "The Tides," are pointed out. Two or three years ago Mr. Schneider caused his explanation of the tides to be printed in a little periodical used extensively by Ohio teachers—I refer to *Notes and Queries*, Salem, Ohio. The errors of fact and philosophy were then pointed out in that journal. And, inasmuch as Prof. Carhart has *abundantly* exposed Mr. Schneider's mistakes, I content myself with showing a single point. The whole article on "The tides" is a bundle of absurdities, mistakes of fact and philosophy, and errors of figures in regard to quantity. Mr. Schneider, knowing absolutely nothing of the theory of the tides, as understood and explained for the last two hundred years, has concocted a mass of nonsense which is set out as the only rational theory. I incline to the opinion that the New York gentleman who advised you to print the article was playing a practical joke on Mr. Schneider, or else he belongs to that order of city mathematicians who recommended Benson's "Geometry," a work in which there is proof (?) that an inscribed polygon of twelve sides is exactly equal to the circle which contains the polygon—i. e., circumscribes the polygon. Had this new philosophy been put forth in the ordinary newspapers of the day, no notice would have been taken of it. On page 276, July number of THE POPULAR SCIENCE MONTHLY, we find the following: "The earth will then feel a centrifugal force on her side farthest from the moon, and equal to the centripetal force felt on her side facing the moon. These two equal forces, acting in opposite directions," etc. On page 279: "This force [centrifugal] acts in a line tangent to the earth's orbit." Then the centripetal force must also act parallel to the "tangent to the earth's orbit;" and so, whether you are a mathematician or not, you can easily see that things are going on at loose ends, if they act in this way. (See Fig. 1.) Did you ever elsewhere see, or hear either, of such a centripetal or such a centrifugal force?

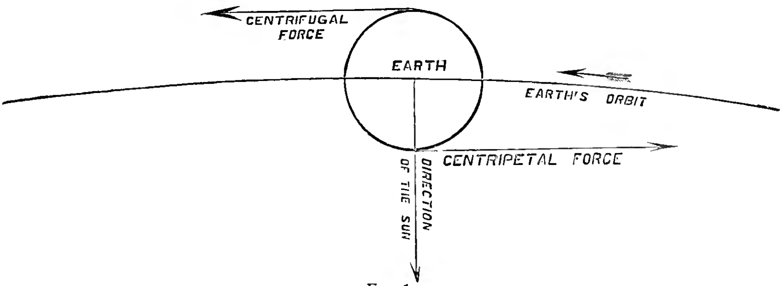


FIG. 1.

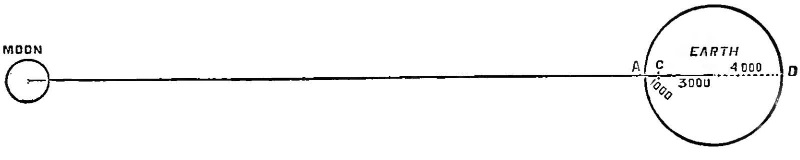


FIG. 2.

Again, on page 276: "This large amount of centrifugal force is produced by axial rotation, by revolution round the sun, and by revolution round the centre of gravity [between the earth and the moon] already named."

Let us see: the centrifugal force, in connection with the revolution of the earth on its axis, is *uniform all around the equator*

—consequently it cannot have any part in producing a tide at *one* side of the earth merely. This must be ruled out.

Let us take up the last item of the three. C (Fig. 2) is the centre of gravity between the moon and the earth, about 3,000 miles from the earth's centre, and 1,000 from the surface. Now, the centrifugal force is always proportional to the distance from the centre of motion, other things being equal (see any work on mechanics). Then the force at D is seven times as great as the force at A, for it is seven times as far from C. Therefore the tide at D will be seven times as high as that at A. Do your New York tides play such tricks?

It is also easy to show that the first item of the three has nothing to do with the tides. So in that sentence there are three bald-faced absurdities; and in fact there are about as many such as there are sentences in the whole article. A hundred pages of manuscript are not sufficient to show them all up.

Take the next two sentences following the preceding, viz.: "The direction of these three forces is in the same line. The motion of this part of her surface, which is in this line of direction, is therefore the most rapid; consequently the centrifugal force felt here is also the greatest."

Scan this closely, and you will find what the logicians call a *vicious circle* in the reasoning.

R. W. McFarland,
Professor of Mathematics, etc., Ohio
Agricultural and Mechanical College.

Columbus, Ohio, *September* 12, 1877.

THE PRESENT STAGNATION OF TRADE.

To the Editor of the Popular Science Monthly.

The discussion of the present economical problem, the depression of profits and wages, which the article of Prof. Bonamy Price ("One per Cent.") initiated, ought to be continued, and facts and opinions ought freely to be contributed toward a full understanding of the subject.

Prof. Price writes from the money-centre, and reflects the state of enlightened opinion as influenced by his surroundings. The money accumulated there represents savings, and he very naturally and very truly finds fault with our extravagance.

Next comes Mr. Bunce, in the July number ("Over-Consumption or Over-Production?"), giving the views as held in a manufacturing centre; he admits over-production and advises restriction.

This, the distributive (or trade) centre, New York, will not submit to; and Mr. Leland, in the August number, exposes the fallacy of some of Mr. Bunce's reasoning. Without wishing to imply that these writers did not intend to present the question in its total aspect, yet they are viewing it through the glass of their surroundings; and, if I now add the opinion which is held in an agricultural region, the next writer will include this and make his exposition more comprehensive.

We in the agricultural districts deny that there is over-production in our line, or stagnation of trade in our articles. The facts are, that with three very good harvests and several average ones previously, we have not produced more than has been consumed. At the end of June, when the present abundant wheat-harvest was begun, there was not old wheat sufficient for a month's home supply in the Western granary. The new wheat was hurried from the threshing-machine to the mill and ground immediately, to fill the regular orders for the Boston, New York, and Philadelphia markets. Evidently, there has been no over-production in wheat or in corn. We have readily sold all our beef-cattle, our sheep and swine, our wool, fruit, and dairy products. The production of all these has met the demand, and we have realized fair prices.

And, as a natural consequence, there has been no stagnation nor depression in our trade. Our farmers and small town and village mechanics, and our small retail stores, have had all the necessaries of life in abundance, and not a few of the comforts. Mortgages have been lifted, improvements have been made, surplus cash is in all our savings-banks at four per cent. or less interest to the depositors. Our trade centres, doing the honest business of first-hand traffic, are prospering.

All through our country, farms and fisheries have not produced more grain, meat, or wool, than has been consumed from one harvest to another. But we have produced more cotton than can be worn out from one year to another. Our mines have yielded more iron, in many places more coal, than is wanted; much less iron is now required for trades-tools, machinery, and railroading, than at that not far-distant period when a great deal was consumed in building new roads and erecting new machinery where there had been none before. Mines are bringing up more silver than can be usefully employed; hence it is being hoarded, and its price must sink.

The cotton and the iron are forced upon the converting trades, in which so many mill-hands and factory-operatives are employed. The raw material in excess becomes cheaper. The converted products, the articles manufactured for consumption, are in excess, and, forcing themselves upon the market, reduce prices, as well their own as the price of the labor that produced and distributed them. And, as a last consequence, these products are glutting the shelves of the merchants' warerooms, diminishing the profits of the carrier and merchant to a trifle, and ending in bankruptcy and strikes.

If all our cotton-mills and their dependencies, all our iron industries, and some others, were to suspend, we should not exhaust the supply on hand of their fabrics for quite a number of years.

To sum up—

1. There is no over-production of grain and meat.

2. There is a great surplus of textile, iron, and similar fabrics.

Hence, there is a one-sided over-production, a one-sided depression of prices for labor and for fabrics; and, on the other side, a normal prosperity and attending accumulation of savings.

The problem for relief at once presents itself in the question whether a change of occupation of a considerable number of factory-operatives, mechanics, and forwarders, from the trades to agriculture, would afford the remedy and reëstablish the equilibrium.

The farmer, even at the most Western frontier, has always a sufficiency of food raised by himself, and generally a surplus, adequate for furnishing his family some comforts, and always independence.

If a large majority of the weavers and machine-workers of to-day were to become agriculturists, they would become consumers instead of producers of the very articles which are now made in excess; and, while the price of the articles might not be advanced, those that made them would have full and steady, instead of interrupted and uncertain, employment—a double gain on the present disturbed state.

No legislative or government interference is needed or desirable. The adjustment of the disturbed equilibrium in the productions will work itself out as soon as the true causes of the "stagnation in trade" are clearly understood.

A case in point will illustrate. In a small county town, the trade-centre of a good farming district, the retail stores had done a very profitable business up to about 1874. As a natural consequence, many persons with a small capital had engaged in this line; finally their sales diminished, profits declined, because their number had increased beyond the former ratio between stores and customers. A few of them looked about for other occupations. One engaged in tanning, which was a good field; another started a custom grist-mill, for which there was a demand; another opened a pork-packing establishment; another went into farming on a large scale. Here, the overcrowding with its attendant evils was understood as the cause of the decline in trade; the enterprising members of the profession left it for occupations that pay better, and the equilibrium has been reëstablished.

All efforts at relief from the dull times must lie in the same direction. A large number of our mill-hands and factory-operatives must take to farming, must raise themselves the food for their families, and some to exchange for comforts which their fields and herds cannot directly give.

The old mill-hands ought not to attempt the change; but the young and middle-aged ought, and escape from their "bondage" in the East to the free fields of our wide Western country.

F. A. Nitchy.

Jefferson City, Missouri.

THE GREAT RAILROAD-STRIKE OF 1877.

To the Editor of the Popular Science Monthly.

The loss from peculation in the management of railways has probably been exaggerated; these important institutions have, in the main, been conducted on business principles, with an eye to dividends. Those in control have aimed—with success, until recently—to secure competent and willing aid, and the *esprit de corps* so essential in great enterprises. But managers and men are alike the victims of a train of circumstances foreseen only by a few political economists. The plain fact is, that the railroad system finds itself in the brunt of a movement that has been long approaching culmination. Multitudes of our native youth, seduced by the supposed attractions and opportunities of the city, and swarms of the poorer immigrants, have precipitated the catastrophe, by swelling the already overcrowded centres of population—have added to the number to be fed, by decimating the army of producers—have lowered the price of labor, by increasing the number of applicants. Reduction of extravagant salaries and other "leaks" is to be commended, but will not, it is to be feared, effect any material increase of wages for a long time to come, and that from no indisposition on the part of managers, but from *causes beyond their control.*

Populations have been passing through the throes of greater social transitions than were ever before crowded into a century, and a vast amount of inconvenience was and is inevitable. The immense industries created by labor-saving machinery have, in not a few instances, outrun the present demand, and hence—too often—an advancing throng of aspirants has found itself confronted with another throng in disorderly retreat: the result is a fierce struggle for existence, in which reason exercises but a feeble sway.

Nature and Providence are inexorable, and take no thought for the individual intruder in their *track.* These forces are now apparently engaged in starving the surplus humanity back into the cornfields.

But he is a sorry physician who is content with a diagnosis of the disease, and prescribes no preventive, or even remedy; and as in the corporeal body, so in the body corporate—the best remedy is that which operates through natural forces: let us see if such cannot be made available. Cannot this drift cityward be checked, or even turned backward, by rendering farm-life more attractive to young men? For example:

Instead of isolated homesteads, often miles asunder, why not dedicate a central space for a good, old-fashioned Saxon "common," which might hold the school, the church, the park, and other amenities of civilization, and be surrounded by the dwellings of the settlement? And why cannot parents, instead of placing their sons in dusty city offices, or behind ignoble counters, enable these young men—with the aid of competent experts, where necessary—to establish such settlements? Might not education in such a community, by embracing the study of natural objects, applied science, and the practice of handicrafts, convert material that now evolves into boors, "hoodlums," or "counter-hoppers," into interested (because intelligent) and occupied producers, for whom rural life and scenes would possess attractions superior to the vulgar dissipations of the faubourg and the feverish competitions of trade?

G. H. KNIGHT.

CINCINNATI, *August* 10, 1877.

EDITOR'S TABLE.

NARROWNESS AMONG MEN OF SCIENCE.

IT is a great mistake to suppose that all the influences exerted on the mind by scientific study are necessarily of a widening or liberalizing character. There is an immense amount of legitimate scientific work that does not tend to produce any such effect, but, on the contrary, has a narrowing and cramping influence upon the intellect. The intense and prolonged concentration of thought upon special inquiries, when it becomes a habit, excludes that breadth of view which can only be attained by contemplating subjects in their wide relations. Absorption in detail is inevitably unfavorable to the grasp of principles, so that the mere specialist is never a philosopher. Of course, all strong scientific men must be more or less specialists, must limit themselves to restricted portions of the scientific field; but in such minds the narrowing influences of particular studies are counteracted by keeping up an interest in various subjects, and the comprehensive results of research. There are many scientific workers, however, who fail to do this, who lose themselves in their own narrow departments, and become, not only inappreciative of the grand connections of scientific truth, but contemptuous of the higher work of scientific generalization. They applaud observation and experiment, and the accumulation of isolated facts, and stigmatize as mere theorizers those who labor to organize these facts and observations into rational systems. It is not to be expected, nor is it desirable, that all scientific workers should be philosophical thinkers, but there is great need that many of them should cultivate a more liberal spirit in this respect, and recognize that the systematic study of the relations of the sciences is as much a legitimate specialty as the working out of their separate and disconnected facts.

There is another respect in which a large class of scientific men exhibit a narrowness of feeling that is far from commendable. They cherish but little sympathy with the work of diffusing science, and take frequent occasion to disparage the motives and character of those of their brethren who devote themselves to this kind of labor. We are glad to notice that the *Saturday Review* administers a just rebuke to these illiberal and censorious gentlemen. Commenting upon President Thomson's address before the British Association, that journal remarks:

"It is a thankless office to have to record, as we are now compelled to do, that this time the impression was not a very favorable one. In one word, the president's discourse was much too technical for the occasion and the audience. It would be ungenerous to cast any personal responsibility for this result on the eminent specialist who was chosen for the office. The gift of interpreting the results of highly-special researches for the benefit of those who are not prepared beforehand by special knowledge is by no means a common one—in fact, it is itself a specialty which very few have mastered; for which reason people who are anxious to parade themselves as amateurs in science are much in the habit of cheapening it. The notion that Prof. Huxley and Prof. Tyndall are mere popularizers—because, forsooth, they can expound as well as discover—has almost attained the rank of a vulgar error. Some remarks to that effect were heard at this very meeting in the Guildhall of Plymouth. Those who imagine that such remarks give them a scientific air may be assured that there is no more certain stamp of a narrow and superficial habit of mind. However, we cannot all go to Corinth; a specialist, however eminent, has not necessarily the gift of large and lucid exposition, and if he has not, the temptation to take refuge in the technical details of his own province is almost irresistible."

The pettiness and jealousy here reprobated is by no means confined to England; it has become a sort of cant among many reputable scientific men in the United States. The contemptuous remarks often made of the efforts of such men as Huxley and Tyndall to make science acceptable to the public are not always inspired by envy; they betray a very low estimate, often tinged with scorn, of all efforts to reduce science to a form acceptable to common people. We have had occasion repeatedly to call attention to the paradox that, in this country, eminent for its popular institutions and its popular education, scientific men are in less hearty sympathy with the work of popularizing scientific education than they are in England. The American Scientific Association has persistently declined to take any interest in the question, while the British Association, upon which it was modeled, has done much to encourage and promote this kind of effort. Although our teachers and boards of education have often and urgently called for assistance in organizing courses of study in which science should receive increasing attention, and be more methodically and efficiently cultivated, we are not aware that any authoritative body of American scientists has ever troubled itself to offer advice or respond to such appeals.

There is, of course, a certain validity in the reply that scientific bodies are organized for other purposes, and that, as Agassiz used to put it, "it is their office to create science, and not to distribute it—the latter function being the office of our educational system." But if our system fail of its duty in this particular, it is certainly incumbent on those influential bodies, who have the interests of science in charge, to exert such an influence upon the schools as shall tend to secure the object, and, failing to do this, they are chargeable with a culpable indifference toward the work of making science common and popular. The plea that scientific men are absorbed in investigations, and have little time to give to these outside considerations, is quite sufficient to excuse a simple non-participation in such work; but there is abundant reason to think that the plea is often an uncandid pretext, and that the disinclination to act is due to narrow and petty prejudices upon the subject.

The indifference of many scientific men to the work of popularizing science, and their ill-concealed disdain of those who succeed in it, are no doubt largely due to their incapacity to share in it. We have, unfortunately, but few scientific men with sufficient literary training to write with elegance or lecture with eloquence upon topics which they may nevertheless thoroughly understand, and the number of scientific professors who fail in exposition before the public, and even before their college classes, is unfortunately large. The art of vivid, effective presentation by language is so difficult that, unless a man has a genius in this way, it requires great labor to attain even a moderate excellence in it, and when attained there is no doubt a presumption that it is at the expense of more solid things. Yet there is no reason why men of real science should not be able to arrive at much greater proficiency as literary artists than is customary with them, if they would cultivate more liberal views of the importance of popular work. At all events, if our scientific men will not be at the pains to train themselves in the art of attractive popular exposition, and will be content to write and speak in the bald, technical, involved, and repulsive style which is so common with many, let them not reproach others for setting a higher value upon the accomplishments of the successful public teacher.

We have spoken in the foregoing article of the propensity of certain scientific men to magnify facts and depreciate theories. This is not only an evidence of narrowness, but of ignorance, for facts are of no value without theories. They are good for nothing until explained, or brought by reason into relation with other facts, so that some step is taken toward the establishment of a law. It is this connection of science with methods of thought, and its value as a means of arriving at the best methods, that give it its claim upon the attention of all intelligent men. The demand for its popular recognition, and its prominent place in education, rests far less upon its service in the grosser utilities of life than on its influence upon the higher intellectual operations. Science being tested and verified, clearly reasoned and demonstrated truth just to the degree in which it is matured, it must stand in the most intimate relations with those logical processes which have for their object the establishment of truth. Logic, of course, grew up into a system before the sciences were developed; but it was a partial and imperfect logic. Following the modern developments of science, growing out of them, and seriously influenced by all their great steps of advance, we have a body of logical and philosophical disquisitions that are presented by such men as Herschel, Whewell, Mill, and Jevons, who deal with the mental operations involved in the investigation of truth, in the full light of modern scientific experience. Yet this interesting field of thought must be regarded as only fairly opened, and the works of the eminent gentlemen referred to, though permanently valuable, are no doubt much in the nature of preliminary inquiries, to be yet carried out more thoroughly, and reduced to greater unity and harmony. Impressed with the importance of this great phase of the intellectual work of the age, which it is one of the leading objects of The Popular Science Monthly to promote, it has been our good-fortune to secure the services of an independent thinker and able writer, who will contribute to our pages a series of articles under the general title of "Illustrations of the Logic of Science." The author has already attained an honorable eminence in the world of science by the promulgation of advanced views of logical method, and he will reduce these views to a more systematic and popular form in the papers now to be published. We call attention to the first essay of this series in the present number, which, though but introductory, may be taken as foreshadowing the interest of the discussions that are to follow.

It will hardly be necessary to invite the reader's attention to an article, to be also followed by others, on "The Growth of the Steam-Engine." That revolutionary machine, which is so intimately interwoven with the development of civilization, is itself a part of that development, and as much a product of evolution as an oak a thousand years old. The interesting story of its unfolding from early germs, through long and laborious experiments, to the complete integration of the mechanism, will be told by Prof. Thurston in successive papers, which will be freely and elegantly illustrated. The accompanying "portrait-gallery" of the great inventors who have contributed to this grand mechanical achievement will be the finest and fullest afforded by the historic literature of the subject.

LITERARY NOTICES.

The Holy Roman Empire. By James Bryce, D. C. L., Regius Professor of Civil Law in the University of Oxford. 12mo. Pp. 479. New York: Macmillan & Co. 1877. Price, $2.

The Holy Roman Empire dates from the year 800 a. d, when a king of the Franks was crowned Emperor of the Romans by Leo III.; and it is on the inner nature of this empire, as the most signal instance of the fusion of Roman and Teutonic elements in modern civilization, that the author dwells, treating of the influence which it exercised over the minds of men, and the causes that gave it power; speaking less of events than of principles, and describing the empire, not as a state, but as an institution created by and embodying a wonderful system of ideas. The forms which the empire took, in the several stages of its growth, are briefly sketched. A glance is taken at the condition of the Roman world in the third and fourth centuries, in order to make clear out of what elements the imperial system was formed.

Expiring antiquity had bequeathed to the ages that followed two great ideas—a world-monarchy and a world-religion. The Roman dominion, giving to many nations a common speech and law, broke down the differences of race and nationality—when foreigner and enemy were synonymous terms—and made citizens of them irrespective of their religious beliefs, which were purely local and national. For these, Christianity substituted the belief in one God, and the doctrine of the unity of God enforced the unity of man; and there was thus formed a community of the faithful—a holy empire—designed to gather all men into its bosom. Thus the Holy Roman Church and the Holy Roman Empire were one and the same thing in two aspects. As divine and eternal, its head was the pope, to whom souls were intrusted; as human and temporal, the emperor, commissioned to rule over men's bodies and acts.

Chapters are devoted to the subjects "Imperial Titles and Pretensions;" "Changes in the Germanic Constitution;" "The Empire as an International Power;" "The City of Rome in the Middle Ages;" "Effects of the Renaissance and Reformation on the Empire;" its last phases and end in 1806 by the abdication of Francis II., 1,006 years after Leo the pope had crowned the Frankish king. A supplementary chapter is added on "The New Germanic Empire," and an appendix of notes on "Imperial Titles and Ceremonies." To the whole is prefixed a "Chronological Table of Emperors and Popes," and "Dates of Important Events in the History of the Empire."

The treatment and style of the work are judicial and scholarly, and the book will doubtless be a standard one on the subjects of which it speaks. It has been remarkably well received on all sides, having already passed through seven editions.

The Physiology of Mind. Being the First Part of a Third Edition, revised, enlarged, and in great part rewritten, of "The Physiology and Pathology of Mind." By Henry Maudsley, M. D. Pp. 547. New York: D. Appleton & Co. 1877. Price, $2.

Ten years ago, Dr. Maudsley issued a large, well-elaborated volume under the title of "The Physiology and Pathology of Mind." It was well received, and a second edition was called for, which has been now for some time out of print. After several years' further study of the subject, and availing himself of the great activity of investigation in this branch during the last decade, Dr. Maudsley has revised his work, and so extended it that it became desirable to make it into two volumes instead of one. That which was the first part now appears as a separate volume, confined to the physiology of mind; and will be followed by its sequel, or companion-work, as a separate treatise on mental pathology. It is an excellent thing on every account to divide the original work in this way, for, although the subjects are most intimately connected, they can be just as well studied together now as before, while there will unquestionably be many who will care chiefly for but one of the volumes. That now issued has an interest for all students of the philosophy of mind, while the one following will more directly concern the medical profession. "The Physiology of Mind" by Dr. Maudsley is a very engaging volume to read, as it is a fresh and vigorous statement of the doctrines of a growing scientific school on a subject of transcendent moment, and, besides many new facts and important views brought out in the text, is enriched by instructive notes and quotations from authoritative writers upon physiology and psychology, and by illustrative cases which add materially to the interest of the book. We have room for but one of these, showing the manner in which the loss of one sense is followed by an extension or increase of function of those which remain:

"Many years ago application was made to Dr. Howe, of the Massachusetts Asylum for the Blind, by a locksmith for the 'loan' of a blind boy, as he said, who had quick ears and a silent mouth. On giving satisfactory answers he got his loan. He wanted a boy to help him open a new and complicated lock. An inventor exhibited a locked safe and the key, saying that there was money within, which should be given to whoever could open the lock without deranging it. The peculiarity of the lock was, that it had ten bolts, which, from all that could be ascertained, seemed exactly alike, but in reality one of them was an inch longer than the others, so that, when all were thrown forward, that one alone held the door closed. The key would lift any of the ten bolts; but in order to open the safe it must be applied to the long bolt, and to that only, and that one must be lifted and turned back in order to open the lock; but if any other of the ten were lifted and turned back ever so little, it deranged the combination, and the lock could only be opened by a peculiar instrument. The object, then, was to ascertain which of the ten was thrown forward without turning back any other one.

"The mechanic lifted each bolt carefully with the key, and let it fall, but without trying to throw it back; and he then tried to ascertain if in falling it made any peculiar noise; for he inferred that, as the only one which held the door was an inch longer than the others, it must fall with a slightly greater force; but the difference was too slight for his ear. He took the blind lad, and asked him to listen carefully to the sound which each bolt made as he lifted and let it fall. After listening to each intently, the lad said the sixth one struck a little the loudest. The mechanic lifted and let each one fall carefully several times, and each time the boy insisted that the sixth bolt sounded the loudest. Upon this the mechanic lifted and turned back the sixth, and the lock was opened without the combination being deranged."

No library of mental philosophy will be complete without this book, and no liberal student of the subject can refrain from giving it his serious and critical attention.

A Practical Treatise on Lightning-Protection. By Henry W. Spang. 12mo. Pp. 180. With Illustrations. Philadelphia: Claxton, Remsen & Haffelfinger. 1877. Price, $1.50.

The above book contains the result of the author's observation and study on the subject of lightning-protection during an eighteen years' experience in the telegraph-business. After an introductory course of experiment with artificial lightning, and an explanation of the principal known facts relating to the electricity of the earth and atmosphere, the author proceeds to show that few of the lightning-rods or conductors now erected can be relied upon for an easy passage of heavy lightning-discharges, and goes on to prove that the metal roof and rain-pipes of a building can be made a better protection at a reduced expense. Explicit directions then follow for the protection of buildings of every description, ships, oil-tanks, steam-boilers, bridges, telegraph-poles, etc.

Notes upon the Lithology of the Adirondacks. By Albert R. Leeds. Pp. 35. From the *American Chemist*.

Prof. Leeds does not assume to present a complete lithology of the Adirondack region, but limits himself to giving an outline of the work already done in that field: a description of the rocks so far collected by himself; analyses of some of the more important typical rocks and minerals; results of microscopic study of rock-sections; and, finally, inferences drawn from these premises.

Jahres-Bericht des Naturhistorischen Vereins von Wisconsin. 1876–'77. Milwaukee: C. Dörflinger, printer.

This Annual Report of the Natural History Association of Wisconsin shows a gratifying increase in the number of members, and in the specimens contained in the various cabinets of natural history. The association embraces a section for zoölogy, one each for botany, mineralogy, geology, and ethnology, and the cabinets of each of these sections received during the year a large number of additional specimens. The list of active members embraces over 200 names.

Relative Ages of the Sun and Certain of the Fixed Stars. By Prof. D. Kirkwood. Pp. 4.

From the facts considered in this essay by Prof. Kirkwood, it appears to follow that —1. The solar system has not existed over twenty or thirty million years; 2. That our solar system is more advanced in its physical history than the larger component of the double star Alpha Centauri; 3. That 61 Cygni has reached a greater degree of condensation than the sun; and, 4. The companion of Sirius has reached a greater state of maturity than the sun, while the contrary seems to be true in regard to the principal star.

The Locust-Plague in the United States. By C. V. Riley, M. A., Ph. D. Pp. 236. With numerous Illustrations and Colored Maps. Chicago: Rand, McNally & Co. Price, $1.25.

We have here the fruit of the author's long-continued studies of the haunts and habits of the Rocky Mountain locust, as published from time to time in the "Entomological Reports of Missouri" and in sundry periodicals. The subject of the book is one that possesses a lively interest for farmers over a wide area of our Western States and Territories. Prof. Riley's object in publishing in a separate volume all the information he has been able to acquire with regard to the Rocky Mountain locust is a practical one—namely, to acquaint the farmer with the means of counteracting this plague—hence he, as far as possible, avoids technicalities, and writes in a style easily intelligible to the popular mind.

Compendium of Facts and Events. Compiled by E. Emery. Pp. 496. Peoria, Ill.: *Transcript* print. Price, $3.

This very convenient volume represents an enormous expenditure of labor in collecting statistical information in regard to "almost everything of interest to man." The matter is gathered in every instance from the most authentic sources, and is presented to the reader in the smallest possible compass. The work is one of permanent value. It is full of useful information for men in every walk of life, as the farmer, the mechanic, the merchant, the publicist, the schoolmaster, the man of letters, etc.

Peters's General History of Connecticut. Edited by Samuel Jarvis McCormick. Pp. 285. New York: D. Appleton & Co. Price, $1.50.

It was in this volume that publication was first made to the outside world of the so-called "Blue-Laws" of Connecticut. Of these laws the author says that they were "never suffered to be printed." He does not profess to do more than to give "a sketch" of some of them, so as to exhibit the spirit which pervades the whole. What that spirit was can be seen from a few of the prohibitions of the code, for instance: "No one shall run on the Sabbath-day, or walk in his garden or elsewhere, except reverently to and from meeting. No woman shall kiss her child on the Sabbath or fasting-day. No one shall read common-prayer, keep Christmas or Saints-days, make minced-pies, dance, play cards, or play on any instrument of music, except the drum, trumpet, and Jew's-harp. No food or lodging shall be afforded to a Quaker, Adamite, or other heretic." The authenticity of these laws has been called in question, and recently Mr. J. H. Trumbull published a work designed to show that the "False Blue-Laws" were invented by Dr. Peters. The object of the editor in republishing the work is to make the public acquainted with the side of the question opposed to that of Mr. Trumbull, and to confirm, as far as possible, by contemporary testimony, the truthfulness of Dr. Peters's summary of the Puritanic legislation of Connecticut and New Haven. But, quite apart from this question, the work is one of real value, and well worthy the honor of republication.

Weighing and Measuring. By H. W. Chisholm. Pp. 192. London: Macmillan. Price, $1.50.

The author of this little treatise, after defining weight and measure, devotes a chapter to "Ancient Standards of Weight and Measure," in which it is shown that accurate standards were totally unknown to the ancients, and in particular that the standards of ancient Egypt were *not* based on the earth's dimensions. The history of English standard units of weights and measures is then given with considerable minuteness; next follows a chapter on the metric system; finally, there is a chaper on "Weighing and Measuring Instruments, and their Scientific Use."

The Bible of Humanity. By Jules Michelet. Translated by Vincenzo Calfa. New York: J. W. Bouton. Pp. 347. Price, $3.

This book is not, as might be inferred from its title, a scripture which would be acceptable to the followers of Comte, nor would it answer as a foundation on which to build any creed. It is one of a class—compilations of moral, religious, and ethical teachings from various sources, with comments and extensions by the compiler, and bearing the impress of his ideas, which in the case of M. Michelet are quite peculiar. It is rather more reverent and refined than John Stewart's "Bible of Nature," but it is an equally great misuse of words to call it a Bible.

The literature and art of India, Persia, and Greece, "the three hearths of light," and of Egypt, "the monument of death," have inspired the greater part of the work. Of course, it is erotic; the commentary on the "Song of Songs," though rather free, presents that drama in a wonderfully bold and vivid way; and Chapters VI., VII., and VIII., which treat of woman, are marked by the unhealthy exaltation which appears in all of Michelet's later works, seeming, as the writer of the biographical sketch says, "to have been written under the influence of an uninterrupted honey-moon."

It aims to be epigrammatic, abounds in italics and exclamation-points, and offers a rich field for phrase-hunters. It is among these and rather sentimental transcendentalists that the book will find its readers.

Lectures and Essays. By Virgil W. Blanchard, M. D. New York: Blanchard Food-Cure Company. Pp. 67. Price, 10 cents.

These so-called essays are papers ostensibly on physiological subjects, but are really written to puff a lot of preparations sold by the author, who styles himself the "originator of the food-cure system." They are written in the style which characterizes that class of literature—various diseases are described, embellished with sensational horrors, which may be avoided and cured by the use of the food-remedies. While Pavy, Frankland, and other able investigators, are becoming more and more wary in their statements as to the way in which food is assimilated, and are beginning to question positions that have heretofore been generally accepted, Dr. Blanchard dogmatically asserts his ability to furnish specific material which shall go directly to the defective spot in the system, and set about the work of repairing the wasted tissues and disorganized nerve and brain cells without delay.

It is probably useless to expose the fallacies of this sort of trash; so long as people are content to remain in ignorance of hygienic rules, and ignore the laws of waste and supply, the platitudes of these venders will have readers, and their nostrums find sale.

A Partial Synopsis of the Fishes of Upper Georgia: with Supplementary Papers on Fishes of Tennessee, Kentucky, and Indiana. By David Star Jordan, M. D. Salem, Mass. Pp. 70.

In a recent notice of Commissioner Baird's Report on Food Fishes, we expressed a hope that a systematic list of the fishes of American waters, with descriptions, and an account of habitat, seasons, etc., would some time be made.

The papers included in the pamphlet before us are valuable contributions to such a work. Over the area indicated in the title the fishes have been catalogued and described with scientific accuracy, the localities, relative abundance, and common names, are given, while the synonyms of their nomenclature receive due attention. No attempt is made to give any account of the seasons, habits, or manner of breeding, which would be of most interest to the lay reader; but this would, perhaps, be too much to expect of the scientific worker attempting to cover so much ground.

The Metallurgical Review. Vol. I., No. 1, September. Published monthly by David Williams, 83 Reade Street, New York. Price, $5 per year. Single copy, 50 cents.

The projectors of this periodical are of the opinion that the metallurgical industries have become sufficiently important to have a current literature of their own, and intend that this *Review* shall be a vehicle for discussions on purely scientific topics, which are too abstruse for newspapers, and are given to the public but slowly through the medium of books.

This first number gives promise that the publication will have an immediate and permanent value. It contains, among others, essays on the "Mechanical Treatment of Metals," by Prof. R. H. Thurston; "Studies of Elemental Iron, and its Modifications," by Prof. Henry Wurtz; "New Iron District of Ohio," by E. C. Pechin; and a miscellany of short articles of metallurgical interest. It is finely printed in large, clear type, on excellent paper, with ample margins, presenting a most creditable appearance.

PUBLICATIONS RECEIVED.

Publishers' Trade List Annual (1877). New York: *Publishers' Weekly* print. Price, $1.50.

Free-Thinking and Plain Speaking. By Leslie Stephen. New York: Putnam's Sons. Pp. 362. Price, $2.50.

Volumetric Analysis. By Dr. Emil Fleischer. London and New York: Macmillan & Co. Pp. 294. Price, $2.50.

Method of Least Squares. By M. Merriman. Same publishers. Pp. 207. Price, $2.50.

Egypt as it is. By J. C. McCoan. New York: Holt & Co. Pp. 226. With Map. Price, $3.75.

Engineering Construction. By J. E. Shields, C. E. New York: Van Nostrand. Pp. 138. Price, $1.50.

Guide to Ridge Hill Farms. Boston: Getchell Brothers print. Pp. 156.

The Complete Preacher. Also, *The Metropolitan Pulpit*. Monthly. New York: Religious Newspaper Agency. $2 per year.

Spiritual Sciences; Revelation of God: Christmas and New-Year's-Day: Good Friday: Biblical Theology: Ascension-Day and Whitsuntide. All by "Kuklos." London: Published by John Harris, Kilburn Square.

Fur-bearing Animals. By Elliott Coues Washington: Government Printing-Office. Pp. 348. With Plates.

Weather Reports for May, 1871. Washington: Government Printing-Office. Pp. 190.

The Hidatsa Indians. By W. Matthews. Washington: Government Printing-Office. Pp. 246.

Geological and Geographical Survey of Colorado and Adjacent Territory (1875). By F. V. Hayden. Washington: Government Printing-Office. Pp. 834. With Maps and Plates.

Contributions to North American Ethnology. By W. H. Dall and George Gibbs (Powell's Survey of the Territories). Washington: Government Printing-Office. Pp. 361. With Plates.

The Geyser Basins of the Yellowstone Park. By I. B. Comstock. From the "Proceedings of the American Association." Pp. 8.

Results of Hypertrophied Tonsils. By A. W. Calhoun, M. D. Atlanta: Dickson print. Pp. 12.

Canadian Reciprocity. Pp. 16. Also, The Hard Times. Pp. 12. Philadelphia: American Iron and Steel Association.

Proceedings of the American Public Health Association. New York: Hurd & Houghton. Pp. 249. Price, $4.

Positivist Prayer. By J. Lonchampt. Goshen, N. Y.: *Independent Republican* print. Pp. 32.

Civilization and the Duration of Life. By C. T. Lewis. Cambridge: The Riverside Press. Pp. 11.

Anthropoidea. Pp. 8. Sketch of Cuvier. Pp. 8. Hunterian Oration. Pp. 7. By Dr. A. J. Howe, of Cincinnati.

Bulletin of the Survey of the Territories (Hayden's). Vol. III., No. 4. Washington: Government Printing-Office. Pp. 120.

Bulletin of the United States National Museum, Nos. 7, 8, and 9. Washington: Government Printing-Office.

Report of New York Meteorological Observatory (1876). New York: Brown print. Pp. 105. With Charts.

Organic Acids in Examination of Minerals. By H. C. Bolton. New York: Gregory Bros. print. Pp. 36. With Plate.

Fifteen-Cent Dinners. By Juliet Corson. New York: Published for gratuitous distribution. Pp. 39.

The Kindergarten Messenger. Vol. I., Nos. 9 and 10. Price, $1 per year.

Both's Method for treating Tubercular Consumption. New York: Cheronny & Kienle print. Pp. 20.

POPULAR MISCELLANY.

"A New Type of Steam-Engine."—Prof. R. H. Thurston read a paper at the Nashville meeting of the American Association on "A New Type of Steam-Engine," a report of which we find in the *American Manufacturer*. The author first gave a history of the steam-engine from Hero's time; then he discussed the modern type of steam-engine, pointing out its shortcomings; finally he proposed a new type, designed to prevent loss of heat-energy. There are, he observed, only two possible methods of utilizing the full heat-energy: the first is by enormous expansion, cooling the steam till it is all condensed into water and till all the heat is even taken out of that water, but this he shows to be impracticable; the other method is to use part of the power of the engine to pump back the discharged steam, containing as it does some water condensed from the steam, into the boiler. This latter method is theoretically practical, and the purely mechanical difficulties in the way of its realization are by no means insuperable.

As the steam in the cylinder of an engine expands, *doing work*, part of it condenses. The difference between the heat-energy of the steam at the beginning of the stroke, and that of the steam and water at the end of the stroke, is equal to the heat-equivalent of the mechanical work done by the steam. The change of mechanical condition which the steam undergoes during the stroke—namely, its conversion into water—renders it possible that the mingled steam and water remaining in the cylinder at the end of the stroke may be forced back into the boiler with a less expenditure of mechanical energy than the steam gave out during the stroke.

The Telephone anticipated.—As is the case with all great inventions, the telephone is now said to be nothing new; its principle was known long ago, and even exemplified in practice. Many are the claimants of priority in solving the problem of the transmission of articulate sound to great distances, but we know of none whose case is stronger than that of "Monsieur Ch. B——," who appears to have solved the problem as early as 1857. In the Count du Moncel's "Exposé des Applications de l'Électricité," published twenty years ago, occurs the following passage (translated in *Nature*):

"After the marvelous telegraphs which are able to reproduce at a distance writing of this or that individual, and designs more or less complicated, it seemed impossible, said M. B——, to advance further in the regions of the marvelous. Nevertheless, essaying to do something more, I asked, for example, if speech itself would not be capable of transmission by electricity; in a word, if one would not be able to speak at Vienna and be heard at Paris. The thing is practicable. This is how: Sounds, it is known, are formed by vibrations and carried to the ear by these same vibrations, which are reproduced by the intermediate media. But the intensity of these vibrations diminishes very rapidly with the distance, from which it follows, even in the employment of speaking-trumpets, tubes, and of acoustical horns, the limits which cannot be surpassed are very restricted. *Imagine that one speaks near a mobile plate, flexible enough not to lose any of the vibrations produced by the voice; that this plate establishes and interrupts successively the communication with a battery. You would be able to have at a distance another plate which would execute at the same time the same vibrations. It is true that the intensity of the sounds produced would be variable at the point of departure, where the plate is vibrated by the voice, and constant at the point of arrival, where it is vibrated by electricity.* But it is demonstrable that this would not alter the sounds. . . . In any case, it is impossible to demonstrate that the electric transmission of sounds is impossible. . . . An electric battery, two vibrating plates, and a metallic wire, will suffice."

The Slaves of Ants.—The subjugation of other insects by various species of ants is a familiar fact of natural history; it is less usual to see two or more species thus subjugated. Prof. Leidy, in some remarks made at a meeting of the Academy of Natural Science of Philadelphia, recounts his observations on a colony of yellow ants (*Formica flava*), which had three different insects in their service, namely, a species of *Aphis*, a *Coccus*, and the larva of an insect, probably coleopterous. The aphides, he tells us, were kept in two separate herds, and these were separated from a herd of cocci. The larva was in the midst of one of the former herds. In another and larger colony of yellow ants there was a herd of aphides which occupied the under-part of one margin of the stone under which the ants had their nest; the surface occupied by these aphides was about ten inches long and three-fourths of an inch broad. The same colony also possessed a separate herd of cocci, closely crowded, and occupying almost a square inch of space. Both aphides and cocci, with few exceptions, adhered to the under-surface of the stone, and were not attached to the roots. They appeared to be carefully attended by the ants, which surrounded them. The larva, too, was carefully attended by the ants, which were frequently observed to stroke it with their antennæ. The aphides and cocci were all in good condition, but without visible means of subsistence, excepting the neighboring grass-roots partially extending into the earth beneath the stones, to which they probably were at times transferred by their masters.

Obituary.—We have to record the death of the astronomer Leverrier, which took place at Paris on September 23d. Leverrier was born in 1811. Early in life he evinced great aptitude for chemical research, but his natural bent lay rather in the direction of the mathematical sciences. On being appointed to a position in the Polytechnic School, he devoted himself with great ardor to the study of the great problems of speculative astronomy, and soon earned high distinction by sundry memoirs. He was elected member of the Paris Academy of Sciences in 1846, and during the same year he made the great astronomical discovery of his life—that of the planet Neptune. In 1849 he entered political life as a deputy in the Legislative Assembly; under the Empire he was a senator, and for some time Inspector-General of Public Instruction. In 1853 he was appointed Director of the Paris Observatory, and so continued till 1870, when he resigned. He was reappointed in 1872, and held the position till his death. That sad event was no doubt hastened by the effects of mental overwork in his search for an intra-Mercurial planet.

The death is announced of J. P. Gassiot, F. R. S., in the eightieth year of his age. Mr. Gassiot was a merchant of London, but devoted his leisure to scientific research. In 1838 he was an active member of an electrical society, and for the remainder of his life devoted himself specially to the study of electrical phenomena. He was the author of several papers contributed to the "Philosophical Transactions" of the Royal Society of London. He was a munificent patron of science, and a helper of scientific men.

British Association Papers.—In his presidential address in Section D of the British Association, Dr. J. Gwyn Jeffreys vehemently attacked the doctrine of evolution, which he declared to be simply a "product of imagination. . . . I cannot," he said, "identify a single species of the Cretaceous Mollusca as now living or recent. All of them are evidently tropical forms. This question of identity depends, however, on the capability of hereditary persistence which some species possess; and although a certain degree of modification may be caused by an alteration of conditions in the course of incalculable ages, our knowledge is not sufficient to enable us to do more than vaguely speculate, and surely not to take for granted the transmutation of species. We have no proof of anything of the kind. Devolution or succession appears to be the law of Nature; evolution (in its modern interpretation) may be regarded as the product of human imagination. I am not a believer in the fixity of species, nor in their periodical extinction and replacement by other species. The notorious imperfection of the geological record ought to warn us against such hasty theorization. We cannot conceive the extent of this imperfection. Not merely are our means of geological information restricted to those outer layers of the earth which are within our sight, but nearly three-fourths of its surface is inaccessible to us, so long as it is covered by the sea. Were this not the case we might have some chance of discovering a few of the missing links which would connect the former with the existing fauna and flora. It is impossible even to guess what strata underlie the bottom of the ocean, or where the latter attained its present position relatively to that of the land. The materials of the sea-bed have been used over and over again in the formation of the earth's crust, and the future history of our globe will to the end of time repeat the past."

Miss A. W. Buckland, in a paper on "The Stimulants of Ancient and Modern Savages," said that the use of stimulants is almost universal. Among the lowest races the form of stimulant employed is now, as in ages past, some sort of root or leaf chewed for its strengthening and invigorating properties, such as the pitberry, recently discovered in use among nations in Central Australia, and the coca-leaf among the Indians of South America; but no sooner did the nations advance to the agricultural stage than they began to make fermented drinks from the roots of grains cultivated for food. Hence the beer of Egypt, which probably found its way with the wheat and barley of that land to the Swiss lake-dwellings, and over a great part of Europe, having been evidently known in Greece and

Rome at a very early period, while a similar liquor still forms the chief beverage of all African nations, being now, as formerly in Egypt, fermented by means of plants. In China and Japan rice was and is used to make wine or beer instead of wheat or barley or American maize. The sour milk or *koumiss* of the pastoral tribes of Central Asia, and the mead of the ancient Scandinavians, both reappear among the Kaffirs of South Africa. Palm-wine is used wherever palms flourish, but wine of the juice of the grape, although known in very ancient times, seems to have been confined to the civilized races of Western Asia and Egypt, extending later to Greece and Rome. The multitude of wines described by Pliny were, however, in almost all cases flavored with herbs or garden-plants for medicinal purposes. The conclusions to be drawn from the history of fermented beverages, as recorded by travelers, are, that the earliest stimulants were simply leaves and roots chosen by animal instinct, chewed, and found by experience to produce exhilaration and strength. The art of distillation, though probably known early in the Christian era, is comparatively modern, and was certainly unknown to savage races until "fire-water" was introduced, to their serious detriment, by Europeans.

In a paper on the "Shifting of the Earth's Axis," Mr. A. W. Waters pointed out how the unequal distribution of land and sea might be an agent for preventing the movements of elevation and depression of the land in one part of the globe balancing those in another, and also showed how similar movements in various localities would differently affect the pole. Any movement, such as submarine elevation, which displaces water, would spread it over the oceanic area; and the effect of this would, with the present configuration, be the same as if about one-twelfth of the weight had been added in the northern hemisphere along east longitude 45° 44′, namely, in a line passing by the entrance of the White Sea, over the Caucasus, and through the middle of Madagascar. As every submarine movement would create a force acting in this direction, there seems reasonable ground for thinking that the tendency would be for the shifting of the axis to take place near this line.

Simultaneous Contrast of Colors.—An incident in the life of Henry IV. of France finds its explanation in an experiment made by Chevreul. While yet Prince of Navarre, Henry IV. was playing dice with two courtiers a few days before the massacre of St.-Bartholomew's-day. They saw, or thought they saw, on the dice spots of blood; and the party broke up in alarm. The phenomenon is explained by Chevreul by the law of simultaneous contrast of colors, and he illustrates this by experiment as follows: Seat yourself in a room so as to receive on the right side the sun's rays at an angle of 20° to 25°, the left eye being closed. On a table covered with gray paper and under diffuse light place two hen's-feathers, one black and the other white, distant 0.6 to 0.8 metre from the eye. After about two minutes, with the right eye in the sun's beams, the dark feather appears red and the white one emerald-green. After a few seconds the black feather of red color seems edged with green and the white feather seems of a rosy color. Now close the right eye and open the left. The black feather will be black and the white one white. The effect is evidently due to insolation: the black feather appears red because it reflects much less light than the white feather. From the law of simultaneous contrast of colors, the insolated eye seeing the green by white light, the black feather must appear of the complementary color of green, which is red.

Constitution of the Nebulæ.—Mr. E. J. Stone, in a paper read before the Royal Society, London, attempts to reconcile Huggins's discovery of bright lines in the spectra of nebulæ with the old view that nebulæ are irresolvable stellar clusters. The sun, he remarks, is known to be surrounded by a gaseous envelope of very considerable extent. Similar envelopes must surround the stars generally. Each star, if isolated, would be surrounded with its own gaseous envelope. These gaseous envelopes might, in the case of a cluster, form over the whole, or a part, of the cluster a continuous mass of gas. So long as such a cluster was within a certain distance from us, the light from the stellar masses would predominate over that of the gaseous envelope. The spectrum would, therefore, be an ordinary stellar spectrum. Suppose such a cluster to be removed farther and farther from us, the light from each star would be diminished in proportion of the inverse square of the distance; but such would not be the case with the light from the enveloping surface formed by the gaseous envelopes. The light from this envelope received on a slit in the focus of an object-glass would be sensibly constant because the contributing area would be increased in the same proportion that the light from each part is diminished. The result would be that, at some definite distance, and all greater distances, the preponderating light received from such a cluster would be derived from the gaseous envelopes and not from the isolated stellar masses. The spectrum of the cluster would, therefore, become a linear one, like that from the gaseous surroundings of our own sun.

Duration of the Flight of Bees.—To determine the length of time that bees can continue to fly about, Dönhoff took some of those insects from a hive, just as they came out of the entrance-hole, and placed them under a glass bell at a temperature of 66° Fahr. First they ran hastily up and down the sides of the glass, and flew about in the jar. Their movements grew gradually slower, and after forty-five minutes they all sat quietly together, or moved very slowly and clumsily, and were unable to fly. On being allowed to crawl upon a pencil, and then thrown off, they fell down perpendicularly without moving their wings. On killing one or two, the honey-bags were found to be empty. The author then fed the others with a sugar solution, and after three or four minutes threw some of them into the air. They were now able to use their wings a little. A minute or two later they appeared to be as lively as ever. The author remarks that if the temperature is under 66° Fahr. the bees lose the power of flying even sooner, and recover it more slowly. With higher temperatures the power returns sooner. Dönhoff's conclusion from these observations is that the bee "loses the power of flying because it does not possess the necessary strength to be converted into muscular action, and that this strength returns to its system because in sugar it finds the necessary vital support."

Singing-Flames and Inaudible Vibrations.—"Singing-flames" are known to be sensitive to the faintest sounds, provided the rate of vibration of the latter is sufficiently high. But are they equally sensible to vibrations that are so rapid as to be inaudible? This question has been studied by Prof. W. F. Barrett, and the results of his experiments, as stated by him in a communication to *Nature*, will be read with interest. Prof. Barrett employed a flame produced by coal-gas contained in a holder under a pressure of ten inches of water, and issuing from a steatite jet having a circular orifice of 0.04 inch diameter; the height of the flame when undisturbed was just two feet, but it fell to seven inches under the feeblest hiss or the clink of two coins. On sounding the lowest note of a "Galton whistle," little effect was produced on the flame; a shrill dog-whistle produced a slight forking, but that was all. Raising the pitch of the Galton whistle, the flame became more and more agitated, until when Prof. Barrett had nearly reached the upper limit of audibility of the left ear, and had gone quite beyond the limit of the right, the flame was still more violently agitated. Raising the pitch still higher, till he had quite ceased to hear any sound, he was astonished to observe the profound effect produced on the flame. At every inaudible puff of the whistle it would fall fully sixteen inches, and give its characteristic roar, at the same time losing its luminosity, and, when viewed in a revolving mirror, presenting a multitude of ragged images, with torn sides and flickering tongues. Nor was this effect sensibly diminished by a distance of some twenty feet from the flame; even at fifty feet the effect was very pronounced.

Functions of the Cerebellum.—The researches and experiments of Flourens have been considered conclusive as to the coordinative function of the cerebellum in animal movements. That eminent physiologist removed the cerebellum from pigeons in successive slices, and found that, on cutting away the superficial layers of the organ, there appeared only a slight feebleness and want of harmony in the movements; but that when the deepest layers were removed the animal lost completely the power of standing, walking, leaping, or flying. Volition and sensation remained; the power of executing movements remained; but the power of coördinating those movements into regular and combined actions was lost. Flourens's experiments have been again and again repeated, always with the same results. But now the subject has been investigated anew by Ovsiannikoff, whose conclusion is that, even though the entire cerebellum be cut out, the faculty of coördination still remains. In one of his experiments a rabbit remained alive during two whole weeks after all the upper half of the cerebellum was cut out, nor did it lose its faculty of coördinating its movements after all the cerebellum was cut out until an effusion of blood produced this result.

Appearance and Habits of the Andaman Islanders.—The natives of the Andaman Islands are described by Surgeon-Major Hodder, of the British Army, as not exactly prepossessing in appearance, though not deformed and hideous, as has been stated. In height they vary from four feet nine inches to five feet one inch; they are extremely black, more so than the African negro, and some of them have "a dull, leaden hue, like that of a black-leaded stove." They are fond of dancing, have a strong sense of the ridiculous, are exceedingly passionate, are easily aroused by trifles, and then "their appearance becomes diabolical." The men go entirely naked, and the women nearly so. They cover their bodies with red earth, and, as ornaments, wear strings of their ancestors' bones round their necks, or a skull slung in a basket over their shoulders. They are tattooed all over their bodies; their heads are shaven, with the exception of a narrow streak from the crown to the nape of the neck. They rarely have eyebrows, beard, mustache, whiskers, or eyelashes. They are very fond of liquor and smoking; are short-lived and not healthy, not many passing forty years of age. Their language consists of few words, harsh and explosive, and chiefly monosyllabic. Almost their only amusement is dancing to a monotonous chant and the music of a rough skin drum, played by stamping with the feet. Their courtship and marriage usages are very simple. The male candidate for matrimony eats a sort of ray-fish, which gives him the appellation of "goo-mo"—bachelor desirous of marrying. The marriageable girls wear a certain kind of flower. The ceremony consists in the pair about to be married sitting down, apart from the others, and staring at one another in silence; toward evening the girl's father or guardian joins the hands of the pair; they then retire, and live alone in the jungle for some days. The only manufactures of the islanders are canoes, bows, arrows, spears, and nets. Of late years "homes" have been established for the Andamanese, consisting of large bamboo sheds, in which those who come in from the jungle put up, coming and going at will. They seem, however, to prefer the jungle, and the attempts made to cultivate their acquaintance do not appear to have been very successful.

The Ancient Ruins of Colorado.—A correspondent of the Worcester *Spy* writes as follows of certain highly interesting discoveries recently made by the Geographical and Geological Survey of the Territories conducted by Dr. Hayden:

"Prof. Hayden has given Southwestern Colorado a new interest, by discovering and describing the ancient ruins in that section and in Southeastern Utah. The fertile valley of the Animas was densely inhabited and highly cultivated by an enlightened race of people centuries ago. The ruins of the houses, corrals, towns, fortifications, ditches, pottery-ware, drawings, non-interpretable writings, etc., show that many arts were cultivated by these prehistoric people which are now entirely lost. Their houses were built of almost every kind of stone, from small bowlders to the finest sandstone.

"The finest of these ruins, and the nearest perfect, are situated about thirty-five miles below Animas City, in a large valley fifteen miles long by seven wide, on the west side of the river. This valley has been covered with buildings of every size, the two largest being 300 by 6,000 feet, and about 300 feet apart. They are built of small blocks of sandstone, laid in adobe mud, the outside walls being four feet and the inside walls from a foot and a half to three feet thick. In the lower story are found port-holes a foot square. There are rooms now left, and walls for about four stories high are still standing. About the second story, on the west side, there was once a balcony along the length of the building. No signs of a door are visible in the outer walls, and the ingress must have been from the top, in the inside there being passages from room to room. Most of them are small, from eight by ten to twelve by fourteen feet, the doors being two by four feet. The arches over the doors and port-holes are made of small cedar poles two inches wide, placed across, on which the masonry is placed. The sleepers supporting the floors are of cedar, about eight inches thick, and from twenty to fifty feet long, and about three feet apart. A layer of small round poles was placed across the sleepers, then a layer of thinly-split cedar sticks, then about three inches of earth, then a layer of cedar-bark, then another layer of dirt, then a carpet of some kind of coarse grass. The rooms that have been protected from exposure are whitewashed, and the walls are ornamented with drawings and writings. In one of these rooms the impression of a hand dipped in whitewash, on a joist, is as plain as if it had been done only yesterday. In another room there are drawings of tarantulas, centipedes, horses, and men.

"In some of the rooms have been found human bones, bones of sheep, corn-cobs, goods, raw-hides, and all colors and varieties of pottery-ware. These two large buildings are exactly the same in every respect. Portions of the buildings plainly show that they were destroyed by fire, the timbers being burned off and the roofs caved in, leaving the lower rooms entirely protected. The rock that these buildings were built of must have been brought a long way, as nothing to compare with it can be found within a radius of twenty miles. All the timber used is cedar, and has been brought at least twenty-five miles. Old ditches and roads are to be seen in every direction. The Navajo Indians say, in regard to these ruins, that their forefathers came there five old men's ages ago (500 years), and that these ruins were here, and the same then as now, and there is no record whatever of their origin."

Political Economy in Law-Schools.—M. Waddington, the French Minister of Public Instruction, has issued a decree making the study of political economy one of the subjects of examination for the degree of licentiate in all the schools of law. The innovation does not seem to give unmixed satisfaction to the French lawyers, who have at all times treated this science with contempt. The basis of the teaching of law, says their organ, is the text of the law; political economy is no branch of the law—it has no texts—it is not positive science—and is at most a conjectural art, or kind of literature, less amusing than others; and to require that men desiring to become magistrates and advocates should pass an examination in the theories of Malthus, Adam Smith, and Say, is absurd. The claims of economic science will, of course, find plenty of defenders; and indeed it would appear, in view of the complications and contentions which have arisen from the pending negotiation of a commercial treaty between France and England, that it might be well to have a knowledge of economic principles made imperative somewhere.

A New Remedy for Wakefulness.—To those whose brains will not subside when the time for rest has arrived, Dr. John L. Cook, of Henderson, Kentucky, proposes a very simple method of securing prompt and refreshing sleep without the aid of drugs. When the mind is active, the circulation in the brain is correspondingly active; we breathe more frequently, and the movements of the heart are more rapid and vigorous. On the other hand, when the mind is at rest, as in healthy sleep, the circulation in the brain is notably diminished, the heart-beats are less rapid and forcible, and the breathing is perceptibly slower. In the wakeful state the mind, as a rule, is intensely occupied, whence we may infer an increased amount of blood in the brain. Dr. Cook's suggestion is to withdraw a portion of this from the head, or lower the brain-circulation, by taking deep and slow inspirations—say twelve or fifteen a minute. By this means the action of the heart will become slower and feebler, less blood is thrown into the brain, and very soon a quiet feeling, ending in sleep, is induced. As by a slight effort of the will any one may try this, we leave the question of its value to the test of actual experiment.

A New Optical Experiment.—Mr. William Terrill offers in *Nature* a new lecture-experiment for proving the compound nature of white light. This method is to arrange seven lanterns so as to project their several circles of light side by side on a white screen, then to color each circle by introducing slides of glass stained to imitate the seven colors of the spectrum (the proper intensity of color being found by trial); in this way are produced seven circles on the screen, colored from red to violet, and arranged side by side. Then by turning the several lanterns, so that the projected circles exactly overlap each other, one circle of white light is obtained, proving that the seven colors together make white light. The same effect can be produced with five colors only, if properly selected; and even two, the ordinary cobalt-blue and deep orange, will nearly do. If these two be made to partially overlap, the effect is very striking.

Dallinger's Studies of Minute Animal Forms.—The Rev. W. H. Dallinger, whose researches into the origin and development of minute life-forms have earned for him a distinguished place in the world of science, in a communication to the Royal Institution of Great Britain, gives a brief historical sketch of his labors in this field. Ten years ago Mr. Dallinger determined to work out, by actual microscopic observation, the life-history of some of the lowly and minute organisms which occur in putrid infusions. After four years of preparation, he commenced his work in conjunction with Dr. Drysdale, the plan needing two observers. Each set of observations was made continuous, so that nothing should have to be inferred. Very high powers were employed, and the largest adult objects examined were $\frac{1}{1000}$ of an inch, the smallest $\frac{1}{4000}$. Six forms altogether were selected, and their whole history was worked out. At first it was supposed that reproduction by fission was the usual method, but prolonged research showed that spores were produced. These were so small that a magnifying power of 5,000 diameters was needed to see them as they began to grow. The glairy fluid from which they developed seemed at first homogeneous, and it was only when growth set in that the spores became visible. All that could be learned about the origin of the glairy fluid was, that a monad larger than usual, and with a granulated aspect toward the flagellate end, would seize on one in the ordinary condition; the two would swim about together till the larger absorbed the smaller, and the two were fused together. A motionless spheroidal glossy speck was then all that could be seen. This speck was found to be a sac, and, after remaining still from ten to thirty-six hours, it burst, and the glairy fluid flowed out. The young spores that came into view in this were watched through to the adult condition. Bearing on the subject of spontaneous generation, this fact was learned, that, while a temperature of 140° Fahr. was sufficient to cause the death of adults, the spores were able to grow even after having been heated to 300° Fahr. for ten minutes. That there is no such thing as spontaneous generation of monads seems to Mr. Dallinger quite clear; and he is satisfied that, when bacteria are studied after the same manner, the same law will be found to hold good with them.

Influence of the Environment.—As a striking instance of the transformation effected in a race by changed conditions of life, *Das Ausland* quotes, from Khanikoff's "Memoir on the Ethnography of Persia," some observations on a colony of Würtembergers which in 1816 settled in the trans-Caucasus country, near Tiflis. The original colonists, we are informed, were "singularly ugly," with broad, square countenances, blond or red hair, and blue eyes. The second generation showed some improvement; black hair and black eyes were no longer rare. The third generation was so entirely altered that their Würtemberg descent was no longer visible, for now black hair and black eyes were the rule, the face had gained in length, and the bodily habit, while nothing was lost in point of stature, was more slender and graceful. As the chastity of the women is not to be disputed, and as the colonists intermarry only among themselves—Khanikoff found only one case of a Würtemberger marrying a Georgian woman—the change in the race-characters can be attributed only to the influence of environment.

Extirpation of Injurious Insects.—A special meeting of the London Society of Arts was held a few weeks ago, to discuss measures for the extirpation of injurious insects. The paper for the occasion was by Andrew Murray, F. L. S., who advocated government interference as being indispensably necessary in the war against insect pests. He spoke of three principal modes of counteracting the ravages of insects, the first being county or district rotation of cropping. Most vegetable-feeding insects subsist on one kind of plant, as wheat, rye, potatoes, etc., and, if we take away their special pabulum, the race dies out. This we do by rotation of crops. The next means of extirpation recommended by Mr. Murray was burning the nidus in which the insect, in whatever stage, passes the winter; or using some substance, as Paris-green, hellebore, etc. There remains the last refuge of all invaded countries, namely, destroying the resources of the country before the invaders, so that they may perish for the want of food. This, Mr. Murray said, can rarely be necessary, but it would be, he thought, the proper course to follow, should the Colorado beetle gain a footing in England. The larvæ of the beetle would probably first appear in some potato-field near Cork, or Londonderry, Liverpool, or Glasgow; the instant this is perceived, the vines of the potatoes should be cut to the ground, and Paris-green scattered over the field.

Recent Observations of Stomach-Digestion.—A man in Paris, having an impermeable stricture of the gullet, was saved, by the operation of gastrotomy, from death by starvation. The patient's gullet is so completely blocked that when a small quantity of potassium ferrocyanide in solution is swallowed, no trace of the salt can be detected in the stomach; hence the gastric juice is absolutely free from any admixture of saliva. The food is reduced to a pulp and injected by a syringe into the artificial opening in the abdominal wall; it remains in the stomach for three or four hours; when milk is introduced, it disappears in from one and a half to two hours. The chyme does not pass gradually, as is commonly supposed, into the small intestine: during the first three hours after its introduction into the stomach its volume does not appear to diminish; then within about fifteen minutes, the entire mass is driven through the pyloric orifice. At the end of four hours the stomach is nearly always empty, but hunger does not begin to be felt till two hours later. The mean acidity of the gastric juice, whether pure or mixed with food, is equivalent to about 1.7 grain of hydrochloric acid per 1,000, never falling below 0.5, or rising above 3.2 grammes. The quantity of liquid present does not seem to exert any influence on the degree of its acidity, which is augmented by wine and alcohol, and lessened by cane-sugar. The gastric juice is more acid while digestion is going on than during the intervals of the process; its acidity seems always to be increased as digestion is drawing to a close.

Contents of a Utah Mound.—In the vicinity of Payson, Utah Territory, are six mounds, covering a total area of about twenty acres of ground. One of these mounds was opened last year, and the discoveries then made are recorded in a letter published in the *Eureka* (Nevada) *Sentinel*. First a skeleton of a man was found, which measured six feet six inches in length. In the right hand was a huge iron weapon, but this crumbled to pieces in handling. There was also found a stone pipe, the stem of which was inserted between the teeth of the skeleton. Near by was found another skeleton, not quite so large, supposed to be that of a woman. "Close by," writes the correspondent of the *Sentinel*, "the floor was covered with a hard cement, to all appearances a part of the solid rock, which, after patient labor and exhaustive work, we succeeded in penetrating, and found it was but the corner of a box similarly constructed, in which we found about three pints of wheat-kernels, most of which dissolved when brought in contact with the light and air. A few of the kernels found in the centre of the heap looked bright, and retained their freshness on being exposed. These were carefully preserved, and last spring planted and grew nicely, though the field-insects seemed determined to devour it. We raised four and a half pounds of heads from these few grains. The wheat is unlike any other raised in this country, and produces a large yield. It is of the club variety—the heads are very long, and hold very large grains. . . . We find houses in all the mounds," he continues, "the rooms of which are as perfect as the day they were built. All the apartments are nicely plastered, some in white, others in a red color; crockery-ware, cooking-utensils, vases—many of a pattern similar to the present age—are also found. Upon one large stone jug or vase can be traced a perfect delineation of the mountains near here for a distance of twenty miles. We have found several mill-stones, used in grinding corn, and plenty of charred corn-cobs, with kernels not unlike what we know as yellow dent-corn. We judge from our observations that these ancient dwellers of our country followed agriculture for a livelihood, and had many of the arts and sciences known to us, as we found moulds made of clay for the casting of different implements, needles made of deer-horns, and lasts made of stone, and which were in good shape. We also find many trinkets, such as white stone beads and marbles; also small squares of polished stones, resembling dominos."

The Origin of Mineral Oils.—Mendelejeff, in a communication to the Russian Chemical Society, questions the current view as to the origin of mineral oils, namely, that they are the products of the decomposition of the fossil remains of organisms, and proposes a theory of his own. He calls attention to the possibility of the interior of our globe containing metallic masses of vast extent. If iron be the prevailing metal, and if it occur in combination with carbon, we have the material from which we can conceive the mineral oils to have been derived. Contact with water at a high temperature, and under great pressure, brought about by the upheaval or disruption of any of the overlying sedimentary strata, would result in the formation of metallic oxides and saturated hydro-carbons. The latter, permeating the porous sandstones of higher levels, condense there, or, by undergoing further change, become the marsh-gas of the "gas-wells," or are converted into unsaturated hydro-carbons. The invariable association of salt-water with mineral oil is not without its bearing on this interesting question. If the view recently advanced by Steenstrup that the curious metallic masses discovered by Nordenskjöld in Greenland, and generally held to be meteoric iron, be correct, and they are erupted matter and not of cosmical origin, their composition, which analysis has shown to be in a considerable degree carbide of iron, approaches nearly that of the material assumed by Mendelejeff as the source of the oil.

A Low Mammalian Brain.—At a meeting of the American Philosophical Society, as we learn from *The American Naturalist*, Prof. Cope exhibited a cast of the brain-cavity of a species of Coryphodon from New Mexico. This, according to Prof. Cope, is the lowest and most reptilian type of mammalian brain so far discovered, inasmuch as the diameter of the hemispheres does not exceed that of the medulla, which itself is as wide as the cerebellum. The latter is small and flat. The middle brain is the largest division, much exceeding the hemispheres in size, being especially protuberant laterally. The hemispheres contract anteriorly into the very stout peduncles of the olfactory lobes. These continue undivided to an unusual length, and terminate in a large bulbus, which is at first grooved above and then bifurcates at the extremity. The length of the hemispheres is $\frac{1}{15}$ that of the cranium, and their united bulk $\frac{1}{27}$ that of the hemispheres of a tapir of the same size. Their surface is not convoluted, and there is no trace of a Sylvian fissure. The region of the pons Varolii is very wide and exhibits a continuation of the anterior pyramids. The large size of the middle brain and olfactory lobes gives the brain as much the appearance of that of a lizard as of a mammal.

The Late Eruption of Mauna Loa.—The Rev. Titus Coan gives, in the *American Journal of Science*, a vivid description of the latest eruption of Mokua-weo-weo, the terminal crater of Mauna Loa, Hawaii. The eruption commenced between nine and ten in the evening of February 14, 1877, with great splendor. The summit of the mountain appeared as though melted, and the heavens seemed on fire. Vast masses of illumined steam, like columns of flaming gas, were shot upward to a height of 14,000 to 17,000 feet, and then spread out into a great fiery cloud. This continued through the night. In the morning the mountain was hidden by thick clouds, and the only symptoms of volcanic action were an occasional thud and a smoky atmosphere. Mokua-weo-weo had entered into a state of inactivity, but soon "a remarkable bubbling was seen in the sea about three miles south of Kealakekua, and a mile from the shore. Approaching the boiling pot, it was found emitting steam, and throwing up pumice and light scoria. This boiling," continues Mr. Coan, whose communication is dated Hilo, March 17th, "was active when we last heard. It is in deep water. On the island new fissures have been opened in the *pahoihoi*, which extend up to the higher lands, indicating the course of a subterranean lava-stream, that terminated in a submarine eruption—a new feature in our modern volcanic phenomena. About the time of this eruption beneath the sea, a tidal or earthquake wave of considerable force was observed along the coast of Kona."

Extraordinary Development of the Sense of Smell.—Dr. Maudsley, in his "Physiology of Mind," noticed elsewhere, speaking of the loss of one sense being followed by a notable increase in the functions of those which remain, in consequence of the greater attention given to them, cites the following instances as related by Dr. Howe in the "Forty-third Report of the Massachusetts Asylum for the Blind:" Julia Brace, a deaf and blind mute, a pupil of the American Asylum, had a fine physical organization and highly-nervous temperament. In her blindness and stillness her main occupation was the exercise of her remaining senses of smell, touch, and taste, so that through them she might get knowledge of all that was going on around her. Smell, however, seemed to be the sense on which she most relied. She smelled at everything which she could bring within range of the sense; and she came to perceive odors utterly insensible to other persons. When she met a person whom she had met before she instantly recognized him by the smell of his hand or glove. If it were a stranger she smelled his hand, and the impression was so strong that she could recognize him long after by again smelling his hand, or even his glove, if just taken off. She knew all her acquaintances by the odor of their hands. She was employed in sorting the clothes of the pupils after they came from the wash, and could distinguish those of each friend. If half a dozen strangers should throw each one his glove into a hat, and they were shaken up, she would take one glove, smell it, then smell the hand of each person, and unerringly assign each glove to its owner. If among the visitors there were a brother and sister, she could pick out the gloves by a similarity of smell, but could not distinguish the one from the other. This case furnishes a strong argument in support of the conjecture that a dog removed to a distant place finds its way home by following backward a train of smells which he has experienced.

Mr. Boyd Dawkins on Museum Reform.—Writing, in *Nature*, of the need of museum reform, Mr. Boyd Dawkins recognizes the existence of a "collecting instinct"—a desire to accumulate whatever strikes the fancy—and this instinct he declares to be almost universal among mankind, whatever their stage of intellectual development. The collections which result from this instinct bear the stamp of the individual who makes them. They are "museum units" which, like molecules, have a tendency to coalesce into bodies of greater or less size, and thus constitute museums. The organization of the latter is of high or low type, according as the units keep or lose the stamp of the individual, and have been moulded into one living whole, or are dissociated. They are highly organized and valuable if the parts are duly subordinated to each other and brought into a living relationship; they are lowly organized and comparatively worthless if they remain as mere assemblages of units placed side by side without organic connection and without a common life. Mr. Boyd Dawkins regards most of the provincial museums in England as belonging to this lower type. His description of one or two of these collections is amusing enough, and worthy of being quoted entire; perhaps it will apply to some lauded collections to be found on this side of the Atlantic. "In one instance which occurs to me," writes Mr. Dawkins, "you see a huge plaster-cast of a heathen divinity surrounded by fossils, stuffed crocodiles, minerals, and models of various articles, such as Chinese junks. In another, a museum unit takes the form of a glass case containing a fragment of a human skull and a piece of oat-cake, labeled 'fragment of human skull very much like a piece of oat-cake.' In a third wax models are exhibited of a pound weight of veal, pork, and mutton-chops, codfish, turnips, potatoes, carrots, and parsnips, which must have cost the value of the originals many times over, with labels explaining their chemical constitution, and how much flesh and fat they will make." Museums of this low type "constitute a serious blot on our educational system, since they are worse than useless for purposes of teaching."

Size of Medicinal Doses.—One of the papers read at the last meeting of the American Medical Association was on "The Effects of Remedies in Small Doses." The author of this paper, Dr. John Morris, held that—1. The true physiological effect of remedies might best be obtained by the administration of small doses frequently repeated; 2. That medicines thus given are cumulative in their operation; 3. That the effect of remedies is greatly increased by combination, the manner of preparation, time and mode of administration, etc.; 4. That large doses of medicine frequently act as irritants; that they produce an abnormal state of the blood, as was evidenced by such conditions as narcotism, alcoholism, iodism, ergotism, bromidism, etc.; 5. That more special attention should be given at the bedside to the influence of remedial agents, to the end that greater certainty may be attained in the prescriptions.

Denationalizing Science.—Sir C. Wyville Thomson having called to his assistance, in working up the Challenger collections, a few foreign naturalists of eminence, Dr. P. Martin Duncan, President of the Geological Society, gives vent to his "feelings of disappointment" in a letter to Sir Wyville, and asserts that "a very large section" of British naturalists are in like manner pained by the way in which English workers have been passed over. Sir Wyville Thomson makes a dignified reply, in which he states that his endeavor had been to select first those who were generally regarded as *authorities* in special branches; and, second, those who could do the work assigned them within the allotted time. Where Englishmen fulfilled these conditions, Englishmen were chosen, because in that way a good deal of risk was avoided, in sending portions of the collections abroad. "Except for this consideration" (i. e., that of avoiding risk of losing collections), writes Sir Wyville, "I confess I saw and see no objection, but rather the reverse, to making a great work of this kind somewhat more catholic." Having thus mildly rebuked the rather despicable nationalism of Dr. Duncan, Sir Wyville gives a list of the naturalists employed in the work. It contains twenty-two names, all of them names of Englishmen, with six exceptions. He then begs the pardon of the Englishmen (if such there be) more eminent than Haeckel, A. Agassiz, Oscar Schmidt, Lyman, Gunther, and Claus, in their respective specialties of Radiolarians, Echinoidea, Sponges, Ophiuridea, Fishes, and Crustacea, but whom he has overlooked in favor of these foreigners. Notice has been taken of Dr. Duncan's letter by some of the most eminent scientific men in England, and a manifesto has been published deprecating national jealousies in science. This paper has received the signatures of Sir J. D. Hooker, Prof. Huxley, Dr. W. B. Carpenter, Mr. Darwin, Mr. St. George Mivart, and many other representative scientific men. *Nature*, in giving an account of this very unpleasant affair, calls attention to the catholic spirit manifested by the directors of the United States Gulf Stream Expedition, who distributed their materials for description among sixteen naturalists, of whom only four were Americans.

NOTES.

It has been found by Lechartier and Bellamy that zinc is constantly present in appreciable quantities in the liver of the human subject and of many lower animals. It also occurs in hen's-eggs, in wheat, barley, and other grains. These facts are of interest for forensic medicine.

It is to be hoped that the following lucid "directions for the formation of the letter *n*" are not a fair sample of the kind of instruction given in public schools throughout the United States: "The letter *n* is one space in height, three spaces in width; commence on the ruled line with a left curve, ascending one space, joined by an upper turn to a slanting straight line, descending to the ruled line joined angularly to a left curve, ascending one space, joined by an upper turn to a slanting line, descending to the rule joined by a base, turn to a right curve ascending one space."

Land that has been flooded by the sea is generally barren for years afterward. According to a German chemist the cause of this barrenness is the presence of an excess of chlorine salts; such land has a tendency to remain damp, and there is a formation of ferrous sulphate, which is highly injurious to plants. The land should be drained as quickly as possible, sown with grass or clover, and allowed to rest.

La Nature cites the great age of an orange-tree in the gardens of the Versailles Palace as an illustration of the longevity of that species of plants. This ancient tree, known as the "Grand-Connétable de François I.," and also as the "Grand-Bourbon," has now stood more than four hundred and fifty years. It is sprung from some seed of the bitter-orange sown in a plant-pot, at the beginning of the fifteenth century by Eleanor of Castile, wife of Charles III., King of Navarre. Several plants were produced from the same lot of seeds, and they were all kept in one box at Pampeluna till 1499. In 1684, more than two hundred years after being first grown from the seed, these orange-trees were taken to Versailles. The "Grand-Connétable" is in all probability the oldest orange-tree in existence; it is still in a very healthy state, and does not appear to suffer from the effects of age.

The coal of the Placer Mountains coal-mines in Arizona Territory possesses, according to Prof. Raymond, the hardness, specific gravity, fixed carbon, and volatile matter, of anthracite; it ignites with difficulty, but burns with intense heat. The supply is declared to be "inexhaustible."

A correspondent of the *Bulletin of the Nuttall Ornithological Club* narrates in that journal an instance of the persistency of a house-wren in nest-building. The nozzle of a pump in daily use was repeatedly found to be obstructed with sticks, which on investigation proved to be nest-building material taken in by a wren. One morning the bird was allowed to carry on its work for two hours, and then he had filled the pump so full that water could not be obtained until a part of the sticks had been removed. The nest was three times destroyed before the bird abandoned his work.

The belief that fish is specially adapted to feed the brain, and that fish-eaters are therefore more intellectual than the average, does not find much favor with Dr. Beard. He says that this "delusion is so utterly opposed to chemistry, to physiology, to history, and to common observation, that it is very naturally almost universally accepted by the American people. It was started," he adds, "by the late Prof. Agassiz, who impulsively, and without previous consideration, apparently, as was his wont at times, made a statement to that effect before a committee on fisheries of the Massachusetts Legislature. The statement was so novel, so one-sided, and so untrue, that it spread like the blue-glass delusion, and has become the accepted creed of the nation."

On the question whether birds hibernate, we have received from Mr. L. S. Abbott, of Reading, Michigan, a communication in which he states an observation made by himself, which goes to show that at least some birds do hibernate. While living in the backwoods of Ohio, our correspondent often noticed the swallows toward evening circling around the top of a sycamore-tree, in the hollow of which they would soon disappear. To determine whether the birds remained within the tree during the winter, Mr. Abbott had the tree cut down some time after the beginning of the cold season. The swallows were found within, clinging to the shell of the tree, stiff, motionless, and to all appearance in a state of suspended animation. The tree was hollow from the ground up, and the swallows were attached to the shell along its whole length.

A singular instance of heredity is recorded in a note from M. Martinet to the Paris Academy of Sciences. In 1871 several chickens on a farm held by the author were affected with polydactylism, having a supernumerary claw. This had been transmitted to them by a five-clawed cock raised on the same farm a year or two before. The type was propagated rapidly until in 1873 an epidemic ravaged the poultry-yard. At present, without any selection, this variety is very numerous; it has been propagated among neighboring farms through the exchange of eggs by the farmers; if nothing interrupts its progressive increase, it promises ere long to be predominant. The peculiarity was not so perfect at first as it is now; the modification has been going on progressively.

A square metre of the wall of a surgical ward in the Paris Hospital la Pitié was washed—an operation that had not been performed during two years previously—and the liquid wrung out of the sponge was immediately examined. It contained micrococci in abundance, some micro-bacteria, epithelial cells, pus-globules, and ovoid bodies of unknown nature. The sponge used was new, and had been washed in distilled water.

Ernst Haeberlein, to whom the world of science is indebted for the discovery of the first Archæopteryx, has now discovered another and more perfect specimen of the same curious reptile-like bird. As we learn from *Die Natur*, the new Archæopteryx has a head, which was wanting in the first individual discovered. Hence the hitherto undecided point whether the animal had the head of a bird or of a reptile can now be determined.

A Norwegian engineer, Meinerk, has invented an ice-breaker for keeping far northern harbors open through the winter. The machine, as briefly described in the *Moniteur Industriel Belge*, is in form like a ploughshare, and is driven by two engines. Two centrifugal pumps throw a stream of water on the fragments of ice as they retreat behind the vessel, and drive them back into the channel made by the plough. In summer the plough may be converted into a powerful dredge.

In a case of poisoning by colored stockings which is recorded in the *Lancet*, the patient suffered a severe itching of the feet with great pain, "like penknives darting into the feet and legs." The cuticle was raised in several places on the soles and sides of the feet, and there was a discharge of fetid pus. Chemical analysis proved that the stockings worn by the patient had been colored with coralline, which is known to produce poisonous effects on the skin.

The following "death-notice" is translated literally from a Zurich newspaper:

"I communicate to all my friends and acquaintances the sad news that at 3 p. m. to-morrow I shall incinerate, according to all the rules of art, my late mother-in-law, who has fallen asleep with faith in her Lord. The funeral-urn will be placed near the furnace.

"The profoundly afflicted son-in-law,
"Brandolf-Lichtler.

"Zurich, *August 3d.*"

A new malady of the grape-vine has made its appearance in Switzerland, where it has already done considerable damage in the vineyards. It is known as *blanc de la vigne*, or white-sickness of the vine, and is caused by the development of a mycelium which overspreads every part of the diseased vine. Recent researches, says *La Nature*, show that the cause of this infection resides in the props used for supporting the vines; the germs of the parasite find a shelter in the cracks of the wood. They may be destroyed by saturating the props with a solution of copper sulphate.

In presenting to Mr. Walter Weldon the Lavoisier medal of the French Society for encouraging National Industry, Prof. Lamy stated that, at the date of the introduction of Mr. Weldon's invention seven or eight years ago, the total bleaching-powder made in the world was only 55,000 tons per annum, whereas now it is over 150,000 tons; and of this fully 90 per cent. is made by the Weldon process. By this process every sheet of white paper and every yard of calico made in the world have been cheapened.

The city of Dunkirk, New York, possesses a Microscopical Society which, with a small membership and very slender resources, has already earned a name in the world of science. At a meeting of this society held in the early part of summer, Dr. George E. Blackham and Dr. C. P. Alling were reëlected respectively president and secretary of the society.

The gorilla of the Berlin Aquarium is now at the Westminster Aquarium, London, "on a visit." His face is by Mr. Buckland pronounced to be very human, but as black as ebony; the nose is snub, the lips thick and heavy. During sleep, as we are informed by Mr. Buckland, "a pleasant smile every now and then lights up the countenance" of the animal.

Prof. Parlatore, the eminent botanist, and for some time Director of the Museum of Natural History at Florence, died suddenly on Sunday, September 9th.

A new use has been found for dynamite, in the slaughter-house. Experiments made at Dudley, England, show that a small quantity of dynamite—a thimbleful—placed on the forehead of an animal and exploded, instantly causes death. In one experiment, two large horses and a donkey, unfit for work, were placed in a line about half a yard apart, the donkey being in the middle. A small primer of dynamite, with electric fuse attached, was placed on the forehead of each, and fastened by a string under the jaw. The wires were then coupled in circuit and attached to the electric machine. The three charges were exploded simultaneously, the animals falling dead instantly without a struggle.

W. J. MACQUORN RANKINE.

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THE GROWTH OF THE STEAM-ENGINE.[1]

By Professor R. H. THURSTON,
OF THE STEVENS INSTITUTE OF TECHNOLOGY.

II.

THE STEAM-ENGINE AS A TRAIN OF MECHANISM.

SECTION III. *The Period of Development.* NEWCOMEN AND WATT, A. D. 1700 to A. D. 1800.—22. The evident defects of Savery's engine, its extravagant consumption of fuel, the inconvenient necessity of placing it near the bottom of the mine to be drained, and of putting in several for successive lifts where the depth was considerable, and, especially, the risk which its use with high pressures involved even in its best form, considerably retarded its introduction, and it came into use very slowly, notwithstanding its superiority in economic efficiency over horse-power.

23. The first important step taken toward remedying these defects was by Thomas Newcomen and John Cawley, or Calley, two mechanics of the town of Dartmouth, Devonshire, England, who produced what has been known as the Atmospheric or Newcomen Engine.

Newcomen was a blacksmith, and Cawley a glazier and plumber.

It has been stated that a visit to Cornwall, where they witnessed the working of a Savery engine, first turned their attention to the subject; but a friend of Savery has stated that Newcomen was as early with his general plans as Savery.

After some discussion with Cawley, Newcomen entered into correspondence with Dr. Hooke, proposing a steam-engine, to consist of a

[1] An abstract of "A History of the Growth of the Steam-Engine," to be published by D. Appleton & Co.

steam-cylinder containing a piston similar to those of Huyghens's and Papin's engines, and driving a separate pump, similar to those generally in use where water was raised by horse or wind power.

Dr. Hooke advised and argued strongly against their plan; but, fortunately, the obstinate belief of the unlearned mechanics was not

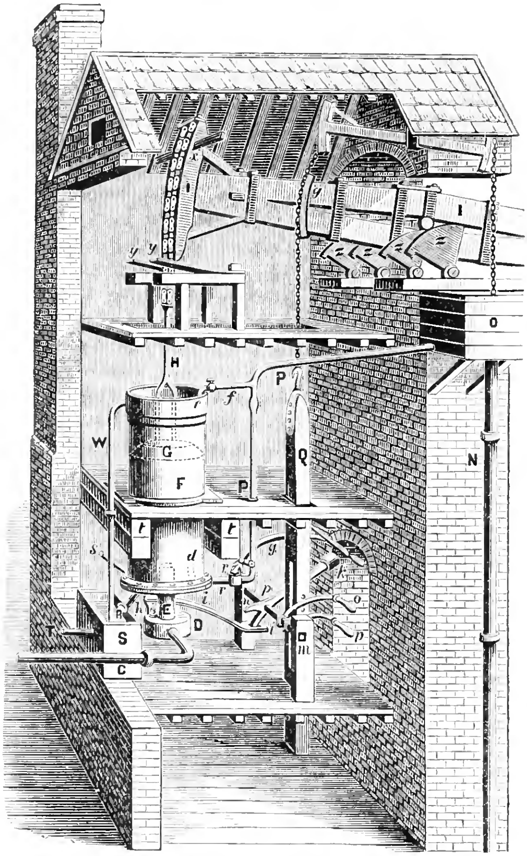


Fig. 10.—The Newcomen Engine, as improved by Smeaton, 1775.

overpowered by the disquisitions of their distinguished correspondent, and Newcomen and Cawley attempted an engine on their peculiar plan.

This succeeded so well as to induce them to continue their labors, and in 1705 to patent[1]—in combination with Savery, who held the right of surface condensation, and who induced them to allow him an interest with them—an engine combining a steam-cylinder and piston, surface condensation, and a separate boiler and separate pumps.

[1] It has been denied that a patent was issued; but there is no doubt that Savery claimed and received an interest in the new engine.

24. In the atmospheric engine as first designed, the slow process of condensation by the application of the condensing water to the exterior of the cylinder to produce the vacuum caused the strokes of the engine to take place at very long intervals. An improvement was, however, soon effected, which immensely increased this rapidity of condensation. A jet of water was thrown directly *into* the cylinder, thus effecting for the Newcomen engine just what Desaguliers had previously done for the Savery engine. As thus improved, the Newcomen engine is shown in Fig. 11.

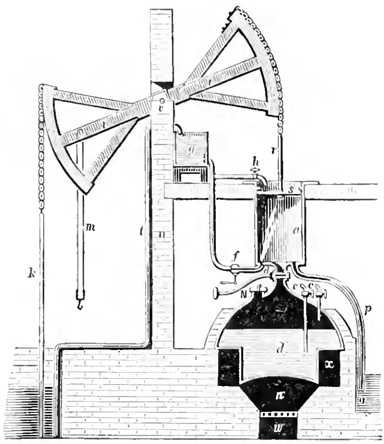


Fig. 11.—Newcomen's Engine, a. d. 1705.

Here *d* is the boiler. Steam passes from it through the cock *d*, and up into the cylinder *a*, equilibrating the pressure of the atmosphere, and allowing the heavy pump-rod *k* to fall, and, by its greater weight, acting through the beam *i i*, to raise the piston *s* to the position shown.

The cock *d* being shut, *f* is then opened, and a jet of water from the reservoir *g* enters the cylinder, producing a vacuum by the condensation of the steam. The pressure of the air above the piston now forces it down, again raising the pump-rods, and thus the engine works on indefinitely.

The pipe *h* is used for the purpose of keeping the upper side of the piston covered with water, to prevent air-leaks—a device of Newcomen.

Two gauge-cocks, *c*, *c*, and a safety-valve, *N*, are represented in the figure, but it will be noticed that the latter is quite different from the now usual form. Here, the pressure used was hardly greater than that of the atmosphere, and the weight of the valve itself was ordinarily sufficient to keep it down. The rod *m* was intended to carry a counter-weight when needed.

The condensing water, together with the water of condensation, flows off through the open pipe *p*. Newcomen's first engine made six or eight strokes a minute; the later and improved engines made ten or twelve.

25. The steam-engine has now assumed a form that somewhat resembles the modern machine.

An important defect still existed in the necessity of keeping an attendant by the engine to open and shut the cocks. A bright boy, however, Humphrey Potter, to whom was assigned this duty on a Newcomen engine in 1713, contrived what he called a *scoggan*—a catch rigged with a cord from the beam overhead—which performed the work for him.

The boy, thus making the operation of the valve-gear automatic, increased the speed of the engine to fifteen or sixteen strokes a minute, and gave it a regularity and certainty of action that could only be obtained by such an adjustment of its valves.

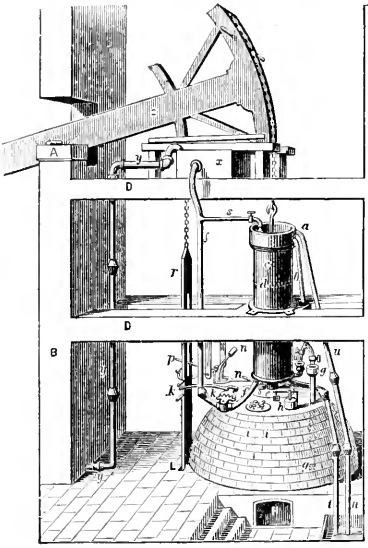


Fig. 12.—Beighton's Valve-Gear, A. D. 1718.

This ingenious young mechanic afterward became a skillful workman, and an excellent engineer, and went abroad on the Continent, where he erected several fine engines.

26. Potter's rude valve-gear was soon improved by Henry Beighton, and the new device was applied to an engine which that talented engineer erected at Newcastle-on-Tyne in 1718, in which engine he substituted substantial materials for Potter's unmechanical arrangement of cords, as seen in Fig. 12.

In this sketch, *r* is a plug-tree, plug-rod, or plug-frame, as it is variously called, suspended from the great beam with which it rises and falls, bringing the pins *p* and *k*, at the proper moment, in contact with the handles *k k* and *n n* of the valves, moving them in the proper direction and to the proper extent. A lever safety-valve is here used, at the suggestion (it is said) of Desaguliers.

The piston was packed with leather or with rope, and lubricated with tallow.

27. Further improvements were effected in the Newcomen engine by several engineers, and particularly by Smeaton, and it soon came into quite extensive use in all of the mining districts of Great Britain, and it also became generally known upon the Continent of Europe.

Its greater economy of fuel as compared with the Savery engine in its best form, its greater safety—a consequence of the low steam-pressure adopted—and its greater working capacity, gave it such manifest superiority that its adoption took place quite rapidly, and it continued in general use in some districts where fuel was cheap up to a very recent date. Some of these engines are even now in existence.

From about 1758 to the time of the introduction of the Watt engine, this was the machine in almost universal use for raising large quantities of water.

28. The success of the Newcomen engine naturally attracted the attention of mechanics, and of scientific men as well, to the possibility of making other applications of steam-power.

The greatest men of the time gave much attention to the subject; but, until JAMES WATT began the work that has made him famous, nothing more was done than to improve the proportions and to slightly alter the details of the Newcomen and Cawley engine, even by such skillful engineers as Brindley and Smeaton.

Of the personal history of the earlier inventors and improvers of the steam-engine very little is known; but that of Watt has been fully traced.

29. This great man was born at Greenock, then a little Scotch fishing-village, but now a considerable and a busy town, which annu-

JAMES WATT.

ally launches upon the waters of the Clyde a fleet of steamships whose engines are probably, in the aggregate, far more powerful than were all the engines in the world at the date of Watt's birth—January 19, 1736.

He was a bright boy, but exceedingly delicate in health, and quite unable to attend school regularly, or to apply himself closely to either study or play.

His early education was given by his parents, who were respectable and intelligent people, and the tools borrowed from his father's carpenter's-bench served at once to amuse him and to give him a dexterity and familiarity with their use that must undoubtedly have been of inestimable value to him in after-life.

M. Arago, the eminent French philosopher, who wrote one of the earliest and most interesting biographies of Watt, relates anecdotes of him which, if correct, illustrate well the thoughtfulness and the intelligence, as well as the mechanical bent, of the boy's mind.

He is said, at the age of six years, to have occupied himself during leisure hours with the solution of geometrical problems, and Arago discovers in a story, in which he is described as experimenting with the tea-kettle, his earliest investigations of the nature and properties of steam.

When finally sent to the village-school, his ill-health prevented his making rapid progress, and it was only when more than fourteen years of age that he began to show that he was capable of taking the lead in his class, and to exhibit his ability in the study particularly of mathematics. His spare time was principally spent in sketching with his pencil, in carving, and in working at the bench, both in wood and metal. His favorite work seemed to be the repairing of nautical instruments.

In boyhood, as in after-life, he was a diligent reader, and he seemed to find something to interest him in every book that came into his hands.

At the age of eighteen Watt was sent to Glasgow, there to reside with his mother's relatives, and to learn the trade of a mathematical-instrument maker. The mechanic with whom he was placed was soon found too indolent, or was otherwise incapable of giving much aid in the project; and Dr. Dick, of the University of Glasgow, with whom Watt became acquainted, advised him to go to London.

Accordingly, he set out in June, 1755, for the metropolis, where, on his arrival, he arranged with Mr. John Morgan, in Cornhill, to work for a year at his chosen business, receiving as compensation twenty guineas. At the end of the year he was compelled by serious ill-health to return home.

30. Having become restored to health, he went again to Glasgow, in 1756, with the intention of pursuing his calling there. But not being the son of a burgess, and not having served his apprenticeship in the town, he was forbidden by the guilds, or trades-unions, to open a shop in Glasgow. Dr. Dick came to his aid, and employed him to repair some apparatus which had been bequeathed to the college; and he was finally allowed the use of three rooms in the university-building, its authorities not being under the municipal rule.

He remained here until 1760, when, the trades no longer objecting, he took a shop in the city, and in 1761 moved again into a shop on the north side of the Trongate, where he earned a scanty living without molestation, still keeping up his connection with the college.

He spent much of his leisure time, of which he had more than was desirable, in making philosophical experiments, and in the manufacture of musical instruments, making himself familiar with the sciences, and devising improvements in the construction of organs.

His reading was still very desultory; but the introduction of the Newcomen engine in the neighborhood of Glasgow, and the presence of a model in the college collections, which model was placed in his hands in 1763 for repairs, led him to study the history of the steam-engine, and to conduct for himself an experimental research into the properties of steam, using a set of improvised apparatus.

31. The Newcomen model, as it happened, had a boiler, which, although made to a scale from engines in actual use, was quite incapable of furnishing steam enough to work the engine.

It was about nine inches in diameter, and the steam-cylinder was two inches in diameter, and of six inches stroke of piston, arranged as in Fig. 13.

This is a picture of the most carefully-preserved treasure in the collections of the University of Glasgow. Watt at once noticed the defect referred to, and immediately sought first the cause and then the remedy.

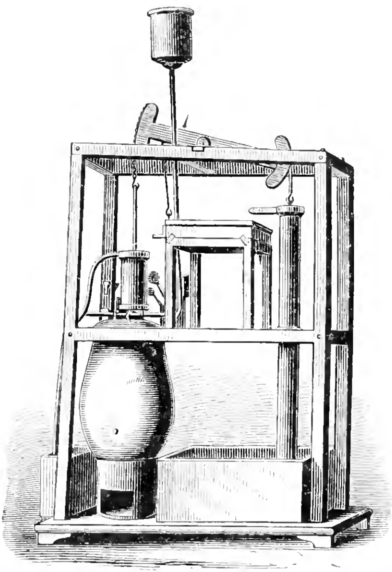


Fig. 13.—The Newcomen Model.

32. He soon concluded that the sources of loss of heat in the Newcomen engine—which loss would be greatly exaggerated in a small model—were: first, the dissipation of heat by the cylinder itself, which was of brass, and was both a good conductor and a good radiator; secondly, the loss of heat consequent upon the necessity of cooling down the cylinder at every stroke in producing the vacuum; and, finally, a loss of power was due to the existence of vapor beneath the piston, the presence of which vapor was a consequence of the imperfect method of condensation which characterizes the Newcomen engine.

He first made a cylinder of non-conducting material—wood soaked in oil and then baked—and found a decided advantage in the economy of steam thus secured.

He then conducted a series of experiments upon the temperature and pressure of steam at such points in the scale as he could readily reach, and, constructing a curve with his results, the abscissas representing temperatures, and the pressures being represented by the ordinates, he ran the curve backward until he had obtained approximate measures of temperatures less than 212°, and of pressures less than atmospheric.

He thus discovered that, with the amount of injection-water used in the Newcomen engine, bringing the temperature of the interior, as he found, down to from 140° to 175° Fahr., a very considerable back-pressure would be met with.

Continuing his research still further, he measured the amount of steam used at each stroke; and, comparing it with the quantity that would just fill the cylinder, he found that *at least three-fourths was wasted.*

The quantity of cold water necessary to produce condensation of a given weight of steam was next determined, and he found that one pound of steam contained enough heat to raise about six pounds of cold water, as used for condensation, from the temperature of 52° Fahr. to the boiling-point; and, going still further, he found that he was compelled *to use, at each stroke of the Newcomen engine, four times as much injection-water as should suffice to condense a cylinder full of steam.* Thus was confirmed his previous conclusion that three-fourths of the heat supplied to the engine was wasted.

His experiments having revealed to him the now well-known fact of the existence of latent heat, he went to his friend Dr. Black, of the university, with this intelligence; and the latter then informed him of the Theory of Latent Heat which had but a short time earlier been discovered by Dr. Black himself.

33. Watt had now, therefore, determined by his own researches, as he himself enumerates them,[1] the following facts:

(1.) The capacities for heat of iron, copper, and of some sorts of wood, as compared with water.

(2.) The bulk of steam compared with that of water.

(3.) The quantity of water evaporated in a certain boiler by a pound of coal.

(4.) The elasticities of steam, at various temperatures greater than that of boiling water, and an approximation to the law which it follows at other temperatures.

(5.) How much water, in the form of steam, was required, at every stroke, by a small Newcomen engine, with a wooden cylinder six inches in diameter and twelve inches stroke.

(6.) The quantity of cold water required, at every stroke, to condense the steam in that cylinder, so as to give it a working power of about seven pounds on the square inch.

34. After these well-devised and truly scientific investigations, Watt was enabled to enter upon his work of improving the steam-engine with an intelligent understanding of its existing defects, and with a knowledge of their cause.

It was on a Sunday afternoon, in the spring of 1765, that he de-

[1] Robinson's "Mechanical Philosophy," edited by Brewster.

vised his first and his greatest invention—the separate condenser. His object in using it was, as he says himself, *to keep the cylinder as hot as the steam that entered it.* He was therefore the first to apprehend and to state a problem which the modern engineer is still vainly endeavoring completely to solve.

Watt was, at this time, twenty-nine years of age. Having taken this first step and made such a radical improvement, the success of the invention was no sooner determined than others followed in rapid succession as consequences of the exigencies arising from the first radical change in the old Newcomen engine.

But in the working out of the forms and proportions of details in the new engine, even Watt's powerful mind, with its stores of happily-combined scientific and practical information, was occupied for years.

35. In attaching the separate condenser, he first tried surface condensation, as in Fig. 14, which is a sketch of his first model; but this not succeeding well, he substituted the jet. Some provision became at once necessary for preventing the filling of the condenser with water.

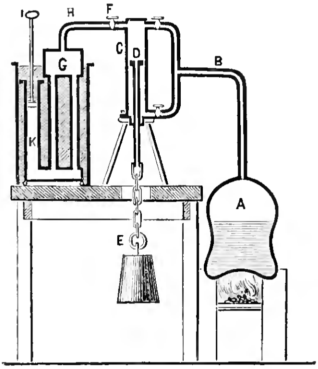


Fig. 14.—Watt's First Model, 1765.

Watt at first intended adopting the same expedient which worked satisfactorily with the less effective condensation of Newcomen's engine, i. e., leading a pipe from the condenser to a depth greater than the height of the column of water which could be counterbalanced by the pressure of the atmosphere; but he subsequently employed the air-pump, which relieves the condenser, not only of the water, but of the air which also usually collects in considerable volume, and vitiates the vacuum.

He next substituted oil and tallow for the water previously used in lubrication of the piston and keeping it steam-tight, in order to avoid the cooling of the cylinder incident to the use of water.

Still another cause of refrigeration of the cylinder, and consequent waste of power in its operation, was seen to be the entrance of the atmosphere, which came in at the top and followed the piston down the cylinder at each stroke.

This the inventor concluded to prevent by covering the top of the cylinder, and allowing the piston-rod to play through a "stuffing-box," which device had long been known to mechanics. He accordingly not only covered the top, but surrounded the whole cylinder with an external casing or "steam-jacket," and allowed the steam from the boiler to pass around the steam-cylinder and to press upon the upper surface of the piston where its pressure was readily variable, and therefore more manageable than that of the atmosphere. It also, besides keeping the cylinder hot, could do comparatively little harm should it leak by the piston, as it might be condensed and readily disposed of.

36. This completed the change of the "atmospheric engine" of Newcomen into the steam-engine of James Watt. The engine as improved is shown in Fig. 15, which represents the engine as patented in April, 1769. Watt's first engine was erected with the pecuniary aid of Dr. Roebuck, the lessor of a coal-mine on the estate of the Duke of Hamilton, at Kinneil, near Borrowstounness. This engine, which was put up at the mine, had a steam-cylinder eighteen inches in diameter.

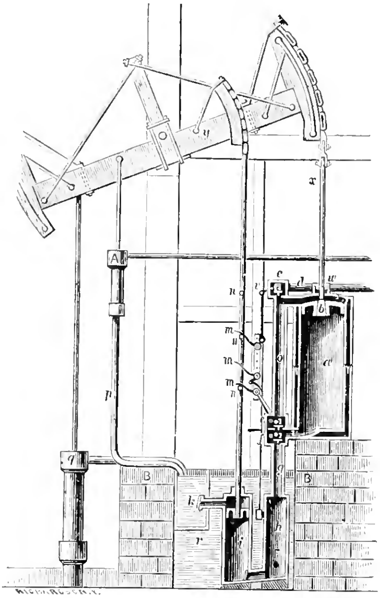


FIG. 15.—WATT'S PUMPING-ENGINE, A. D. 1769.

In the figure, the steam passes from the boiler through the pipe *d* and the valve *c* to the cylinder casing, or steam-jacket, *Y Y*, and above the piston *b*, which it follows in its descent in the cylinder *a*, the valve *f* being at this time open to allow the exhaust to pass into the condenser *h*.

The piston now being at the lower end of the cylinder, and the pump-rods at the opposite end of the beam *y* thus raised, and the pumps filled with water, the valves *c* and *f* close, while *e* opens, allowing the steam which remains above the piston to flow beneath it, until, the pressure becoming equal above and below by the weight of the pump, it is rapidly drawn to the top of the cylinder, while the steam is displaced above, passing to the underside of the piston.

Now the valve *e* is closed, and *c* and *f* are again opened, and the down-stroke is repeated as before. The water and air entering the condenser are removed, at each stroke, by the air-pump *i*, which communicates with the condenser by the passage *s*. The pump *q* supplies condensing-water, and the pump *A* takes away a part of the water of condensation, which is thrown by the air-pump into the "hot well" *k*, and with it supplies the boiler. The valves are moved by valve-gear very similar to Beighton's, by the pins *m m* in the "plug-frame" or "tappet-rod" *n n*.

The engine is mounted upon a substantial foundation, *B B*. *F* is an opening, out of which, before starting the engine, the air is driven from the cylinder and condenser.

37. In the building and erection of his engines, Watt had the greatest difficulty in finding skillful workmen to make the parts with accuracy, to fit them with skill, and to erect them properly when once finished.

The fact that both Newcomen and Watt found such serious trouble indicates that, even had the engine been designed earlier, it is quite unlikely that the world would have seen the steam-engine a success until this period, when mechanics were just acquiring the skill requisite for its construction. But, on the other hand, it is not at all certain that, had the mechanics of an earlier period been as skillful and as well educated in the manual niceties of their business, the steam-engine might not have been much earlier brought into use.

In the time of the Marquis of Worcester, it would have probably been found impossible to obtain workmen to construct the steam-engine of Watt, had it been then invented. Indeed, Watt, upon one occasion, congratulated himself that one of his steam-cylinders *only lacked three-eighths of an inch* of being truly cylindrical.

38. Pecuniary misfortunes soon deprived Watt of the assistance

MATTHEW BOULTON.

of his friend and partner Dr. Roebuck, but in 1773 he became connected with an intelligent, energetic, and wealthy manufacturer of Birmingham, Matthew Boulton. Thenceforward, the establishment of Boulton & Watt, at Soho, near Birmingham, for a long time furnished the greater proportion of all the steam-engines made in the world.

In the new firm, Boulton took charge of the general business, and Watt superintended the design, construction, and erection, of their engines. Boulton's business capacity, with Watt's wonderful mechanical ability; Boulton's physical health, and his vigor and courage, offsetting Watt's feeble health and depression of spirits; and, more than all, Boulton's pecuniary resources, both in his own purse and in the wealth of his friends, enabled the firm to conquer all difficulties, whether in finance, in litigation, or in engineering.

39. Watt had, before meeting Boulton, conceived the idea of economizing some of that power the loss of which was so plainly indicated by the violent rush of the exhaust steam into the condenser, and had described the advantages that would follow the use of steam expansively, by means of a "cut-off," in a letter to Dr. Small, of Birmingham, dated Glasgow, May, 1769. He had also planned a "compound engine."

This invention of the expansion of steam, which, in importance, was hardly exceeded by any other improvement of the steam-engine, was adopted at Soho in 1776, but the patent was not obtained until 1782.

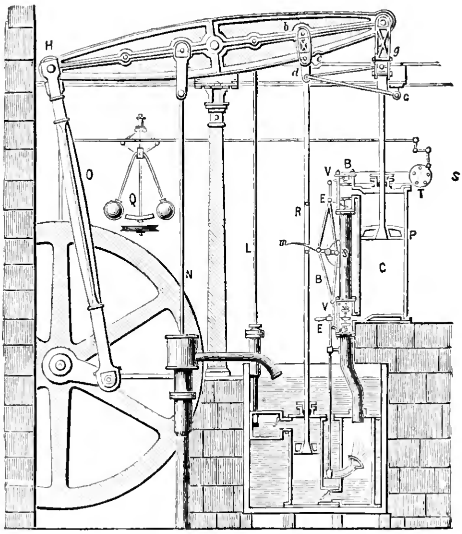


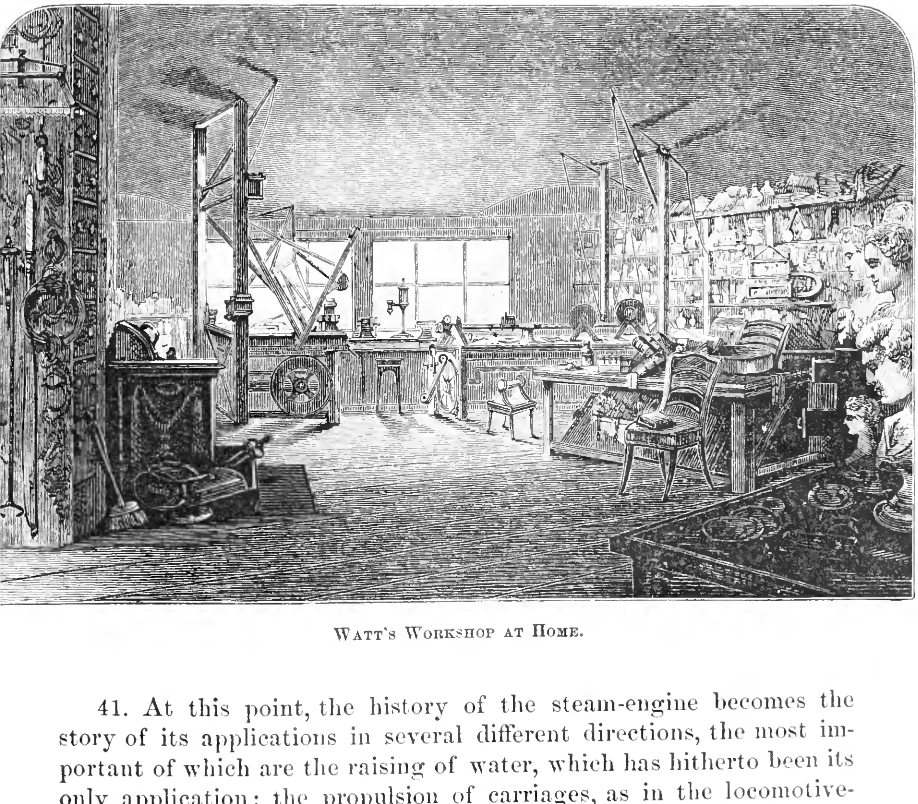
FIG. 16.—WATT'S STEAM-ENGINE, A. D. 1780.

During this interval, Watt invented the crank and fly-wheel, but, as the former had been first patented by Wasborough, who is supposed to have obtained a knowledge of it from workmen employed by Watt, the latter patented several other methods of producing rotary motions, and temporarily adopted that known as the "sun-and-planet wheels," subsequently using the crank.

The adaptation of the steam-engine to the production of rotary motion was soon succeeded by the introduction of the Double-Acting Engine, the Fly-ball Governor, the Counter, the Steam-Engine Indicator, and other minor but valuable improvements, which were the final steps by which the Watt steam-engine became applicable to driving mills, to use on railroads, to steam-navigation, and to the countless purposes by which it has become, as it has already been denominated, the great material agent of civilization.

40. Fig. 16 represents the Watt Double-Acting engine. It will be noticed that it differs from the Single-Acting engine in having steam-valves, *B B*, and exhaust-valves, *E E*, at each end of the cylinder, thus enabling the steam to act on each side of the piston alternately, and practically doubling the power of the engine.

The end of the beam opposite to the cylinder is usually connected with a crank-shaft.



WATT'S WORKSHOP AT HOME.

41. At this point, the history of the steam-engine becomes the story of its applications in several different directions, the most important of which are the raising of water, which has hitherto been its only application; the propulsion of carriages, as in the locomotive-engine; the driving of mills and machinery; and steam-navigation.

Here we take leave of James Watt, of whom a French author[1] says, "The part which he played, in the mechanical application of the power of steam, can only be compared to that of Newton in astronomy, and of Shakespeare in poetry."

Retiring from the firm in the first year of the present century, Watt remained quietly on his estate at Heathfield. He fitted up a little workshop in his house, and there spent nearly all his time, inventing, designing, and constructing ingenious machines for special purposes. He died peacefully, full of years and great in fame, August 25, 1819.

Since the time of Watt, improvements have been principally in matters of mere detail, and in the extension of the range of application of the steam-engine.

42. To complete the history of its application to raising water, the succeeding figures are given as exhibiting the principal forms of pumping-engine as now constructed.

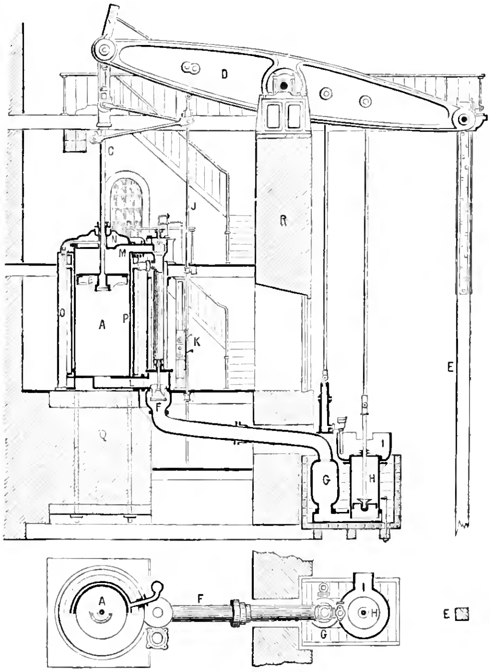


Fig. 17.—The Cornish Pumping-Engine, 1877.

Fig. 17 represents the Cornish pumping-engine, which, in spite of its great weight and high cost, is still much used.

It will be seen that it is the engine of James Watt in all its general features.

[1] "Traité des Machines à Vapeur," E. M. Bataille, Paris, 1847.

It is single-acting, and has a steam-jacket and a plug-rod valve-gear, *J K*. The improvements are principally in the form and proportions of its parts, and in its adaptation to high steam and "short 'cut-off.'"

A is the steam-cylinder, *B C* the piston and rod, *D* the beam, and *E* the pump-rod. The condenser is seen at *G*, and the air-pump at *H*. The steam-cylinder is "steam-jacketed," and is surrounded by a casing, *O*, composed of brickwork or other non-conducting material. Steam is first admitted above the piston, driving it rapidly downward and raising the pump-rod. At an early point in the stroke the admission of steam is checked by the sudden closing of the induction-valve, and the stroke is completed under the action of expanding steam assisted by the inertia of the heavy parts already in motion. The necessary weight and inertia are afforded in many cases, where the engine is applied to the pumping of deep mines, by the immensely long and heavy pump-rods. Where this weight is too great, it is counterbalanced; and where, as when used for the water-supply of cities, too small, weights are added. When the stroke is completed, the "equilibrium-valve" is opened, and the steam passes from above to the space below the piston, and, an equilibrium of pressure being thus produced, the pump-rods descend, forcing the water from the pumps and raising the steam-piston. The absence of the crank or other device which might determine absolutely the length of stroke compels a very careful adjustment of steam admission to the amount of load. Should the stroke be allowed to exceed the proper length, and should danger thus arise of the piston striking the cylinder-heads, the movement is checked by buffer-beams. The regulation is effected by a "cataract," a kind of hydraulic governor, consisting of a plunger-pump with a reservoir attached. The plunger is raised by the engine, and then automatically detached. It falls with greater or less rapidity, its velocity being determined by the size of the eduction orifice, which is adjustable by hand. When the plunger reaches the bottom of the pump-barrel, it disengages a catch, a weight is allowed to act upon the steam-valve, opening it, and the engine is caused to make a stroke. When the outlet of the cataract is nearly closed, the engine stands still a considerable time while the plunger is descending, and the strokes succeed each other at long intervals. When the opening is greater, the cataract acts more rapidly, and the engine works faster. This has been regarded until recently as the most economical of pumping-engines, and it is still generally used in Europe in freeing mines of water.

43. Fig. 18 represents a lighter, cheaper, and almost equally effective machine, known as the Bull Cornish or Direct-Acting Cornish engine. It was first designed by the competitor of Watt, by whose name it is known. As is seen by reference to the engraving, its cylinder *a* is directly above the pump-rods *c*, *d*, *g*, and is carried on

cross-beams, *b b*. The air-pump *m l o p*, the tank *n*, and valve-gear *q r s*, are quite similar to those of the beam Cornish engine. The balance-beam is seen at *h i*.

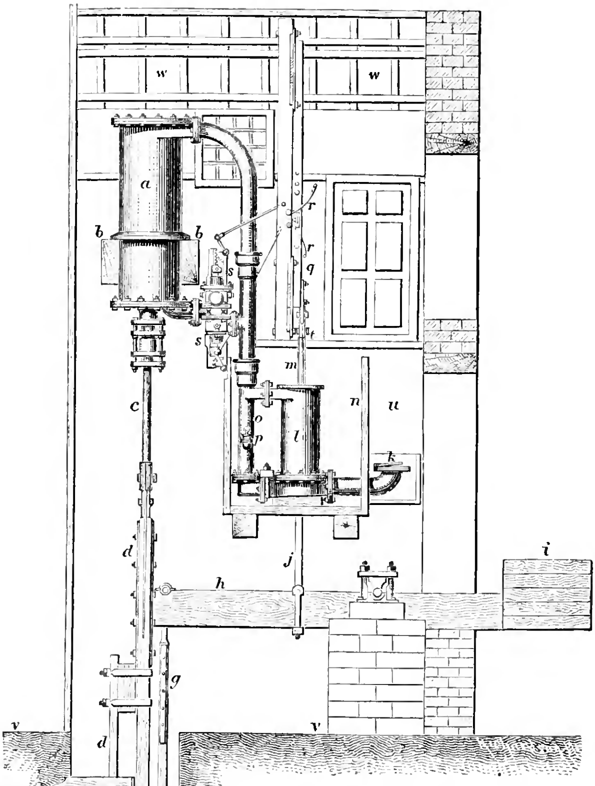
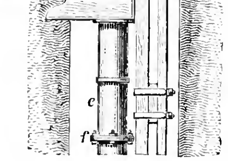



FIG. 18.—BULL'S CORNISH ENGINE, 1798.

Fig. 19 represents another form of pumping-engine which belongs to the class known as the "compound" or "two-cylinder" engine.

This class of engines, in which the steam exhausted from one cylinder is further expanded in the second, was first introduced by Hornblower, in 1781, and was patented, in combination with the Watt condenser, by Woolf, at a later date (1804), with a view to adopting high steam and considerable expansion.

The Woolf engine was to some extent adopted, but was not successful in competing with Watt engines where the latter were well built, and, like Hornblower's engine, was soon given up.

The compound engine has come up again within a few years, and, with what is *now* considered high steam and considerable expansion, and designed with more intelligent reference to the requirements of economy in working steam in this manner, it seems gradually displacing all other forms of engine.

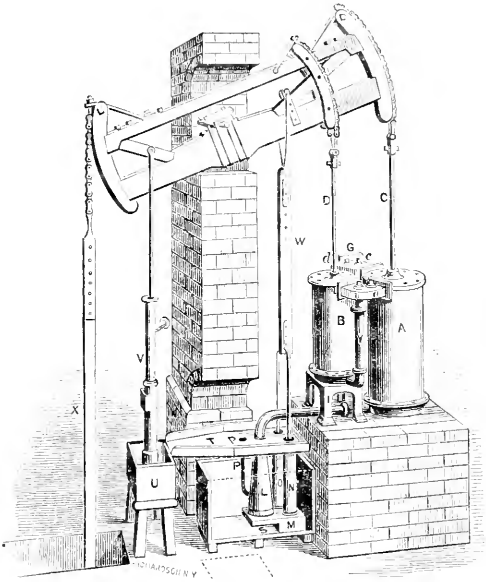


FIG. 19.—HORNBLOWER'S COMPOUND ENGINE, 1781.

44. An example of this form of pumping-engine, and one which is a favorite with many engineers, is the beam and crank engine (Fig.

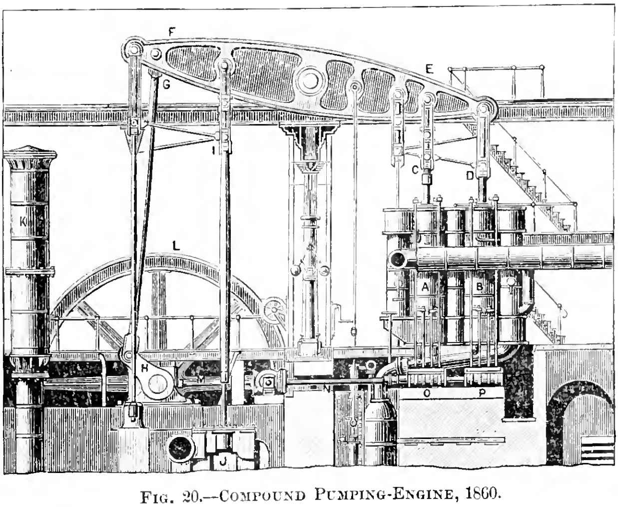


FIG. 20.—COMPOUND PUMPING-ENGINE, 1860.

20), *C D*, *E F*, with double cylinder, *A*, *B*, working the "combined bucket and plunger," or double-acting pump, *J*. In its cylinders steam is usually expanded from four to eight times. The Leavitt compound engine is shown in Fig. 21.

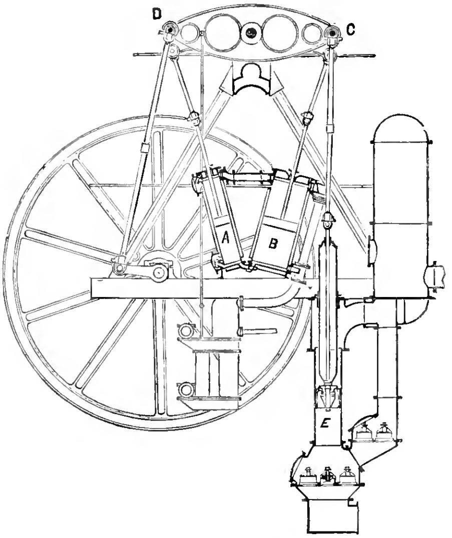


Fig. 21.—Leavitt's Pumping-Engine, 1875.

In this engine the lower ends, *A*, *B*, of the two cylinders are brought close together under the centre of the beam, thus shortening

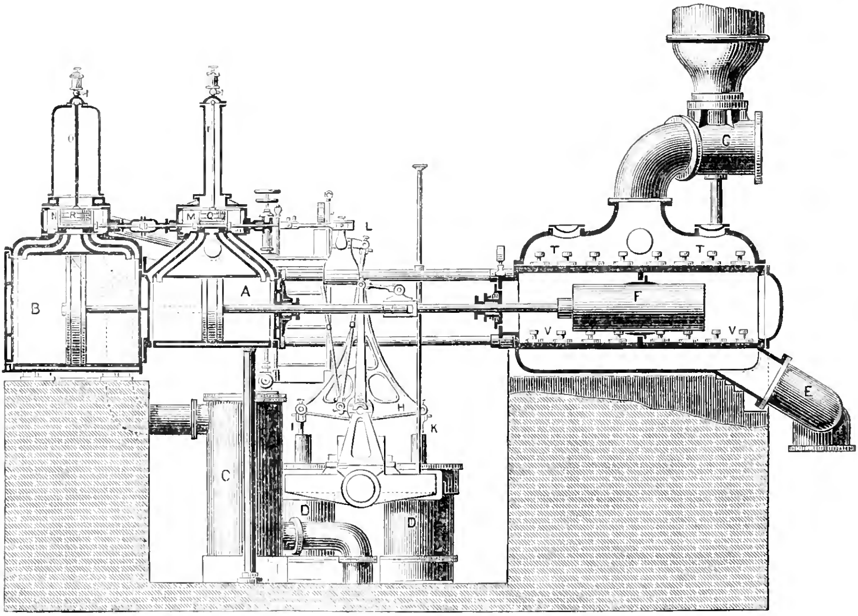
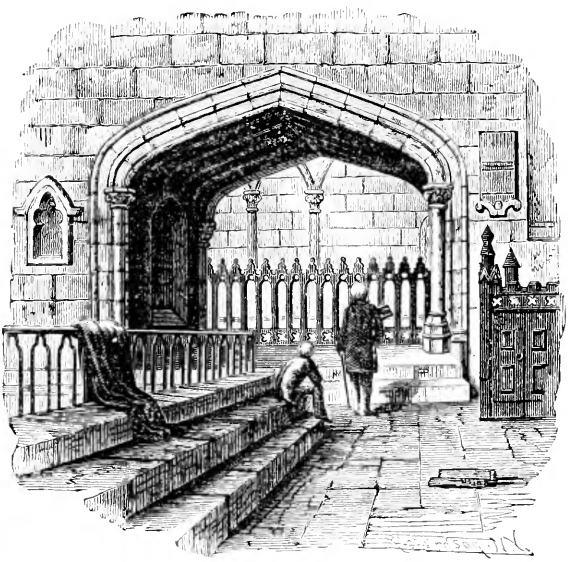


Fig. 22.—The Worthington Compound Pumping-Engine, 1870.

the steam-passages between them, permitting a symmetrical distribution of strain, and the use of the usual general type of beam-engine. A readily-adjustable valve-gear is attached, and its cut-off gives an expansion of about ten times, the boiler steam-pressure being about eighty pounds per square inch. The cylinders are steam-jacketed, and very thoroughly clothed with a non-conducting felting and lagging. This engine has given the best economical results yet reported in this country, attaining a "duty" on a test-trial of more than 100,000,000 pounds of water raised one foot high by each 100 pounds of fuel burned.

Still another recent form of steam pumping-engine, noted for its cheapness combined with efficiency, is that of Worthington (Fig. 22), in which two pairs of steam cylinders, *A*, *B*, are placed side by side, each pair driving a pump-plunger, *F*, attached to its piston-rod, and each having its valve-gear, *H L*, *M N*, actuated by the movement of the piston of the other. The cylinders together form a compound engine; the steam exhausted from the smaller, *A*, passing into the



Tomb of James Watt, Handsworth Church, 1819.

larger, *B*, where it is further expanded. The valve-gear of this engine is peculiarly well adapted to this type of engine. There is no fly-wheel, and the motion of each of the two independent engines, which together form the pair, is controlled by its neighbor, the valve-gear of the one being moved by the piston of the other. This ingenious combination permits each piston to move from end to end of its cylinder, holds it stationary an instant while the pump-cylinders become completely filled and their valves closed, and then sets it in motion on the return-stroke. Thus the pistons move alternately. These engines have given a very high duty. The condenser is seen at *C*, and the air-pump is at *D*, the latter being worked from the bell-crank lever *H* by means of links, *I*, *K*. The steam-valves, *Q*, *R*, are balanced. *V V* are the water-induction valves, and *T T* those on the eduction-side.

Here we leave the steam-engine as applied to raising water. We have invariably noticed, in the forms of engines so used, that a condenser forms a part of the apparatus.

We will next briefly trace the history of that now familiar form of engine in which the steam, having done its work, is discharged directly into the atmosphere.

STAR OR STAR-MIST.

By RICHARD A. PROCTOR.

A REMARKABLE discovery has been made by the astronomers of Lord Lindsay's observatory at Dunecht—a discovery the true meaning of which is not as yet fully perceived. It may be remembered that some nine months ago a new star, as it was called, made its appearance in the constellation Cygnus.[1] This object shone out where before no star had been known to astronomers—not merely, be it noticed, where there was no visible star, but where none was recorded even in lists like Argelander's "Durchmusterung," containing hundreds of thousands of telescopic stars. It was not, however, altogether impossible that some small star within moderate telescopic range had existed in the spot where the new star shone out, and that in some way this small star had escaped observation. This seemed the more likely because the new star had appeared in a part of the heavens very rich indeed in telescopic stars; at any rate, astronomers had reason to believe that they would be readily able to determine the question with a high degree of probability by watching the star as it gradually faded out of view. For a "new star" which had shone out in the constellation of the Northern Crown in May, 1866, and had been identified with a tenth-magnitude star in Argelander's list, had gradually faded out of view, and, growing yet fainter, had sunk through one telescopic magnitude after another until it shone again as a tenth-magnitude star only. Since that star had resumed its former lustre, or rather its former faintness, it seemed not unreasonable to conclude that so also would the star in Cygnus. We shall presently see how far this expectation was from being fulfilled.

[1] See Popular Science Monthly, vol. xi., p. 59.

During its time of greatest observed brilliancy the new star in the Swan was very carefully watched by spectroscopists. The results were in many respects interesting. The star in the Crown had shown the bright lines of hydrogen, superposed upon a faint rainbow-tinted spectrum, which was understood to signify that around a real, though probably a small, sun, some outburst of glowing hydrogen had taken place, the chief part of the star's new light being due to this outburst. The same bright hydrogen lines were seen also in the case of the star in Cygnus. But in addition to them other bright lines were seen, which seemed to be identical with those belonging to the solar sierra (or, as many astronomers unclassically call it, the chromosphere) and corona. This, at least, was the opinion of M. Cornu, of the Paris Observatory. Herr Vogel, who began his observations on December 5th, when the star was between the fourth and fifth magnitude, and continued them to March 10th, when the star had sunk below the eighth magnitude, does not agree on this point with M. Cornu, since a line not agreeing with any known line in the spectrum of the sun's sierra was clearly visible from the beginning in the spectrum of the new star. But the most interesting point in connection with Vogel's observations, confirmed also by Mr. Copeland, at the Dunecht Observatory, and by Mr. Backhouse, of Sunderland, was this: that, as the new star died out, not only did the rainbow-tinted background of the spectrum fade gradually out of view, but the relative lightness of the bright lines steadily changed. At last, on March 10th, very little was left of the spectrum which Cornu and Vogel had seen in December. The blue and violet portion of the spectrum had faded entirely from view, a dark gap had appeared in the green, and a very broad, dark band in the blue. Of the bright lines two only remained. One, the F line of hydrogen, in the green-blue, which had been singularly conspicuous last December, was now faint. The other, in the green, which had been faint in December, was now very bright—in fact, nearly the whole light of the star seemed at this time to come from this bright line.

Now, the changes which had thus far taken place were altogether unlike those which had been noticed in the case of the new star in the Northern Crown. As that star faded from view the bright lines indicative of glowing hydrogen died out, and only the ordinary stellar spectrum remained. In the case of the star in Cygnus the part of the spectrum corresponding to stellar light—that is to say, the rainbow-tinted streak crossed by dark lines—faded gradually from view, and bright lines only were left, at least as conspicuous parts of the star's spectrum. This body, then, did not seem to be returning to the stellar condition at all, but actually fading out into a nebula. Not only so, but the lines which still remained conspicuous last March were lines known to belong to the so-called gaseous nebulæ. One of them, that which had been the faintest, but was now the brightest, corresponded to the nitrogen line of the nebular spectrum; the other, which was still conspicuous, though faint, corresponded to the hydrogen line of nebulæ.

That, however, was by no means the closing chapter of this singular history. Vogel seems to have ceased from observing the star's spectrum, strangely enough, at the very time when the most remarkable part of the process of change seemed to be approaching. At the Dunecht Observatory also, through pressure of work relating to Mars, no observations were made for nearly half a year. But, on September 3d, Lord Lindsay's 15-inch refractor was turned on the star. In the telescope a star was still shining, but with a faint blue color, utterly unlike that of the orb which had shone out so conspicuously last November. Under spectroscopic examination, however, the blue star was found to be no star at all, if we are to regard those orbs only as stars which present a spectrum in some degree analogous to that of our own sun. We regard Sirius as a sun, though in his spectrum the lines of hydrogen are abnormally strong; and, passing over the class of stars more closely resembling our sun, we regard as a true star the orange orb, Betelgeux, though the lines of hydrogen are wanting in its spectrum; nor do we reject from among the suns those stars which, like Gamma of Cassiopeia, show the lines of hydrogen bright upon a fainter rainbow-tinted spectrum. There is yet another order of stars —those whose spectrum presents bright bands with faintly lustrous intervals, which, again, we regard as true suns, though they differ doubtless notably from our own. But we have been in the habit of regarding all the star cloudlets, whether consisting of multitudinous stars, like the clusters, or of luminous star-mist, as differing *toto cœlo* from the sun and from all his fellow-stars. The clusters, indeed, give a spectrum resembling the sun's, and we regard them as different only because of their clustering condition. But the nebulæ which Sir W. Herschel regarded as consisting entirely of luminous vapor, and which spectroscopic analysis has proved to be so constituted, we have regarded not merely as different because of the structure and arrangement of their component parts, but as differing altogether in constitution. Now, the object seen as a faint blue star showed the same spectrum as these gaseous nebulæ, or rather as the very faintest of these nebulæ. For most of them show three bright lines, and one or two even show four bright lines; only the faintest shine with absolutely monochromatic or one-tint light. The star in Cygnus now shines like these faintest of the gaseous nebulæ—that is, with a light which, under spectroscopic analysis, presents only one bright line.

The words in which Lord Lindsay announced this remarkable discovery are these: "*There is little doubt but that this star has changed into a planetary nebula of small angular diameter*," though, he goes on to say, "such a result is in direct opposition to the nebular hypothesis." On this last point I venture to express dissent from Lord

Lindsay's opinion, which is in any case a somewhat bold inference from a single observation. Assuredly the discovery just made is in direct opposition to a certain argument, derived from the gaseity of nebulæ, in favor of the gaseous hypothesis of Laplace—an argument which had always appeared to the present writer insufficiently established. But the nebular hypothesis, regarded not merely in the form suggested by Laplace (in which form it was utterly inconsistent with physical facts now known), but in the wider sense which would simply present our solar system in the remote past as in a nebular state, without defining its nebulosity as due either to gaseity on the one hand, or to a mixed meteoric and cometic constitution on the other, has most certainly not received a shock, but rather receives strong support, from Mr. Copeland's observation. A theory of the evolution of the solar system, advocated by me during the last seven years, according to which the solar system had its origin in meteoric and cometic aggregation, requires that during the long ages through which the process of development continued there should be occasional outbursts of light and heat in moderate degree from the rest of the system, even to its outskirts. That intense heat imagined by Laplace as pervading the entire gaseous mass, extending originally far beyond the path of the remotest planet of our system, would require, indeed (if it were a physical possibility in other ways), that the spectrum of a developing solar system should be uniformly that of gaseity for millions on millions of years. If it had been found or could be proved that the gaseous nebulæ are in a state of intense heat, Laplace's gaseous hypothesis would have had one powerful argument in its favor. This argument has been strongly urged by those who have taken that special view of the gaseous nebulæ which the recent discovery shows to be erroneous. But those who have maintained, as I have, that in the gaseous nebulæ we probably "see vast systems of comets traveling in extensive orbits around nuclear stars," will find confirmation, not disproof, in the discovery lately made, especially when considered in combination with the circumstance that Prof. Wright, of Yale, has found the cometic spectrum to be emitted by meteoric masses exposed to moderate heat; while, under slight changes of condition, the cometic spectrum of bright carbon bands appears to give place to the nebular bright-line spectrum.

However, speculation apart, we have in the discovery just made a most important fact for our guidance—the fact, namely, that a body which to ordinary observation has been in all respects like the star in the Crown, and even under spectroscopic observation shone for a while with true stellar light, has dwindled into a nebula giving the spectrum which has heretofore been regarded as indicative of ordinary gaseity.—*English Mechanic.*

LANGUAGE AND THE ENGLISH CIVIL SERVICE.[1]

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THE system of competitive examinations for the public service, of which I have laid before the section a brief history compiled from the reports, is one of those radical innovations that may ultimately lead to great consequences. For the present, however, it leads to many debates. Not merely does the working out of the scheme involve conflicting views, but there is still great hesitation in many quarters as to whether the innovation is to be productive of good or of evil. The report of the Playfair Commission, and the more recent report relative to the changes in the India Civil Service regulations, indicate pretty broadly the doubts that still cleave to many minds on the whole question. It is enough to refer to the views of Sir Arthur Helps, Mr. W. R. Greg, and Dr. Farr, expressed to the Playfair Commission, as decidedly adverse to the competitive system. The authorities cited in the report on the India examinations scarcely go the length of total condemnation; but many acquiesce only because there is no hope of a reversal.

The question of the expediency of the system as a whole is not well suited to a sectional discussion. We shall be much better employed in adverting to some of those details in the conduct of the examinations that have a bearing on the whole education of the country, as well as on the Civil Service itself. It was very well, at first starting, for the commissioners to be guided, in their choice of subjects and in assigning values to those subjects, by the received branches of education in the schools and colleges. But, sooner or later, these subjects must be discussed on their intrinsic merits for the ends in view.

I shall occupy the present paper with the consideration of two departments in the examination programme—the one relating to the physical or natural sciences,[2] the other relating to languages.

This second topic is one of very serious import. It concerns the Civil Service competitions only as a part of our whole scheme of education. I mean the position of languages in our examinations. While the vast field of natural science is rolled up in one heading, with a total of 1,000 marks, our Civil Service scheme presents a row of five languages besides our own—two ancient and three modern—with an aggregate value of 2,625 marks. The India scheme has, in addition,

[1] From advance-sheets of a paper entitled "The Civil Service Examination Scheme considered with Reference—1. To Sciences; and, 2. To Languages," read at the recent meeting of the Social Science Congress in Aberdeen, Scotland.

[2] This part of the address is omitted for want of space.

Sanskrit and Arabic, at 500 marks each; the reasons of this prescription being, however, not the same as for the foregoing.

The place of language in education is not confined to the question as between the ancient and the modern languages. There is a wider inquiry as to the place of languages as a whole. In pursuing this inquiry, we may begin with certain things that are obvious and incontestable.

In the first place, it is apparent that if a man is sent to hold intercourse with the people of a foreign nation, he must be able to understand and to speak the language of that nation. Our India civil servants are, on that ground, required to master the Hindoo spoken dialects.

In the next place, if a certain range of information that you find indispensable is locked up in a foreign language, you are obliged to learn the language. If, in course of time, all this information is transferred to our native tongue, the necessity apparently ceases. These two extreme suppositions will be allowed at once. There may, however, be an indefinite number of intermediate stages: the information may be partially translated; and it will then be a question whether the trouble of learning the language should be incurred for the sake of the untranslated part. Or, it may be wholly translated; but viewing the necessary defects, even of good translations, if the subject-matter be supremely important, some people will think it worth while to learn the language in order to obtain the knowledge in its greatest purity and precisions. This is a situation that admits of no certain rule. Our clergy are expected to know the original languages of the Bible, notwithstanding the abundance of translations, many of which must be far superior in worth and authority to the judgment of a merely ordinary proficient in Hebrew and Greek.

It is now generally conceded that the classical languages are no longer the exclusive depository of any kind of valuable information, as they were two or three centuries ago; yet they are still continued in the schools as if they possessed their original function unabated. We do not speak in them, nor listen to them spoken, nor write in them, nor read in them, for obtaining information. Why, then, are they kept up? Many reasons are given, as you know. There is an endeavor to show that, even in their original function, they are not quite effete. Certain professions are said to rely upon them for some points of information not fully communicated by the medium of English. Such is the rather indirect example of the clergy with Greek. So it is said that law is not thoroughly understood without Latin, because the great source of law, the Roman code, is written in Latin, and is in many points untranslatable. Further, it is contended that Greek philosophy cannot be fully mastered without a knowledge of the language of Plato and Aristotle. But an argument that is reduced to these examples must be near its vanishing-point. Not one of the cases stands a rigorous scrutiny, and they are not relied upon as the main justification of the continuance of classics. A new line of defense is opened up that was not at all present to the minds of sixteenth-century scholars. We are told of numerous indirect and secondary advantages of cultivating language in general and the classic languages in particular, which make the acquisition a rewarding labor, even without one particle of the primary use. But for these secondary advantages, languages could have no claim to appear, with such enormous values, in the Civil Service scheme.

My purpose requires me to advert to these alleged secondary uses of language—not, however, for the purpose of counter-arguing them, but rather to indicate what seems to me the true mode of bringing them to the proof.

The most usual phraseology for describing the indirect benefit of languages is that they supply a *training* to the powers of the mind; that, if not information, they are *culture;* that they react upon our mastery of our own language, and so on. It is quite necessary, however, to find terms more definite and tangible than the slippery words "culture" and "training;" we must know in precise language what particular powers or aptitudes are increased by the study of a foreign language. Nevertheless, the conclusions set forth in this paper do not require me to work out an exhaustive review of these advantages. It is enough to give as many as will serve for examples.

Now, it must be freely admitted, as a possible case, that a practice introduced, in the first instance, for a particular purpose, may be found applicable to many other purposes; so much so that, ceasing to be employed for the original use, this practice may be kept up for the sake of the after-uses. For example, clothing was no doubt primarily contrived for warmth; but it is not now confined to that—decoration or ornament, distinction of sexes, ranks, and offices, modesty—are also attained by means of clothes. This example is a suggestive one. We have only to suppose ourselves migrating to some African climate, where clothing for warmth is absolutely dispensed with. We should not on that account adopt literal nudity—we should still desire to maintain those other advantages. The artistic decoration of the person would continue to be thought of; and, as no amount of painting and tattooing, with strings of beads superadded, would answer to our ideal of personal elegance, we should have recourse to some light, filmy textures, that would allow the displays of drapery, colors, and design, and show off the poetry of motion; we should also indicate the personal differences that we were accustomed to show by vesture. But now comes the point of the moral: we should not maintain our close, heavy fabrics, our great-coats, shawls, and cloaks. These would cease with the need for them. Perhaps the first emigrants could keep up the prejudice for their warm things, but not so their successors.

Well, then, suppose the extreme case of a foreign language that is entirely and avowedly superseded as regards communication and interpretation of thoughts, but still furnishing so many valuable aids to mental improvement that we keep it up for the sake of these. As we are not to see, speak, or read the language, we do not need absolutely to know the meaning of every word; we may, perhaps, dispense with much of the technicality of its grammar. The vocables and the grammar would be kept up exactly so far as to serve the other purposes, and no further. The teacher would have in view the secondary uses alone. Supposing the language related to our own by derivation of words, and that this was what we put stress upon, then the derivation would always be uppermost in the teacher's thoughts. If it were to illustrate universal grammar and philology, this would be brought out to the neglect of translation.

I have made an imaginary supposition to prepare the way for the real case. The classical, or language, teacher is assumed to be fully conscious of the fact that the primary use of the languages is as good as defunct; and that he is continued in office because of certain clearly-assigned secondary uses, but for which he would be suspended entirely. Some of the secondary uses present to his mind, at all events one of those that are put forward in argument, is that a foreign language, and especially Latin, conduces to good composition in our own language. And as we do compose in our own language, and never compose in Latin, the teacher is bound to think mainly of the English part of the task: to see that the pupils succeed in the English translation, whether they succeed in the other or not. They may be left in a state of considerable ignorance of good Latin forms—ignorance will never expose them—but any defects in their English expression will be sure to be disclosed. Again, it is said that universal grammar or philology is taught upon the basis of a foreign language. Is this object, in point of fact, present to the mind of every teacher, and brought forward, even to the sacrifice of the power of reading and writing, which, by the supposition, is never to be wanted? Further, the Latin grammar is said to be a logical discipline. Is this, too, kept in view as a predominating end? Once more, it is declared that through the classics we attain the highest cultivation of taste, by seeing models of unparalleled literary form. Be it so; is this habitually attended to in the teaching of these languages?

I believe I am safe in saying that, while these various secondary advantages are put forward in the polemic as to the value of languages, the teaching practice is not in full consistency therewith. Even when in word the supporters of classics put forward the secondary uses, in deed they belie themselves. Excellence in teaching is held by them to consist, in the first instance, in the power of accurate interpretation, as if that obsolete use were still *the* use. If a teacher does this well, he is reckoned a good teacher, although he does little or nothing for the other ends, which, in argument, are treated as the reason of his existence. Indeed, this is the kind of teaching that is alone to be expected from the ordinary teacher; all the other ends are more difficult than simple word-teaching. Even when English composition, logic, and taste, are taught in the most direct way, they are more difficult than the simple teaching of a foreign language for purposes of interpretation; but when tacked on as accessories to instruction in a language, they are still more troublesome to impart. A teacher of rare excellence may help his pupils in English style, in philology, in logic, and in taste; but the mass of teachers can do very little in any of those directions. They are never found fault with merely because their teaching does not rise to the height of the great arguments that justify their vocation; they would be found fault with if their pupils were supposed to have made little way in that first function of language which is never to be called into exercise.

I do not rest satisfied with quoting the palpable inconsistency between the practice of the teacher and the polemic of the defender of languages. I believe, further, that it is not expedient to carry on so many different acquisitions together. If you want to teach thorough English you need to arrange a course of English, allot a definite time to it, and follow it with undivided attention during that time. If you wish to teach philology, provide a systematic scheme, or text-book of philology, and bring together all the most select illustrations from languages generally. So for logic and for taste: these subjects are far too serious to be imparted in passing allusions while the pupil is engaged in struggling with enigmatic difficulties. They need a place in the programme to themselves; and, when so provided for, the small dropping contributions of the language-teacher may easily be dispensed with.

The argument for languages may, no doubt, take a bolder flight, and maintain that the teacher does not need to turn aside from his plain path to secure these secondary ends—now the only valuable ends. The contention may be that in the close and rigorous attention to mere interpretation, just as if interpretation were still the living use, these other purposes are inevitably secured—good English, universal grammar, logic, taste, etc. I think, however, that is too far from the fact to be very confidently maintained. Of course, were it correct, the teacher should never have departed from it, as the best teachers continually do, and glory in doing.

On the face of the thing, it must seem an unworkable position to surrender the value of a language, as a language, and keep it up for something else. The teaching must always be guided by the original, although defunct, use. This is the natural, the easy course to follow; for the mass of teachers at all times it is the broad way. Whatever the necessities of argument may drive a man to say, yet in his teaching he cannot help postulating to himself, as an indispensable fiction, that his pupils are some day or other to hear, to read, to speak, or to write, the language.

The intense conservatism in the matter of languages, the alacrity to prescribe languages on all sides, without inquiring whether they are likely to be turned to account, may be referred to various causes. For one thing, the remark may seem ungracious and invidious that many minds, not always of the highest force, are absorbed and intoxicated by languages. But apart from this they are, by comparison, easy to teach and easy to examine upon. Now, if there is any motive in education more powerful than another, it is ease in the work itself. We are all, without exception, copyists of that Irish celebrity who, when he came to a good bit of road, paced it to and fro a number of times before going forward on the rougher footing.

So far I may seem to be arguing against the teaching of language at all, or, at any rate, the languages expressively called dead. I am not, however, pressing this point further than as an illustration. I do not ask any one to give an opinion against classics as a subject of instruction; although, undoubtedly, if this opinion were prevalent, my principal task would be very much lightened. I have merely analyzed the utilities ascribed to the ancient and modern languages, with a view to settling their place in competitive examinations.

My thesis, then, is that languages are not a proper subject for competition with a view to professional appointments. The explanation falls under two heads:

In the first place, there are certain avocations where a foreign language must be known, because it has to be used in actual business. Such are the Indian spoken languages. Now, it is clear that in such cases the knowledge of the language, as being a *sine qua non*, must be made imperative. This, however, as I think, is not a case for competition, but for a sufficient pass. There is a certain pitch of attainment that is desirable even at first entering the service; no one should fall below this, and to rise much above it cannot matter a great deal. At all events, I think the measure should be absolute and not relative. I would not give a man merit in a competition because another man happens to be worse than himself in a matter that all must know; both the men may be absolutely bad.

It may be the case that certain languages are so admirably constructed and so full of beauties that to study them is a liberal education in itself. But this does not necessarily hold of every language that an official of the British Empire may happen to need. It does not apply to the Indian tongues, nor to Chinese, nor, I should suppose, to the Feejee dialects. The only human faculty that is tested and brought into play in these acquisitions is the commonest kind of memory exercised for a certain time. The value to the service of the man that can excel in spoken languages does not lie in his superior administrative ability, but in his being sooner fitted for actual duty. Undoubtedly, if two men go out to Calcutta so unequal in their knowledge of native languages, or in the preparation for that knowledge, that one can begin work in six months, while the other takes nine, there is an important difference between them. But what is the obvious mode of rewarding the differences? Not, I should think, by pronouncing one a higher man in the scale of the competition, but by giving him some money-prize in proportion to the redemption of his time for official work.

Now, as regards the second kind of languages, those that are supposed to carry with them all the valuable indirect consequences that we have just reviewed. There are in the Civil Service scheme five such languages—the two ancient, and three modern. They are kept there, not because they are ever to be read or spoken in the service, but because they exercise some magical efficacy in elevating the whole tone of the human intellect.

If I were discussing the Indian Civil Service in its own specialties, I would deprecate the introduction of extraneous languages into the competition for this reason, that the service itself taxes the verbal powers more than any other service. I do not think that Lord Macaulay and his colleagues had this circumstance fully in view. Macaulay was himself a glutton for language; and, while in India, read a great quantity of Latin and Greek. But he was exempted from the ordinary lot of the Indian civil servant; he had no native languages to acquire and to use. If a man both speaks and writes in good English, and converses familiarly in several Oriental dialects, his language-memory is sufficiently well taxed, and if he carries with him one European language besides, it is as much as belongs to the fitness of things in that department.

My proposal, then, goes the length of excluding all these five cultivated languages from the competition, notwithstanding the influence that they may be supposed to have as general culture. In supporting it, I shall assume that everything that can be said in their favor is true to the letter; that they assist us in our language, that they cultivate logic and taste, that they exemplify universal grammar, and so on. All that my purpose requires is to affirm that the same good ends may be attained in other ways; that Latin, Greek, etc., are but one of several instruments for instructing us in English composition, reasoning, taste, and so on. My contention, then, is that the ends themselves are to be looked to, and not the means or instruments, since these are very various. English composition is, of course, a valuable end, whether got through the study of Latin, or through the study of English authors themselves, or through the inspiration of natural genius. Whatever amount of skill and attainment a candidate can show in this department should be valued in the examination for English; and all the good that Latin has done for him would thus be entered to his credit. If, then, the study of Latin is found the best means of securing good marks in English, it will be pursued on that account; if the candidate is able to discover other less laborious ways of attaining the end, he will prefer these ways.

The same applies to all the other secondary ends of language. Let them be valued in their own departments. Let the improvement of the reasoning faculty be counted wherever that is shown in the examination. Good reasoning powers will evince themselves in many places, and will have their reward.

The principle is a plain and obvious one. It is the payment for results, without inquiring into the means. There are certain extreme cases where the means are not improperly coupled with the results in the final examination; and these are illustrations of the principle. Thus, in passing a candidate for the medical profession, the final end is his or her knowledge of diseases and their remedies. As it is admitted, however, that there are certain indispensable preparatory studies—anatomy, physiology, and materia medica—such studies are made part of the examination, because they contribute to the testing for the final end.

The argument is not complete until we survey another branch of the subject of examination in languages. It will be observed in the wording of the programme that each separate language is coupled with "literature and history." It is the language, literature, and history, of Rome, Greece, etc. And the examination-questions show the exact scope of these adjuncts, and also the values attached to them, as compared with the language by itself.

Let us consider this matter a little. Take history first, as being the least involved. Greece and Rome have both a certain lasting importance attaching to their history and institutions; and these, accordingly, are a useful study. Of course, the extant writings are the chief groundwork of our knowledge of these, and must be read. But at the present day all that can be extracted from the originals is presented to the student in English books; and to these he is exclusively referred for this part of his knowledge. In the small portion of original texts that a pupil at school or college toils through, he necessarily gets a few of the historical facts at first hand, but he could much more easily get these few where he gets the rest, in the English compilations. Admitting, then, that the history and institutions of Greece and Rome constitute a valuable education, it is in our power to secure it independently of the original tongues.

The other branch—literature—is not so easily disposed of. In fact, the separating of the literature from the language, you will say, is a self-evident absurdity. That, however, only shows that you have not looked carefully into examination-papers. I am not concerned with what the *a priori* imagination may suppose to be literature, but with the actual questions put by examiners under that name. I find that such questions are, generally speaking, very few, perhaps one or two in a long paper, and nearly all pertain to the outworks of literature, so to speak. Here is the Latin literature of one paper: In what special branch of literature were the Romans independent of the Greeks? Mention the principal writers in it, with the peculiar characteristics of each. Who was the first to employ the hexameter in Latin poetry, and in what poem? To what language is Latin most nearly related, and what is the cause of their great resemblance? The Greek literature of the same examination involves these points: The Aristophanic estimate of Euripides, with criticisms on its taste and justice (for which, however, an historical subject is given as an alternative); the Greek chorus, and choric metres. Now, such an examination is, in the first place, a most meagre view of literature: it does not necessarily exercise the faculty of critical discernment. In the next place, it is chiefly a matter of compilation from English sources; the actual readings of the candidate in Greek and Latin would be of little account in the matter. Of course, the choric metres could not be described without some knowledge of Greek, but the matter is of very trifling importance in an educational point of view. Generally speaking, the questions in literature, which in number bear no proportion to historical questions, are such as might be included under history, as the department of the history of literature.

The distribution of the 750 marks allotted respectively to Latin and to Greek, in the present scheme, is this: There are three papers—two are occupied exclusively with translation. The third is language, literature, and history: the language means purely grammatical questions; so that 583 marks are given for the language proper. The remaining number, 167, should be allotted equally between literature and history; but history has always the lion's share, and is, in fact, the only part of the whole examination that has, to my mind, any real worth. It is generally a very searching view of important institutions and events, together with what may be called their philosophy. Now, the reform that seems to me to be wanted is to strike out everything else from the examination. At the same time, I should like to see the experiment of a real literary examination, such as did not necessarily imply a knowledge of the originals.

It is interesting to turn to the examination in modern languages, where the ancient scheme is copied, by appending literature and history. Here the literature is decidedly more prominent and thorough. There is also a fair paper of history questions. What strikes us, however, in this, is a slavish adherence to the form, without the reality, of the ancient situation. We have independent histories of Greece and Rome, but scarcely of Germany, France, and Italy. Instead of partitioning modern European history among the language-examiners for English, French, German, Italian, it would be better to relieve them of history altogether, and place the subject as a whole in the hands of a distinct examiner. I would still allow merit for a literary examination in French, German, and Italian, but would strike off the languages, and let the candidate get up the literature as he chose. The basis of a candidate's literary knowledge, and his first introduction to literature, ought to be his own language; but he may extend his discrimination and his power by other literatures, either in translations or in originals, as he pleases; but the examination, as before, should test the discrimination and the power, and not the vocabulary, of the languages themselves.

In order to do full justice to classical antiquity, I would allow the present markings to continue, at the rate of 500 for political institutions and history, and 250 for literature. Some day this will be thought too much; but political philosophy or sociology may become more systematic than at present, and history questions will then take a different form.

In like manner, I would abolish the language-examination in modern languages, and give 250 marks for the literature of each of the three modern languages—French, German, Italian. The history would be taken as modern history, with an adequate total value.

The objections to this proposal will mainly revolve themselves into its revolutionary character. The remark will at once be made that the classical languages would cease to be taught, and even the modern languages discouraged. The meaning of this I take to be, that, if such teaching is judged solely by its fruits, it must necessarily be condemned.

The only way to fence this unpalatable conclusion is to maintain that the results could not be fully tested in an examination as suggested. Some of these are so fine, impalpable, and spiritual in their texture, that they cannot be seized by any questions that can be put, and would be dropped out if the present system were changed. But results so untraceable cannot be proved to exist at all.

So far from the results being missed by disusing the exercises of translation, one might contend that they would only begin to be appreciated fairly when the whole stress of the examination is put upon them. If an examiner sets a paper in Roman law, containing long Latin extracts to be translated, he is starving the examination in law by substituting for it an examination in Latin. Whatever knowledge of Latin terminology is necessary to the knowledge of law should be required, and no more. So, it is not an examination in Aristotle to require long translations from the Greek; only by dispensing with all this does the main subject receive proper attention.

If the properly literary part of the present examinations were much of a reality, there would be a nice discussion as to the amount of literary tact that could be imparted in connection with a foreign language, as translated or translatable. But I have made an ample concession, when I propose that the trial should be made of examining in literature in this fashion; and I do not see any difficulty beyond the initial repugnance of the professors of languages to be employed in this task, and the fear, on the part of candidates, that undue stress might be placed on points that need a knowledge of originals.

I will conclude with a remark on the apparent tendency of the wide options in the commissioners' scheme. No one subject is obligatory; and the choice is so wide that by a very narrow range of acquirements a man may sometimes succeed. No doubt, as a rule, it requires a considerable mixture of subjects: both sciences and literature have to be included. But I find the case of a man entering the India service by force of languages alone, which I cannot but think a miscarriage. Then the very high marks assigned to mathematics allow a man to win with no other science, and no other culture, but a middling examination in English. To those that think so highly of foreign languages, this must seem a much greater anomaly than it does to me. I would prefer, however, that such a candidate had traversed a wider field of science, instead of excelling in high mathematics alone.

There are, I should say, three great regions of study that should be fairly represented by every successful candidate. The first is the sciences as a whole, in the form and order that I have suggested. The second is English composition, in which successful men in the India competition sometimes show a cipher. The third is what I may call loosely the humanities, meaning the department of institutions and history, with perhaps literature: to be computed in any of the regions of ancient and modern history. In every one of these three departments I would fix a minimum below which the candidate must not fall.

ON THE COMPARATIVE STUPIDITY OF POLITICIANS.[1]

WE owe an apology to a very respectable class of persons for the apparent, but we trust only apparent, and certainly involuntary, discourtesy of the thesis to which we invite attention. The late Mr. Mill, in a well-known passage, called the Conservatives the stupid party. We do not call them so, nor their opponents. All we venture to assert of both is, that in a universe of graduated intelligence they are not highest in the scale. The great majority of even prominent politicians have just the gifts which make a man conspicuous in a town-council or a board of guardians: physical energy, moral persistency, and ideas on a level with those of their fellows. Miss Martineau, in her very candid "Autobiography," has recorded her sense of the mental and moral inferiority of the political men with

[1] Condensed from *Fraser's Magazine*.

whom, during her period of lionizing in London, she was brought into contact, as compared with the men of letters, and still more with the men of science, whose acquaintance she made. She observed in the politicians a much lower type of mind and character, expressing itself even in a certain vulgarity of manners, the lowest point being reached in all these particulars by the Whig aristocracy of the day.

In the long prevalence of an aristocratic monopoly, diminished now, but not altogether done away with, and subsisting still in its effects even more powerfully than in itself, one of the special causes of the comparative stupidity of politicians in England may be discerned. But the evil is inherent in the very conditions of what are called practical politics. The real development of mind is to be sought in what Mr. Arnold calls its disinterested play in science and art. Discipline in the methods of research after truth, familiarity with the highest conceptions of the universe, delight in the most perfect forms of expression, whether they take the shape of literature or of the plastic and imitative arts, these are the feeders and purifiers of the mind. The artist, including the author as well as the sculptor, the painter, and the actor, and the man of science, live, so far as they are true to their work, in the society of Nature and of its great interpreters. They are constantly in the presence of their betters. The statesman lives habitually in the society of county and borough members; or, if we restrict our view to the intimate associations of the cabinet, of men little, if at all, above these intellectually. In other words, the finest mind is habitually in the presence of its inferiors, whose ideas and impulses are to it what his daily beer was to Mr. Justice Maule, the instrumentality with which he brought himself down to the level of his work. He must think their thoughts and speak their language. To be over their heads, to be, as a dexterous politician said of a great philosopher, too clever for the House of Commons, to have nobler and farther-reaching conceptions than they, is to commit the sin for which there is no parliamentary forgiveness. It is sometimes said that the House of Commons is wiser than any single member; a saying which, according as it is interpreted, is either an absurdity or a truism. It may mean, what is indisputable, that the whole is greater than the part, or, what is impossible, that the average is higher than the elements which raise it. The House of Commons can only be wiser than some particular member by following the guidance of some other member who, on that particular occasion, is wiser than he; that is to say, it is wiser than one of its less wise members. The saying, however, is intended to affirm the position that intellectual superiority is not the truest guide in politics, or, in other words, that politicians, in so far as they are successful, are comparatively stupid, a position which we are far from disputing. On the contrary, we affirm it as a truth of observation and experience, and are at the present moment doing our best to account for it. As regards the proposition itself, it means simply that the House of Commons knows its own mind, such as it is, and, whatever the worth of that knowledge, better than any single member of it; and as a rule the average member who is in sympathy with it will interpret it better than the member of much higher powers who is above its level. But it is only wiser than its wisest members in the sense in which the field may be said to be wiser than the farmer, or the ocean than the navigator; that is to say, in no intelligible sense at all. Like Nature, if it is to be commanded it must be obeyed, and the necessity of understanding it is, by confusion of thought, taken for its understanding of itself.

The inferior society in which politicians live, inferior in intelligence and cultivation, and the necessity of adapting their own thoughts and aims to those of the ordinary minds and characters they have to influence, brings about the decline and deterioration of men of originally fine endowments. It either prevents these qualities from developing, or stunts them where they have a certain degree of growth. Their "nature is subdued to what it works in, like the dyer's hand." This evil is in part qualified by another. It is chiefly the second-rate order of minds and characters that betake themselves now to politics in England—minds already on the level to which superiority needs to be reduced before it can be effective. For this reason, probably, whenever an occasion demands a hero in politics, he has been seldom found in the walks of professional statesmanship. The national crisis which asks for a deliverer finds him not among those who have been deteriorated and dwarfed by the ordinary work and associations of politics, but in a man who has lived among nobler ideas and associations, and cultivated a larger and more liberal nature. The practice of affairs is, no doubt, a discipline of some value; but nearly everything depends on what the affairs are. To manage the House of Commons, to get bills through committee, to administer a public office, does not seem usually to be good training for very difficult business. When a considerable emergency occurs there is almost invariably a breakdown of the departments. The true discipline of public business is to teach men readiness in action and fertility in resources. Its ordinary effect is to harden them in routine, which suits poorly enough even the common round and the daily task of business, and which is a hinderance, and which may be ruin when necessities, transcending precedents and rules of office, have to be encountered. The fact is, that the training of affairs, invaluable as it is, seldom bears its proper fruit, unless the affairs are a man's own, or when the consequences of failure are sure to come upon him in a rapid and crushing manner. The merchant or capitalist, whose ventures depend upon his personal vigilance; the engineer, who has to deal with overwhelming physical forces; the military commander, who has to contend at once with the not always benevolent neutral-ity of Nature and the watchfulness of human enemies, cannot afford to take things easily. Action is forced upon them; they must either succeed or conspicuously fail. In politics, usually, the state of things is entirely different. The demand is rarely made for heroic measures; the prudence which is taught is that rather which shuns difficulty and dreads failure, than that blending of caution and audacity which finds in the way of seeming danger the true path of safety. The education of practice in parliamentary politics is, therefore, for the most part, an education in the arts of inaction, evasion, and delay. The blame of doing nothing is usually less than the blame of doing amiss. A great writer, whose instinctive sagacity was often wiser than the elaborated reflections of more painful thinkers, embodied the characteristic weakness of political training in England when he made "How not to do it" the aim of our statesmen. Lord Melbourne's "Can't you leave it alone?" gave expression to the same paralysis of action in excessive caution and prudence. Politics of this sort will attract feeble minds and characters, or will enfeeble those naturally stronger. The oratory which they foster will be that of mystification, amusement, and excitement. Acquaintance with political philosophy or economic science will be felt to be wholly superfluous. Even that empirical knowledge of his age and country, and of the assembly in and through which he rules, which are essential to every practical statesman, will be little more than the charlatan's or demagogue's acquaintance with the foibles and passions of popular sentiment and opinion. The admiral who boasted that he brought his ships home uninjured from seas in which he had not encountered the enemy, and the Frenchman whose achievement it was to have kept himself alive during the French Revolution, represent the prevalent aims of modern statesmanship. A ministry exists to keep itself in existence; if the ship, without going anywhere or doing anything, can be kept afloat, that is held to be all that can be required. This *fainéant* policy does not require any high range of intellect. Men of the first order will seek careers which afford ampler scope to capacity. If they betake themselves to public life, which affords them no opportunity of great public work, there is danger of their devoting their energies to their own private and personal ends; or, merely to establish a character for "honesty" will often prove enough to repose on. A picture, a statue, or a poem, does not receive additional value from the fact that its author is a very pleasant and straightforward sort of fellow; but "honest Jack Althorp's" statesmanship rested entirely on this basis of character; and a late parliamentary leader has been commended on the ground that "there is not the making of a lie in him." A career in which character may be a substitute for capacity must, from the nature of the case, be pursued on a lower intellectual level than those in which intelligence and cultivation and general or special knowledge are absolutely essential.

The natural and almost necessary inferiority of politicians as a class is compatible with the unsurpassed intellectual and moral greatness of statesmanship of the highest class. Men are not wanting in the history of any country, least of all in that of ours, and they have representatives among us now, who have found or made work for themselves to do which taxes the very highest gifts, and in the doing of which the very humblest and most commonplace allies and instruments acquire a sort of transfiguration. Their appearance and exertions mark the high-water point in the national life, an epoch of brief but fruitful work, an epoch of civil heroism. But the languor comes after the exertion; and in such a period of languor we seem now to be plunged. Even the men who counted for much when they followed a great leader become mere ciphers when the figure which stood at their head is removed.

Apart from these singular cases of moral and intellectual ascendency, the gifts which make a parliamentary leader are just those which make a man popular in society. The cheerful animal spirits and vigorous gayety of temperament which characterized Lord Palmerston, or the amusing qualities of a public entertainer which marked Charles Townshend (not to seek for living illustrations), are what it most relishes—the qualities which make a first-rate host in a country-house, or an amusing diner-out in town.

THE LARYNGOSCOPE AND RHINOSCOPE.

HOW THE AIR-PASSAGES ARE EXPLORED.

By F. SEEGER, M. D.

FROM the above names, most persons of average culture would at once infer that they are instruments for exploring the larynx and nose, and yet but few would suspect what simple little instruments they are—merely bits of looking-glass set in a frame and attached to a handle. But, when they give the matter a little further investigation, they are surprised at the greatness of the benefits which have already been reaped by mankind from the discovery of these self-same little instruments. They will learn that only a few years ago physicians were absolutely in the dark when applied to by those afflicted with disease of the throat; and that where then all was darkness, there now is clear light, thanks to the zeal and scientific devotion of Prof. Türck, of the University of Vienna, who in 1857 was the first to successfully use the laryngoscope as a means of determining the nature of a disease in the throat of a patient then in the wards of the General Hospital of Vienna, of which latter Türck was the physician-in-chief. Justice and the truth of history, however, require that we should not omit mentioning the experiments and efforts of Senn, of Geneva (1827); Babington, of London (1829); Belloc, of Paris (1837); Baumes, of Lyons (1838); Liston, of London (1840); of Warden (1844); and, finally, of Manuel Garcia, a singing-teacher, of London. With the exception of the last, all of the experimenters had been disappointed in their efforts to devise an instrument sufficiently suitable and generally practical. Their experiments all lacked *that essential practical element* which made the subsequent labors of Türck and Czermak the solid basis for the grand superstructure which has grown up since their time. While Prof. Türck at Vienna, and Prof. Czermak, of the University of Krakau, the latter having become interested by Prof. Türck in the experiments, were thus developing the practical application of the laryngeal mirror (*Kehlkopffragen-spiegel*, as Türck named it), Garcia, the now justly famous Spanish tenor and singing *maestro*, and father of the gifted songstress, Malibran, was at the very same time experimenting in London, but with totally different purposes. The object which Türck and Czermak had in view was to make the laryngoscope available as an adjunct and aid to the art and practice of medicine, or, in other words, as a means of diagnosis in disease of the throat. Garcia, on the other hand, was prompted by a desire to observe the actions of the vocal cords and larynx when producing tones and sounds. His observations were published in the *Royal Philosophical Magazine and Journal of Science* (vol. x., 1855), and they constitute the first physiological records of the human voice as based upon observations in the living subject. It is interesting at this date to turn to his remarks and to note the thoroughness therein displayed. The curious may refer to Madame Seiler's "The Voice in Singing," or to the writer's translation of Sieber's "Art of Singing." It is but proper to add that although Türck and Garcia were thus experimenting at one and the same time, neither, however, knew of the other nor of his efforts. Garcia accomplished his aim by standing with his back to the sun and catching its rays upon a looking-glass held in his left hand, which he then reflected into his opened mouth. Next he carried a dentist's mirror to the back of his mouth; and the sun's light which, in the first instance, was reflected from the mirror in the hand, being in turn reflected upon the dentist's mirror, served to illuminate the larynx below, and thus caused its picture to become visible in the dentist's mirror. Türck also used the sun's rays, but in a more direct manner, viz., without previous reflection. Prof. Czermak, as already remarked, soon became interested in Türck's experiments, and, borrowing some of Türck's mirrors, repeated the experiments. His labors resulted in a yet further and most brilliant development of the subject, by his introduction of a powerful artificial light, thus making us independent of sunlight, and enabling an examination to be made at any time of the day or night.

For the clearer comprehension of the reader, I here introduce cut No. 1, which depicts the laryngoscope, or laryngeal mirror. At the left end we see the mirror, which is set in a silver frame and back; this in turn is attached to a metal stem, and the stem itself is set in a wooden handle, which latter is merely a matter of convenience by which the physician is enabled to handle it with more ease and facil-

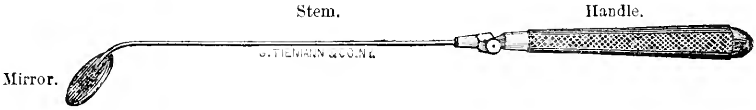


Fig. 1.

ity. The mirror is made of various sizes, from that of a cent to that of a silver half-dollar, and is so attached to the stem as to describe an angle of 120° to 125°.

Prior to the discovery of the laryngoscope, the great obstacle to the diagnosis and comprehension of disease of the larynx lay in the fact that this organ was so placed as to be at an almost direct angle to the line of vision. If we look into the mouth of another person, we see the back of the mouth; but if we wish to see the larynx, or organ of tone and voice, we are unable to do it, even though its position is just back of and below the root of the tongue. And, even though we press down the tongue, we derive no aid. Nor are we enlightened by symptoms of pain or discomfort in the throat, for these are not only insufficient, but may be absolutely deceptive. A patient may complain of aches and pains, and may imagine them in the larynx, and all the while the organ be in a perfectly sound state; and, on the other hand again, grave forms of throat-disease may exist, and with so little of actual pain as to cause the victim hardly any uneasiness. The revolution in this department of the medical art may perhaps be best illustrated when I refer to the fact that ere the introduction of the laryngeal mirror, barely twenty years ago, there were but two or three forms of laryngeal disease recognized or treated of in the text-books on the practice of medicine. At the present time, the study of the numerous and varied diseases of this wonderful little organ, the larynx, has made such strides that laryngology has, like ophthalmology, otology, and gynæcology, demanded and received recognition as a separate and distinct department of medical practice, and has its special practitioners in almost every city of size and population. Whereas, formerly, the two or three recognized forms of throat-disease were dismissed in a scant dozen of pages in the medical text-works, we now have exhaustive and elaborate treatises in all of the great languages of the civilized world. Twenty years ago inflammation, laryngeal phthisis, or, popularly speaking, throat-consumption, and œdema, constituted the three recognized forms of throat-affection; but, in eight years from the first practical application of this instrument, the revolution was such that separate treatises described and treated of forty and more varieties of disease, such as acute laryngitis and the various acute affections; simple chronic laryngitis, chronic ulcerative laryngitis; of six or seven forms of inflammation of special parts of the larynx; of tubercular and syphilitic laryngitis, œdema, abscess, etc. Next we find descriptions of the diseases which attack the laryngeal cartilages or framework of the larynx, as perichondritis and chondritis. Then follow nervous forms of derangement, and then paralytic forms of difficulty. In the first we have conditions of nervous exaltation, such as spasmodic coughs, spasms, etc. Under the second head we have paralytic affections of the vocal cords and laryngeal muscles. These paralytic difficulties of the larynx may exist in the larynx without much or even any impairment of the general health. Then we have anæmia or impoverished blood-supply, and finally the varied forms of tumors and morbid growths, cancerous, syphilitic, etc. I might prolong this list yet further, and even dwell at length upon the many and ingenious instruments for operating within the larynx, but to do so would be to exceed the limits of my article.

The rhinoscopic mirror, or rhinoscope, is practically but a laryngeal mirror of a smaller size. The stem and handle are the same, and attached in the same manner, at about the same angle, but there is the difference of a much smaller size as compared to the laryngoscope, the mirror being usually about the size of a silver three-cent piece. Its use is to enable us to see the back or inner parts of the nose (posterior nares), and the upper part of the pharynx or vault of the back of the mouth. Its discovery, which occurred soon after that of the laryngoscope, is due to the patience and genius of Czermak, and was a direct result of the discovery of the laryngeal mirror. The parts which it enables us to see are hidden behind and above the palate, and the office of the rhinoscopic mirror is simply to so reflect the light as to illuminate these parts, and in turn enable their image to become visible in the mirror. In the first instance the little mirror is placed at the back of the opened mouth of the patient. At the same time a powerful and clear light from an illuminating apparatus is directed into the patient's mouth, and the rays striking upon the mirror are so reflected upward and forward as to illuminate the parts we seek to examine, and these are then, as just remarked, made visible in the mirror. And in this principle lies the entire secret of the art of making a laryngoscopic or rhinoscopic examination. It is simply a dexterous management of mirrors to secure proper reflection of light, and the consequent illumination and examination of hidden recesses.

The rhinoscope also enables us to examine the nasal or pharyngeal orifices of the Eustachian tubes. These latter are passages leading from the inner side of the drum of the ear, and opening, as already indicated, at a point situated in the posterior nasal parts. It is not the province of this article to enter into minute or precise detail, and therefore we shall merely add that these tubes bear a very important relation to the faculty of hearing. If the nasal orifices of these tubes become swollen by disease, or choked with diseased mucus, greater or less impairment of the hearing-power results. Consequently, the rhinoscope has rendered no small service to us for determining causes of deafness, and of curing them, which formerly were but guessed at or remained unknown.

But to make the laryngeal and rhinal mirrors available, the artificial illumination of these parts is necessary. To depend upon the sun's rays, as was the case with the original experiments, was too uncertain. Czermak, as we have seen, substituted artificial light, and thus enabled an examination to be made at any hour of the day or night. Tobold, of Berlin, after a time, brought forward an apparatus which is depicted in the following cut, and which embodied the most perfect apparatus of the time. The cut also shows us the position of the patient and of the examiner.

As introduced by him, it consisted of a common study-lamp: *a*

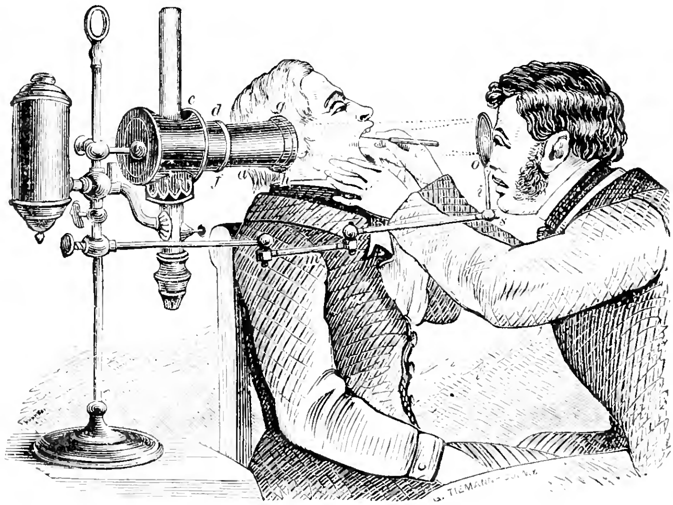


Fig. 2.

is a brass tube, or light-condenser, in which are convex lenses, *c*, *d*, *g*. The lenses *c* and *d*, it will be observed, are close together, while the third, *g*, is at the distal extremity of this brass tube. At *f* this brass tube can be unscrewed, thus enabling the cleansing of the lenses.

The lens *g* can also be removed at *h*. *m* is a brass arm having three joints, and fastened to the lamp. At the extremity of this arm is a perforated knob, *s*, through which the handle of the reflector, *i*, is passed, and which is fastened by a screw. At *o* is a single *charnière* joint, which permits of the forward or backward motion of the reflector—the illuminating agent being oil. By substituting gas burned through an Argand burner, and fed from any ordinary burner, the apparatus has been made more available, and better light obtained. The following cut represents the improved apparatus as now made.

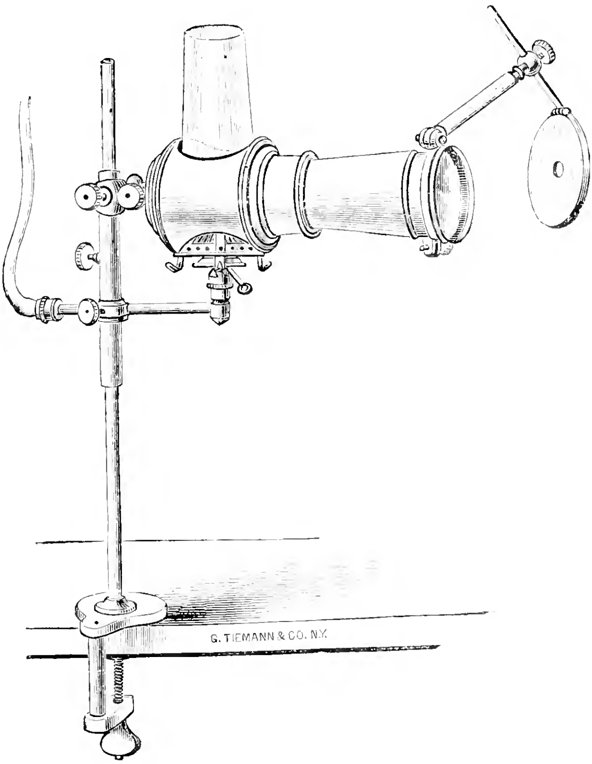


Fig. 3.

It is not necessary to dwell upon the changes. Suffice it that by these the apparatus has been made much more ready and simple in management, and less liable to derangement of focus at important moments when a steady light is needed for intra-laryngeal operations. It is here that we should call a brief attention to the vast strides which, under the influence of the laryngoscope, have been effected in the operative procedures upon this organ. All of these are now made by means of instruments curved at a direct angle to the line of vision, and in none of these operations does the operator directly see the objective point. His operations are all made under the guidance of the image which he sees reflected in the laryngeal mirror, and are comparatively bloodless and accompanied by little or no pain.

A laryngoscopic examination is made as follows: In the second cut we see the positions of the examiner and patient. The patient opens his mouth as widely as possible, and at the same time protrudes his tongue. The examiner, then, with a small napkin takes the protruded tongue between his thumb and forefinger, thus gently steadying it and preventing its slipping back into the mouth. The object in thus protruding the tongue is to enlarge the cavity of the mouth as much as possible. The laryngeal mirror is next warmed either over the chimney of the illuminator or in some warm water, so as to prevent its becoming obscured or dimmed by the breath. It is then quickly and dexterously carried to the back of the mouth. A bungling manner of doing this, by causing great irritation of sensitive parts of the mouth, causes gagging and even vomiting, and, this once excited, all further examination is either very difficult or impossible at this sitting. It is not to be taken for granted, however, that examinations can readily be made in all cases, nor even in the larger majority of the patients. With many there is no trouble, but there are also quite a number of patients whose throats are so irritable from disease as to prevent the introduction of the laryngoscope. In other cases the patient's tongue has an almost irresistible tendency to keep rising up toward the roof of the mouth and thus obstruct the view. Enlargement of the tonsils according to the degree of their enlargement makes an examination either very difficult, or else, if so much enlarged that they meet and almost close up the throat, makes it impossible until the enlargement has been reduced. For the overcoming of mere irritability of the throat or fauces when this pertains to a degree sufficient to be troublesome, various means have been resorted to, to produce local anæsthesia of the fauces. A piece of ice held in the mouth, the water being swallowed, is one plan. Another is to drop twenty drops of chloroform on a handkerchief and let the patient inhale it for a minute. With most cases of irritable throat this is quite sufficient, and without at all rendering the patient drowsy or uncomfortable. Bromide of potash has been used, but has not given satisfaction practically.

The examiner, having avoided touching the back of the tongue and of the pharynx with the mirror, carries it, as already said, to the back of the mouth to an oblique position below the soft palate and with the uvula or "drop" of the palate at its back. The rays of light from the illuminating apparatus, striking the laryngeal mirror, are then reflected in a downward direction and light up the parts (the larynx) below. These, being illuminated, are in return depicted upon the laryngeal mirror above. The process may be compared to that of the management of toilet-mirrors to enable us to see the back of the head. In the latter proceeding it is not the back of the head which we see, but, as is hardly necessary to add, merely its reflection in the mirror.

And at this point we should remark that, while the laryngeal examination to one versed in the art is comparatively easy, the rhinoscopic examination, on the other hand, is a very difficult matter, and calls into play no small amount of skill and ingenuity. The reasons for this are mainly because of the unruliness of most palates, which have a tendency to bob up and down in a very provoking manner. We shall not dwell further upon this point, but briefly add a few remarks as to what this instrument has done for us. Where we can apply it we are no longer in the dark as to whether a case of disease is that of a chronic catarrh, nasal tumor, simple inflammation, swelling, or ulceration. In our climate, in which diseases of the nasal cavities, and particularly catarrh, are so prevalent that it has been estimated that 10,000,000 of our people have the disease called catarrh to a greater or less degree, every advance by which we are enabled the more successfully to combat these complaints is of general interest and importance. How potent our climate is in causing catarrh is illustrated in the case of Charles Dickens, who contracted it so rapidly and severely as to necessitate his abandoning many engagements and compel his flight from this country. Interesting is the fact, which Darwin records in his "Descent of Man," that the *Cebus azaræ*, a species of Paraguayan monkey, is liable to catarrh with all of the symptoms found in his more human relatives, and which when often recurrent leads in them to consumption.

The higher animals, like man, are endowed with an organ of voice and sound, but man alone has the supreme gift and faculty of expressing the ideas and thoughts which his intellectual endowments and powers give rise to, or, plainly speaking, he alone has an articulate language equal to the expression of most of his feelings and sentiments. How wonderful, then, it becomes to us when we study the little organ which has the great task of placing man in direct communication with his fellow-beings! And how wonderfully this little organ modulates its tones in accordance with the varying degrees of emotion and earnestness! And when we consider that each voice has its own peculiarities and characteristics which distinguish it from all others, our interest deepens. And yet there is little or in fact no difference in the mechanism of the various kinds of voice, the variations in pitch being due chiefly to the greater length of the vocal cords in the low-pitched voices and to their shortness in the high voices. Tone, whether in speech or song, is simply a result of the action of a volume of air in a quantity which is regulated by the will of the speaker or singer, which, coming up from the lungs through the windpipe, passes up through the larynx, where it causes the elastic vocal cords to be put upon the stretch to a greater or less degree according as the intended note is high or low, to vibrate, and thus is produced the tone which upon its entrance into the pharyngeal cavity and mouth becomes articulated, and the sound of which is variously and essentially modified according to the varying peculiarities of structure and formation of the larynx, pharynx, and mouth. It is also changed or modulated according as the various parts of the mouth, tongue, palate, teeth, and lips, assume different positions. Cultivation of the voice also impresses its stamp. The tone-waves, as they rush out of the open mouth, communicate their vibrations to the air, which conducts the sound onward until it reaches our ears, provided we are within the reach of these atmospheric vibrations. The difference between a cultivated voice or note is soon detected in the purity and regularity with which its sounds reach us as compared to the harsh, irregular, discordant waves impelled by one not so cultivated. Johannes Müller places the extreme range of the human voice at four octaves, but it is quite seldom that the range exceeds two and a half octaves. In some phenomenal voices, like those of the gifted Parepa-Rosa, Peschka-Leutner, Mara, Farinelli, and other great singers, we meet with astounding range and power. Parepa-Rosa had a voice ranging full three octaves, from sol_2 to sol_3; and Flint, the learned and indefatigable physiologist, tells that at the World's Musical Festival at Boston, in 1869, she gave the most astounding exhibitions of the wonders which this little organ, the larynx, is capable of. In some of the solos by Madame Rosa, accompanied by a chorus of 12,000 with an orchestra of more than a thousand, and largely composed of brass instruments, Prof. Flint distinctly heard the pure and just notes of this remarkable soprano, standing alone, as it were, against the entire choral and instrumental force; and this in an immense building containing an audience of 40,000 persons! Mara's voice had compass, with equal fullness of tone, of three octaves, and she possessed such power of musical utterance that she imitated the most difficult passages of the violin and flute with perfect facility. Farinelli on one occasion competed with a trumpeter, who accompanied him in an aria. After both had several times dwelt on notes in which each sought to excel the other, they prolonged a note with a double trill in thirds, which they continued until both seemed exhausted. At last the trumpeter gave up, entirely out of breath, while Farinelli, without taking breath, prolonged the note with renewed volume of sound, trilling and ending finally with the most difficult roulades.

But these wonderful displays of the power of the larynx must not be ascribed entirely to the intensity of the tone, but are in no small measure due to the absolute mathematical equality of the sonorous vibrations and the comparative absence of discordant waves. By the degree of tension of the vocal cords which is required for the pitch of a prescribed tone, and which, as we have seen, is greater in the higher and less in the lower notes, the muscles of the larynx really become the determining forces of the ability to sing, and a great deal depends upon securing for them the necessary practice, as for instance for the execution of rapid successions of tones. And herein lies the difference in the voices of singers, the purity of the tone depending upon the accuracy with which they put the vocal cords upon the stretch, while in those whose tones are impure and faulty, the difficulty lies in their inability to give the requisite tension, and of course the muscles take part in the shortcoming. A correct idea of the sound, height, and depth, of the tone which the singer intends to communicate, enables him to strike the correct tension as by intuition, and carries him along its continuance, and through its purity of modulation, until it has ceased.

DR. DRAPER'S LECTURE ON EVOLUTION.[1]

ITS ORIGIN, PROGRESS, AND CONSEQUENCES.

WHEN, in the beginning of the present year, I received a request to deliver before this Institute a lecture on the subject of Evolution, I was at first disposed to excuse myself. Holding religious views which, perhaps, in many respects are not in accordance with those that have commended themselves to you, I was reluctant to present for your consideration a topic which, though it is in truth purely scientific, is yet connected with some of the most important and imposing theological dogmas. Whatever conclusion is eventually reached respecting it will have an influence on them. But there was that liberality of sentiment in your letter—that earnest desire for the ascertainment of truth—that I cast aside these hesitations, and am now here in obedience to your wishes.

Not that I can do justice in an hour to so great a subject, the literature of which ranges through many centuries. It is no new-fangled romance, as some would have us believe. It comes to us from a venerable antiquity. The theorems it expresses, and indeed on which it is based, have long ago been clearly known.

Considering the shortness of the time allotted me, the vast extent of the subject, the special character of this audience, and the nature of your request, I perceive that it is not an elaborate exposition of the evidence in favor of the theory of evolution that I must

[1] The ministers of the Unitarian Church have recently held a meeting of their Institute at Springfield, Massachusetts. They had requested Dr. John W. Draper to deliver before them a lecture on the subject of Evolution. This accordingly was done on Thursday, October 11th. Some passages omitted in the lecture for want of time are here introduced.

give, but a reference to those facts connected with it that are of chief interest to you. I must bear in mind that this is an institute of clergymen seeking information on a topic which they consider to have a bearing on their pursuits, and that it is from a corresponding point of view that I must present it.

Two explanations have been introduced to account for the origin of the assemblage of organic beings, plant and animal, that surround us. These are conveniently designated as the hypothesis of Creation and that of Evolution.

The hypothesis of CREATION asserts that Almighty God called into sudden existence, according to his good pleasure, the different types of life that we see. This hypothesis has an ecclesiastical form, that the world, with all its various animals and plants, was created about six thousand years ago. The work was completed in six days, and was perfect, needing no improvement. At the close of each day the Almighty surveyed what he had done, and pronounced it very good. He brought all the animals thus made before Adam in the garden of Eden to receive their names. There was nothing more necessary, and on the seventh day he rested.

The hypothesis of EVOLUTION asserts that from one or a few original organisms all those that we see have been derived, by a process of evolving or development. It will not admit that there has been any intervention of the divine power.

The former of these hypotheses considers each species as independent of all the others; the second considers them as inter-related. Creation reposes on the arbitrary act of God: Evolution on the universal reign of law.

The hypothesis of Evolution in its scientific form presents three factors: 1. Heredity; 2. Environment; 3. Adaptation. By heredity is meant the tendency manifested by an organism to develop in the likeness of its progenitor. By environment, the sum total of the physical conditions by which the developing organism is surrounded—the ambient world. By adaptation, the disposition so to modify as to bring an organism and its environment into harmony. This may be accomplished either by progression or retrogression.

As to the origin of organisms, it withholds, for the present, any definite expression. There are, however, many naturalists who incline to believe in spontaneous generation. In its most improved form it occupies itself with two classes of problems, the direct and the inverse, considering in the former the effect of the environment on the organism, and in the latter deducing from the organism the nature of the environment. Thus Schleiden gathers from the structure of the stems of certain pine-trees the distribution of climates at the time of their growth; and the ancient geographical connections of Madagascar and of Australia may be thus ascertained from their fauna.

After a very long and exhaustive survey of the plants and animals of his own locality, and of all that the power and favor of Alexander the Great enabled him to inspect, this is the result to which Aristotle, the prince of ancient Greek naturalists, came. In the eighth book of his "History of Animals," when speaking of the chain of living things, he says: "Nature passes so gradually from inanimate to animate things, that from their continuity the boundary between them is indistinct. The race of plants succeeds immediately that of inanimate objects, and these differ from each other in the proportion of life in which they participate; for, compared with minerals, plants appear to possess life, though when compared with animals they appear inanimate. The change from plants to animals is gradual; a person might question to which of these classes some marine objects belong." Aristotle referred the primitive organisms to spontaneous generation.

In the Museum of Alexandria the views of Aristotle were greatly expanded. There it was discovered that animated Nature presents something more than a mere connection; that each link of Aristotle's chain, if such a phraseology must be continued, was the descendant of its predecessor, the progenitor of its successor. The idea now lost its mechanical aspect and assumed a physiological one.

We remark an important extension of this view after the conquest of Alexandria by the Arabians. If we compare the order of affiliation in successive points, it obviously presents a new fact—progress; and not progress only, but progress from the imperfect to the more perfect. This view included lifeless as well as living Nature. A practical application of it arose, to which the designation Alchemy was given. There is an unceasing progression, in which all things take part, to a better and nobler state. In this slow development Nature has no need to hasten; she has eternity to work in. Thus, in the mineral world, base and unworthy metals, such as lead and tin, are slowly on their way to perfection. They reach their goal on turning into gold. It is, then, for us to ascertain the favoring conditions, and, by imitating or increasing them, to hasten on the work.

The literature of those ages is pervaded with the idea of the mutability of everything—a proneness of all living beings to suffer transmutation, with changes in the environment, or in the physical conditions to which they are exposed; and thus arises a slow but continuous procession, in the unceasing lapse of time, to the beautiful and good. We meet with this in both the serious philosophical works of the Mohammedans, and in their lighter compositions of romance. They wrote books on the production of animals both by generation and putrefaction. They thought that in the germ there exists a latent force tending to evolve it. Ibn Roschd says: "There are, as respects the origin of living beings, two opposite theories. Some explain their existence by development, others by creation. The latter is the opinion of the Christians, as well as of our Motacallemin." Abubacer accepts the reality of spontaneous generation by means of putrefaction and the action of the sun. These philosophers did not hesitate to say that the dogma of creation is an impossibility, an absurd opinion, only fit for the vulgar who will believe anything. According to these elevated views, living beings are merely a movement of matter under the influence of heat. Man himself is like the flame of a lamp, a form or shape through which material substance is passing, receiving supplies, dismissing wastes, and evolving force. As regards transmutation, Al Khazini says that an animal passes through successive stages of development, but we must not suppose that naturalists mean to say that "man was once a bull, and was changed into an ass, and afterward into a horse, and after that into an ape, and finally became a man."

Arabian philosophers had therefore speculated on spontaneous generation, and the conditions necessary for its occurrence; on the development of a germ by the latent force it contains; on the transmutation of species; and the production of the animal series. They had rejected the theory of creation, and adopted that of evolution. They had gained ideas respecting the unceasing dominion of law, but at these they had arrived through their doctrine of emanation and absorption, rather than from an investigation of visible Nature. In the religious revolt against philosophy that took place toward the twelfth century, these ideas were exterminated and never again appeared in Islam.

If the doctrine of the government of the world by law was thus held in detestation by Islam, it was still more bitterly refused by Christendom, in which the possibility of changing the divine purposes was carried to its extreme by the invocation of angels and saints, and great gains accrued to the Church through its supposed influence in procuring these miraculous interventions. The Papal Government was no more disposed to tolerate universal and irreversible law than its Paynim antagonist had been. The Inquisition had been invented and set at work. It speedily put an end, not only in the south of France, but all over Europe, to everything supposed to be not in harmony with the orthodox faith, by instituting a reign of terror.

The Reign of Terror in revolutionary France lasted but a few months; the atrocities of the Commune at the close of the Franco-German War only a few days; but the Reign of Terror in Christendom has continued from the thirteenth century with declining energy to our times. Its object has been the forcible subjugation of thought.

The Mohammedans had thus brought the theory of evolution up to that point at which, for any further advance, clear views of the operation of law in the government of the world were necessary. In their speculations in this particular they had been guided by theological considerations. These were now to be replaced by others of a more definite and solid kind, derived from physical science.

The starting-point of Christendom in the theory of evolution, for the Mohammedans had now ceased to philosophize, was the publication by Copernicus of the book "De Revolutionibus Orbium Celestium." In this the Pythagorean view of the emplacement of the solar system was revived. The way for this restoration had been prepared by such books as that of Cusa "On Learned Ignorance." He conceived of the universe as a vast organism, the life of which is the breath of God, and which has neither centre nor circumference, but is infinite as its maker. Such views were largely prevalent in Italy, at that time the focus of infidelity, and there Copernicus had been. His work was followed by Kepler's great discovery of the three laws that bear his name.

After the invention of printing, the "Index Expurgatorius" of prohibited books had become essentially necessary to the religious Reign of Terror, and for the stifling of the intellectual development of man. The Papal Government, accordingly, established the Congregation of that Index.

It was very plain that the tendency of Kepler's discoveries was to confirm the dominating influence of law in the solar system, as well as to destroy geocentric and anthropocentric theories. It was, therefore, adverse to the Italian theological views, and to the current religious practices. Kepler had published an epitome of the Copernican theory. This, as also the book itself of Copernicus, was placed in the Index, and forbidden to be read.

The Reformation came. It did not much change the matter. It insisted on the Mosaic views, and would tolerate no natural science that did not accord with them. Nevertheless, under the shadow of the political power it shortly gathered, Newton's "Principia" was safely published. The two great powers into which Christendom was divided held each other in check. The sectarian divisions fast springing up in Protestantism found occupation in their contentions with each other. The bearing which Newton's book had upon those already condemned consisted chiefly in this—it gave indisputable reasons that Kepler's laws are a mathematical necessity. For the finger of Providence it substituted mechanical force. And thus the Reign of Law, that great essential to the theory of evolution, was solidly established.

But not alone did the discoveries of physical astronomy lead to these views. If the heavens were observed, the earth, also, was examined. There could no longer be any doubt that fossil remains were the relics of beings that were once alive, as Xenophanes in the old times, and Da Vinci and Palissy more recently, had affirmed—not mere *lusus naturæ*; that the earth's strata were not all of the same age; that in the oldest no fossils could be found; that there had been a time when there was no life on the earth; that of the strata some are of marine, some of fresh-water formation; that they are often intercalated like leaves in a book, and therefore cannot be referred to any single cataclysm such as the deluge.

From considerations connected with the primary rocks, Leibnitz (1680) had inferred that the earth was once at a far higher temperature than now, and in fact must have been in an ignited state; that it had undergone a gradual cooling. Werner subsequently introduced the Neptunic theory, and Hutton the Plutonic. These cosmographical theories were, however, of less importance than what was done in paleontology. It was discovered that while similar fossil remains extend over vast horizontal surfaces, different fossils are found to succeed each other very rapidly when a vertical examination is made. There is a geological as well as a geographical distribution of plants and animals—geological as to time, geographical as to surface.

In the works of Maillet (1748), and again in those of Buffon, the old doctrine of evolution reappears. A more formal presentment was, however, made by Lamarck in his "Philosophie zoologique," published in 1809. He advocated the doctrine of descent, and announced the propositions now known as Darwinism. According to him, organic forms originated by spontaneous generation, the simplest coming first, and the complex being evolved from them. Variations and transmutations occur through external influences, the environment modifying the organism, and as these in the lapse of time become essential differences, new species arise. Moreover, wants experienced cause the will to develop new organs by the modification of previously-existing ones, and these are transmitted by heredity or generation. Organisms are developed out of one another; so far from being permanent, they have only a temporary existence.

Though an organism tends to be like its progenitor, it will undergo changes by the use or disuse of its parts; by the former it is developed, by the latter deteriorated. The changes produced thus, or by the environment, always have been, and always will be, continuous, not catastrophic.

Lamarck recognized the struggle of each against all. He saw plainly the influence of heredity, and understood the relation of environment and adaptation. He defined in the clearest manner the doctrine of transmutation and theory of descent. According to him, if time enough be allowed, any modification may take place.

So far from meeting with acceptance, the ideas of Lamarck brought upon him ridicule and obloquy. He was as much misrepresented as in former times the Arabian Nature-philosophers had been. The great influence of Cuvier, who had made himself a champion of the doctrine of permanence of species, caused Lamarck's views to be silently ignored, or, if by chance they were referred to, denounced. They were condemned as morally reprehensible and theologically dangerous. In this, the authority of Cuvier in regard to evolution acted as the authority of Newton had done in regard to the undulatory theory of light.

In like manner the views of Oken met with resistance, especially his deduction that the highest animals are the result of development, not of creation. Man, he significantly says, has been developed, not created. He conceived all Nature to be in a process of evolution. His demonstration, that the bones of the skull are only vertebral modifications, however, reconciled many persons to a more favorable opinion of his hypothesis of development.

Geoffroy St.-Hilaire (1828) did not doubt that animals now living are descended by an unbroken succession from extinct ones, by transformation from form to form; that different species are degenerations of the same type, being due to the influence of the environment (*monde ambiant*). He thus became the opponent of Cuvier, and did very much to break down the influence of that zoölogist. In these variations he considered that the organism is passive, differing in this from Lamarck, who thought it active. His views of the influence of the environment were very precise: thus he thought that birds arose from reptiles, through the diminution of carbonic acid and increase of oxygen in the air, at the time of the formation of coal; the activity of the animal circulation becoming greater, and the reptile scales being transformed into the feathers of the bird. As is now known, this was substantially a correct interpretation.

Though the principles of the doctrine of evolution were thus thoroughly understood, the control of heredity, the influence of environment, the modeling by adaptation, public attention failed to be drawn to it until 1844, when there was published in England an anonymous book under the title of the "Vestiges of the Natural History of Creation." In this the author set forth Lamarck's views, and the work, being clearly and attractively composed, passed through a great many editions. Very fortunately, it may be said, it accepted some unsubstantiated facts and contained some physical mistakes. These tempted many skillful and bitter criticisms of hostile theologians. The reviews and journals were filled with their attacks and answers to them. Thus, happily, the whole subject was brought into such prominence that it could be withdrawn into obscurity no more.

In the discussions of this book the author made use of a most important anatomical discovery, that even in the case of the highest species, man himself, the embryo does not simply grow or increase in size, but passes in succession through a series of forms, which, examined from epoch to epoch, are totally dissimilar. It had been the vulgar opinion that after the first moment of conception all the parts of the animal that is to be are present, and that they simply grow. The human embryo, according to this, reaches birth very much in the same way that the infant passes from birth to manhood. That was, I say, the vulgar opinion, but, in laying before our eyes the development of the individual, God has given us a revelation of the course of life by the world.

The evolutionary history of animals establishes that there is not this homogeneousness of development, but that the higher pass through the forms of the lower; that the mammal, for instance, passes through stages at which the lower vertebrates remain fixed. All are therefore pursuing a journey along the same road, though some may travel to a longer, some to a shorter, distance. There is thus a parallelism between individual and race development; a close connection between the phases of development in the individual and in the species.

The type of each animal is from the first as it were imbedded in the embryo and controls its evolvement. The embryo never makes any attempt to change from one type to another, but sometimes the tendency to a form and not the form itself is transmitted.

The parallelism that exists between the career of the individual and the career of the race reappears in the life of the world. There is a resemblance—indeed more than a resemblance—between the successive forms through which man himself in his prenatal life has passed, and those that have appeared in myriads of ages in the biography of the earth. Common-sense revolts against the idea that these transformations are in the individual due to divine intervention. In that, and in the case of the earth, they must be due to natural law.

In the year 1859 there was published by Mr. Darwin a work on "The Origin of Species by Means of Natural Selection, or the Preservation of Favored Races in the Struggle for Life."

In this, and in other subsequent works, it is shown that the individuals of each species tend to increase in a very rapid ratio—an increase more rapid than that of their means of subsistence. Each has, therefore, to contend with his competitors; and hence all must exhibit "a struggle for existence."

But modifications are incessantly taking place in the form and characteristics of individuals, giving to some an advantage, to some a disadvantage, as compared with their competitors. Hence, the former will prevail, the latter will succumb in the struggle. This in the language of the hypothesis is formulated "the survival of the fittest."

And as the pigeon-fancier or other person who devotes himself to the breeding of animals can produce any form he wishes by selecting its progenitors and pairing them together, exercising thus artificial selection, so if any of the chance-forms that have arisen should be better adapted than others for perpetuation, they will be perpetuated, or Nature may be said to have made a selection. Hence the term "natural selection," which has been made to designate this hypothesis.

It is to be regretted that this phrase "natural selection" has been introduced. It is very unscientific, very inferior to the old expression adaptation. It implies a personification of Nature. It is anthropomorphic. But Nature never selects, never accepts or rejects, knows nothing about duties, nothing about fitness or unfitness. Nature simply obeys laws.

Natural selection is thus supposed to perpetuate an organism after adaptation to its environment has taken place. The change implied by adaptation must precede it. It should be regarded rather as a metaphorical expression than a scientific statement of an actual physical event.

Darwinism, therefore, does not touch the great question as to the manner in which variation of organisms arises. It only teaches how such variations are perpetuated.

The publication of Humboldt's "Essay on the Geography of Plants" (1805) first formally drew the attention of botanists to the connection between the distribution of plants and the distribution of heat on the surface of the earth. As an advance is made from the equator toward the pole in either hemisphere, the mean annual temperature declines, and in succession a series of vegetable zones is encountered, merging gradually into each other, though each, where best marked, is perfectly distinguished from its successor. In the tropics there are the palms which give so striking a characteristic to the landscape, the broad-leaved bananas, and great climbing plants throwing themselves from stem to stem like the rigging of a ship. Next follows a zone of evergreen woods, in which the orange and citron come to perfection. Beyond this, another of deciduous trees, the oak, the chestnut, and the fruit-trees of our orchards. Here the great climbers of the tropics are replaced by the hop and the ivy. Still farther is a belt of conifers, firs, larches, pines, and other needle-leaved trees; and these lead through a range of birches, becoming more and more stunted, to a region of mosses and saxifrages, but which at length has no tree nor shrub; and finally, as the perpetual polar ices are reached, the red-snow alga is the last trace of vegetable organization.

A similar series of facts had long previously been observed by Tournefort in an ascent of Mount Ararat. The distribution of vegetation from the base to the top of the mountain bears a general resemblance to the distribution from the base to the polar regions. These facts were generalized by subsequent observers. It was established that there exists an analogy between horizontal distribution on the surface of the globe, and vertical distribution at different altitudes above the level of the sea. Even in the tropics, if a mountain be sufficiently high, a short ascent suffices to carry us from the characteristic endogenous growths at its foot through a zone of evergreens into one of deciduous trees, and this again into one of conifers, the vegetation declining through mosses and lichens as we reach the region of perpetual snow.

In these cases of horizontal and vertical distribution which thus present such a striking botanical resemblance, there is likewise so clear a meteorological analogy that it is impossible to avoid the conclusion that the distribution of plants depends very largely on the distribution of heat. And, indeed, what better illustration of the influence of heat could we have than this, that by artificially adjusting the temperature of hot-houses we can cause any plant to grow in any latitude?

But temperature alone does not determine the distribution of plants. If it did, we should find the same species in the same isothermal zones. Throughout the old continent, with the exception of the torrid zone, heaths abound; but in America not a single heath occurs. In the New World, through forty degrees on each side of the equator, the cactus tribe flourishes; in the Old not a single cactus is to be seen—the spurges there replace them. So, again, in Australia, the forests present a melancholy, a shadeless character, from their casuarinas, acacias, eucalypti, whereas, if temperature alone were concerned, they should offer the same aspect as the forests of North America and Europe.

As regards animals the same remark may be made. In the temperate zone, eastward beyond the Caspian, there are men whose complexion is yellow; in Europe the complexion is white; the American Indian is red. Asia has its Tibet bear, Europe its brown bear, North America its black bear. The European stag finds in America its analogue in the wapiti, its Asiatic in the musk-deer. The wild-ox of Lithuania differs from the North American buffalo, and this, again, from the Mongolian yak. The llama in America replaces the camel of Asia, the puma replaces the lion. Brazil has had in times long past representatives of its existing sloths and armadillos. Australia, which has isothermal zones like those of other continents, has no apes or monkeys, no cats or tigers, no wolves or bears, hyenas, horses, squirrels, rabbits; no woodpeckers or pheasants. Instead of them it has the kangaroo, wombat, ornithorhynchus, cockatoos, and lories, nowhere else found.

Then, though heat is a dominating influence in the distribution of plants and animals, it is by no means the only one. There are also other conditions, such as the supply of water, the composition of the soil, the access of light, etc. It has been found convenient to group all these together, and to speak of them, as I have already stated, under a single designation, "The Environment."

Change in the environment, and change in its organisms, go hand-in-hand. Should the warmth of the tropics be diffused into the polar circle, a tropical vegetation would replace the vanishing snows.

Should the ices of the poles spread over the temperate region, the reindeer would accompany their invading edge.

While the environment thus influences the organism, the organism reacting influences the environment. The most striking instance of this, perhaps, will be found on comparing the constitution of the atmosphere before and since the Carboniferous epoch. Prior to that epoch, all the myriads of tons of coaly substance now inclosed in the strata of the earth existed as carbonic acid in the air. By the agency of the sunlight acting on the leaves of the luxuriant vegetation of those times, this noxious gas was gradually removed, and replaced by an equivalent volume of oxygen. A hot-blooded, quickly-respiring animal could not possibly exist in an atmosphere laden with carbonic acid. Anterior to the coal deposit, the fauna was cold-blooded and slow-respiring. The flora thus changed the aërial environment, and this, in its turn, reacting, changed the fauna.

It is on all sides admitted that plants tend by their removal of carbonic acid from the air, replacing it by oxygen, to compensate for the disturbance occasioned by animals. In this way, through very many centuries, the same percentage constitution of the atmosphere is maintained, the sum total of vegetable being automatically adjusted to the sum total of animal life—automatically, and not by any interference of Providence—a fact of great value in its connection with the theory of evolution. For, if we admit what has been conclusively established by direct experiment, that plants would grow more luxuriantly in an atmosphere somewhat richer in carbonic acid than the existing one, we may see how upon this condition depends a principle of conservation, which must forever retain the air at its present constitution, no matter how animal life may vary.

Cuvier speaks of the inferior organisms as furnishing us with a series of experiments made by the hand of Nature, an idea often quoted and often admired, but which, perhaps, is scarcely consistent with enlarged conceptions of the system of the world. An organism, no matter how high or low, is not in an attitude of isolation. It is connected by intimate bonds with those above and those beneath. It is no product of an experimental attempt, which, either on the part of Nature or otherwise, has ended in failure or only partial success.

The organic series—an expression full of significance and full of truth implies the interconnection of all organic forms—the organic series is not the result of numberless creative blunders, abortive attempts or freaks of Nature. It presents a far nobler aspect. Every member of it, even the humblest plant, is perfect in itself. From a common origin, or simple cell, all have arisen; there is no perceptible microscopic difference between the primordial vesicle which is to produce the lowest plant, and that which is to produce the highest, but the one, under the favoring circumstances to which it has been exposed, has continued in the march of development, while the career of the other has been stopped at an earlier point. The organic aspect, at last assumed, is the representation of the physical agencies that have been at work—the environment. Had these for any reason varied, that variation would at once have been expressed in the resulting form, which is, therefore, actually a geometrical embodiment of the antecedent physical conditions. For what reason is an offspring like its parent, except that it has been exposed during development to the same conditions as was its parent. Comparative physiology is not a fortuitous collection of experiments. Our noblest conception of it is the conception we have of analytical geometry. Each member of the organic series is an embodied result of a discussion of the equation of life for one special case.

It was a felicitous thought of Descartes that we may represent a geometrical form in an algebraic equation, and, by the proper consideration and discussion of such an expression, determine and delineate all the peculiarities of such a form; that here it should become concave, there convex; here it should run out to infinity, there have a cusp. The equation determines all the peculiarities of the form, and enables us to construct it. In like manner, all living and lifeless forms are related; an increase in the value of one condition carries development forward in one direction; an increase in the value of another condition determines development in another way, and these variations give rise in their succession to the whole organic series.

Nature ever geometrizes and ever materializes. Every organism is the result of the development of a vesicle, under given conclusions, carried out into material execution. It is the incarnation, the embodiment, the lasting register of physical influences, the daughter of the environment.

Let us now rapidly survey the changes that have taken place in the earth's organisms:

In the earliest, or Primordial period, there existed of plants only water-organisms—tangled sea-weeds. Then in the following, the Primary, came the more perfect cryptogams, such as ferns. Then followed, in the Secondary, pine-forests. In the Coal period the phanerogamia developed out of the more perfect cryptogamia. Not until the Chalk did the higher corollifloræ appear. In the beginning of the Tertiary the earth had sufficiently cooled at the poles, climate-zones were produced, and the land was covered with leaved forests. Flowerless plants had been succeeded by flowering ones, the latter first without a distinct corolla, and then by those with one; and of these, first the lower and then the higher.

Turning to the order of succession of animal life—of the Primordial, the forms are skull-less; then in the following, the Primary, came fishes, first those with the heterocercal tail, as in the embryos of existing ones. In the Secondary, reptiles, and out of them birds, were developed; the decreasing amount of carbonic acid and the increasing amount of oxygen permitting that change. Of birds, the earliest had a long, lizard-like tail, composed of thin vertebræ, to every one of which were attached strong, rudder-like feathers in pairs. The same formation of the tail part of the vertebral column still occurs transiently in the embryos of later birds. The transition from the reptile to the bird is manifested by some of the latter having teeth set in one order in grooves, in another in distinct sockets. Among mammals as among fishes the imperfect appeared first. About the middle of the Mesolithic period, out of a branch of the cloacal animals the marsupials were evolved; and in the beginning of the Tertiary the placentals were developed out of the marsupials. The latter were at one time distributed over the whole earth; now they are fast approaching extinction. In Europe, Asia, Africa, not a single member of the group remains. The cloacal animals, the marsupials, the placentals, stand therefore in an order of succession.

Such has been the order of evolution in Europe. For its order in America I may refer you to the recent admirable address of Prof. Marsh before the American Association for the Advancement of Science. The general conclusions at which we arrive in one case are substantiated in the other.

In accordance with his descent, the cloacal structure exists in man in the earlier period of his embryonic life. The separation into two openings takes place about the twelfth week of his uterine development. Shall we not, therefore, infer from the evidence of his embryonic forms that he has been developed step by step out of the lower vertebrates?

In the early stages of their evolution, amphibia, reptiles, birds, cannot be distinguished. The first steps of development in all vertebrates are identical. Man passes now through the same series of transmutations which his animal predecessors passed through in immense spaces of time, long ago. The progress he makes in the lapse of a few days in the darkness of the womb is the same that has been followed by the procession of animated Nature in the lapse of myriads of centuries in the daylight of the world.

From a comparison of their studies embryologists and paleontologists unite in the conclusion that individual development is a rapid repetition of race-development, and that the paleontological movement is to be interpreted by the embryonic. The connecting links supposed to be missing in the former may be sought for in the latter. Individual development, paleontological development, and comparative anatomy, through their combined evidence guide us to a deduction of the genealogy of any organism. The dominion of law is everywhere manifest. The capricious intrusion of a supernatural agency has never yet occurred.

Each of the geological periods has its dominating representative type of life. Perhaps it may be asked: "How can we be satisfied that the members of this long series are strictly the successive descendants by evolution from older forms, and in their turn the progenitors of the later? How do we know that they have not been introduced by sudden creations, and removed by sudden extinctions?" Simply for this reason: The new groups make their appearance while yet their predecessors are in full vigor. They come under an imperfect model which very gradually improves. Evolution implies such lapses of time. Creation is a sudden affair.

A striking illustration of this is offered by two of the most imposing types of life, the reptile and the mammal. The former is the characteristic of the Secondary, the latter of the Tertiary period. In the Secondary, when reptile life was at its culmination, there were reptiles flying in the air, swimming on or in the sea, crawling on the land, or climbing the trees. After this type of life had reached its culmination, and extinction began to set in, that process went forward in a gradual and orderly way. The flying lizards were the first to disappear, then those of the sea; they now have scarcely any representative left. The fluviatile and terrestrial ones, though greatly diminished both in numbers and size, still maintain a struggle for life; but the complete dying out of animated forms, though irresistible, requires for its completion countless centuries.

While reptile life was in full vigor, mammal life was introduced. It came under the lowest forms, the imperfect orders appearing first.

What does this coexistence of two different forms of life, through immense lapses of time—the one declining and on its way to disappearance, the other marching forward to increase—what does this overlapping mean? Not sudden creation, but slow development. The environment is slowly becoming unsuitable to the one, and slowly becoming suitable to the other.

If time permitted, I would ask your close attention to rudimentary organs, for they illustrate strikingly the theory of evolution. They are organs existing in an apparently undeveloped and useless condition, such, for instance, as the incisor teeth in the midbone of the upper jaw in embryos of common cattle, the rudimentary wings of the penguin and dodo, the mammæ of the male mammalian, the subcutaneous feet of certain snakes. In the embryos of whales teeth are found in the jaw, precisely as we find them at birth in the human infant. In the latter instance, we think we see a wise provision and foresight of Nature, which does not give to man these masticatory organs before the time they are wanted. But what are we to make of the parallel case of the whale? Shut up as these rudimentary teeth are in the interior of the jaw, never to be developed and never to be used, does not that look something like a useless work? And why has Nature, in the case of certain snakes, placed under the skin bony representatives of the extremities, the movements of those animals being by the use of the ribs, and feet never being wanted?

We may also turn to the vegetable world, and there we find rudimentary organs, excesses and deficiences of development. As Treviranus says, adaptation to the surrounding world may be shaped either by gradual development or by degeneration, which is equally effective. The same organ may be expanded into a compound leaf, or degenerated into a scale. Development can turn a reptile into a bird; degeneration can turn it into a serpent. Any flower may be regarded as a transformed branch—that which might have evolved into a leaf turns indifferently, as circumstances may direct, into a sepal, a petal, or a stamen.

Rudimentary organs come into existence as part of a general plan. They are the manifestation of heredity in the type of life of the animals or plants in which they occur. They prove that the form has been developing, not teleologically, or for a purpose, but in obedience to law.

Now I have answered, and I know how imperfectly, your question, "How does the hypothesis of evolution force itself upon the student of modern science?" by relating how it has forced itself upon me, for my life has been spent in such studies, and it is by meditating on facts like those I have here exposed that this hypothesis now stands before me as one of the verities of Nature.

In doing this I have opened before you a page of the book of Nature—that book which dates from eternity and embraces infinitude. It reveals millions of suns and worlds of surpassing glory. Among its most insignificant pages are the vast rock-strata of the earth. We have been looking at some of them. No Council of Laodicea, no Tridentine Council, is wanted to indorse its authenticity, nothing to assure us that it has never been tampered with by any guild of men, to perpetuate their influence, secure their profits, or otherwise promote their ends.

Then it is for us to study it as best we may, and to obey its guidance, no matter whither it may lead us.

And this brings me face to face with the third division of my subject. I have spoken of the origin and the progress of the hypothesis of evolution, and should now consider the consequences of accepting it. Here it is only a word or two that time permits, and very few words must suffice. I must bear in mind that it is the consequences from your point of view to which I must allude. Should I speak of the manner in which scientific thought is affected, should I dwell on the influence this theory is exerting on general knowledge, I should be carried altogether beyond the limits of the present hour.

The consequences! What are they, then, to you? Nobler views of this grand universe of which we form a part, nobler views of the manner in which it has been developed in past times to its present state, nobler views of the laws by which it is now maintained, nobler expectations as to its future. We stand in presence of the unshackled, as to Force; of the immeasurable, as to Space; of the unlimited, as to Time. Above all, our conceptions of the unchangeable purposes, the awful majesty of the Supreme Being, become more vivid. We realize what is meant when it is said, "With Him there is no variableness, no shadow of turning." Need I say anything more in commending the doctrine of evolution to you?

Let us bear in mind the warning of history. The heaviest blow the Holy Scriptures have ever received was inflicted by no infidel, but by ecclesiastical authority itself. When the works of Copernicus and of Kepler were put in the Index of prohibited books, the system of the former was declared, by what called itself the Christian Church, to be "that false Pythagorean system, utterly contrary to the Holy Scriptures." But the truth of the Copernican system is now established.

There are persons who declare of the hypothesis of evolution, as was formerly declared of the hypothesis of Copernicus, "It is utterly contrary to the Holy Scriptures." It is for you to examine whether this be so, and, if so, to find a means of reconciliation. Let us not be led astray by the clamors of those who, not seeking the truth and not caring about it, are only championing their sect, or attempting the perpetuation of their own profits.

My friends, let me plead with you. Don't reject the theory of evolution. There is no thought of modern times that more magnifies the unutterable glory of Almighty God! Remember, I beseech you, what was said by one of old times: "Ye men of Israel, take heed to yourselves what ye intend to do. And now I say unto you, if this counsel be of men it will come to naught; but if it be of God, ye cannot overthrow it, lest haply ye be found to be fighting against God"—shall I continue the quotation?—"and to him they all agreed!"

We often hear it affirmed that our age is becoming more and more irreligious, and that men wantonly reject sacred things of which their ancestors approved. But I think we may profitably inquire whether very much of this is not due to the profound changes that are taking place in our conceptions of the Supreme Being? Things and acts which at one time men attributed to him without hesitation, they can attribute to him no more. They have learned to demand of every dogma, "Is it derogatory to the awful majesty of God?"

These modifications of opinion have had no little to do with the progress of the subject we have been considering. Let us ever bear in mind that the doctrine of evolution has for its foundation not the admisssion of incessant divine interventions, but a recognition of the original, the immutable fiat of God. In whatever direction we commune with Nature, the dominion of universal, of everlasting law confronts us.

The establishment of the theory of evolution has not been due to any one science, but is attributable to the conjoint movement of all. It is due to the irresistible advance of human knowledge. To refer it to geology alone, as is often done, is altogether a mistake. It was not possible that Astronomy should fail to maintain her grand position. She took the lead in the intellectual revolution which marks the close of the middle ages. Single-handed and alone, she fought and won the great battles of the globular form of the earth, the central sun, the plurality of worlds. It cost her the blood of some of her leaders. For some there was the fagot, the rack, the prison-cell, the scourge. But they departed from their tormentors, rejoicing that they were accounted worthy to suffer even death in this cause. And now she found stepping-stones for herself in the trackless infinitude of space, and beckoned her comrade sciences to come and share with her the glorious view she had gained of the majesty of the universe. Anatomy, both human and comparative, paleontology, chemistry, physiology, microscopy, even philosophical history, have given their aid. Wherever any one science has made a marked advance, its movement has been covered by some of the others, and the ground thus occupied secured. As matters now stand, all are well to the front—the entire line is dressed.

It often takes many victories to establish one conquest. Knowledge, fresh from so many triumphs, unfalteringly continues her movement on the works of Superstition and Ignorance.

Now, in parting, let us bear this in mind: So great is the intellectual advance men have made, that questions which at one time divided Christendom into sects are now far in the rear. Those which once separated good men socially, are passing out of sight. They are replaced by others of a very different order. Among such, one of surpassing importance confronts us—the eternal reign of law. Let us bear in mind what the theory of evolution so loudly proclaims: "We are what we are, because the universe is what it is." If it acts upon us, we react upon it. Our conception of the sphere of being we occupy is enlarging, and we are thus brought into close relationship with all that is beautiful on earth, all that is magnificent in the heavens.

Then let us reverently commune with Nature. Let us try to raise our eyes from the varying phenomena of the world, to the solemn grandeur of that silent, that imperishable reign of law that governs all those changes; let each of us earnestly address to himself the remonstrance of "The Minstrel:"

"Oh! how canst thou renounce the boundless store
Of charms that Nature to her votary yields,

The warbling woodland, the resounding shore,
The gloom of groves, the garniture of fields,
All that the genial ray of morning gilds,
And all that echoes to the song of even,
All that the mountain's sheltering bosom shields,
And all the dread magnificence of heaven—
Oh! how canst thou renounce, and hope to be forgiven?"

THE GREAT BENGAL CYCLONE OF 1876.[1]

By CARL DAMBECK.

NO more convincing proof could, perhaps, be given of the headlong pace of our modern life, or of the thoughtlessness of our age, than the fact that, though we still hear of the earthquake at Lisbon, hardly a word is said of the fearfully destructive cyclone which, on the 31st of October, 1876, swept over the Delta of the Ganges. Even in the queen's last speech from the throne, there is not so much as a simple mention of that disastrous event, whereby a quarter of a million of British subjects in India were destroyed. The after-effects of the cyclone in themselves constituted a fearful calamity, for thousands are still[2] dying of disease and hunger—evils the seeds of which had been sown in October.

Cyclones usually occur toward the end of spring and in the fall—from April to June, and from September till November—the periods of the change of direction in the monsoons. By far the greater number of the cyclones occur at the cessation of the southwest and the setting in of the northeast monsoons in the fall: out of eighty-eight observed in the Indian Ocean, forty-nine occurred in the fall and only twenty-nine in the spring. The former, almost without an exception, came from a point lying somewhat to the north of latitude 15° north, in the bay of Bengal; while the latter had their rise in the neighborhood of the Andaman Islands. The whole east coast of India is exposed to the fury of these storms, and from Ceylon to Chittagong there is hardly a point on the coast that has not more or less frequently felt the power of the cyclones, though the localities which suffer most are the low-lying portions of the coast, more particularly when they are situated in a bight or in an angle, for wind and water are there brought into violent conflict. One of the earliest cylones of which authentic accounts are extant occurred in 1789, at an unusual season of the year—December. Furthermore, it was attended by three enormous storm-waves, which flooded the coast at Coringa,

[1] Translated from the German, by J. Fitzgerald, A. M.

[2] May, 1877, when this article was written.

near the mouth of the Godavary, destroying nearly the entire town with its 30,000 inhabitants, and driving far inland the ships which lay at anchor in the bay. In 1839 the same locality was visited by another cyclone, which was nearly as destructive as the preceding. The coast of Madras and of Coromandel has again and again been the theatre of cyclones, though here the wave is not so destructive in its effects as elsewhere, owing to the situation and the formation of the coast. In Madras the cyclone usually appears to expend its fury on the many ships at anchor in the roads, and on the buildings on the land, as was the case in the years 1773, 1783, and 1872. As on October 15, 1783, so on the 1st and 2d of May, 1872, an enormous amount of shipping was lost. In the latter case the greater part of the vessels might have put out to sea, if the officer of the port had been at his station and given warning in time. The destruction of life and property caused by the wind and rain, as also by the swell of the sea, was very considerable. Another cyclone which on October 15 and 16, 1874, swept the inland districts of Midnapore and Burderan, claimed but few victims comparatively: in Midnapore only about 3,000 persons lost their lives, while in Burderan there were but a few fatal casualties. Of all the coasts of India the mouths of the Ganges and the Hooghly appear to have suffered oftenest and most severely from this catastrophe, for there wind and water are, as it were, "forced into one sack."

Thus the country situated about the mouth of the former river was, on October 31, 1831, overflowed by a storm-wave to a distance of 150 miles from the coast, and 300 native villages with their 10,000 inhabitants were destroyed; and it was visited a second and a third time by cyclones on October 7, 1832, and September 21, 1839. At the mouth of the Hooghly on the 21st of October, 1833, some 10,000 lives were lost in a storm-wave, and on May 21st of the same year, near Coringa, 600 villages, with 50,000 souls, were swept away. In the last-named case the wave rose nine feet higher than the highest point ever before observed, and the barometer suddenly fell all of two inches. During the cyclone of October 5, 1864, at Calcutta, 1,500 square miles of country was overflowed, though the banks of the Hooghly and its tributaries, and the shores of the islands in the mouth of the stream, were protected by dikes eight to ten feet high. But even though these dikes had been sufficiently strong to resist the pressure of the water, still they were far from being sufficiently high. On this occasion the storm-wave rose sixteen and a half feet over the water-mark of the spring-tide, and twenty-seven feet above the mean level of the sea; still, it attained this height only because it entered the river at about high water. The wave was noticed as far as Mehurpore, on the Matabangha. It caused the loss of 50,000 human lives, but the destruction of life would have been far greater had the cyclone occurred at night, and had the people, as at Bacarganch been surprised in their sleep. While this wave was ascending the Hooghly, and spreading over the neighboring districts, a portion of the same wave seems to have struck the coast near Chittagong, and, having swept along the same, to have overflowed the islands of Shahabazpore and Hattia from the rear. And this is the cause of the fearful devastation it wrought, for we shall not err if we suppose waves coming from two opposite directions to have met at these islands The number of human victims in the catastrophe of 1864 was nearly doubled in consequence of the diseases produced by the multitude of unburied dead bodies, and which carried off 30,000 souls. Hardly four weeks after the Hooghly catastrophe of 1864, namely, on November 5th, the coast at Masulipatam, on the Kistnah—a locality specially adapted for concentrating the force of the storm-wave and intensifying its powers of destruction—was overflowed and 35,000 lives were lost. Three years later, on November 1, 1867, the Calcutta district was again visited; but, fortunately, on this occasion only 1,000 lives were lost, though 30,000 huts of the natives were swept away. But of all the disasters of this kind which have occurred prior to 1876, that of June 6, 1822, was the most appalling and destructive, and the only one to be compared with that of last October. As is shown by Beveridge in his recently-published work on Bacarganch, the cyclone had a very wide track, extending far inland on the east, and beyond Calcutta to the west. The wave which overflowed the mouths of the Ganges and the adjoining coasts fortunately appeared early in the evening, and the people were somewhat prepared for it; nevertheless, 100,000 human beings lost their lives, and an equal number of cattle, and the damage otherwise exceeded 1,000,000 rupees.

Concerning the latest deplorable catastrophe, we possess the following data: Down to 11 P. M. there was no sign of impending danger; before midnight the storm burst suddenly, and without warning, surprising the people in their beds and dwellings. Three storm-waves swept over an area of 3,000 square miles, containing a population of 1,000,000 souls. In a few minutes, 215,000 human beings were swept off by the waters, and there perished. This estimate, however, is probably far too low; for nearly all the officials from whom authentic information might have been obtained themselves perished in the flood, and many villages are known to have lost seventy per cent. of their inhabitants. This is undoubtedly the gravest calamity ever caused by water. Three great islands, and innumerable small ones, were entirely swept by the flood, as also the mainland, over an area of five or six miles in length by about four miles in width. These islands all lie near the mouth of the Meghna, a river formed by the union of the Ganges with the Brahmapootra. The largest of the islands—Dakhin Shahabazpore—is 800 miles in circumference, and had 240,000 inhabitants, while the other two great islands—Hattia and Sundney—had in all about 100,000 inhabitants. The people had only a few minutes to think of their safety, when the wave rose ten to twenty feet above the land. Two hours later the flood began to subside, but not till noon of the following day could the survivors quit their places of refuge in the trees, etc. As luck would have it, the villages are surrounded by groves of cocoanut and palm trees: those who saved themselves did so by taking to the trees. Some took refuge on the house-tops, but the water entered the houses and rose to the roofs, and carried them off to the sea, together with the people upon them. There was hardly a household on the islands, or on the neighboring coast, but had lost several of its members. All the cattle were lost. Boats were swept away, and as wagons on wheels are unknown in that region, all means of communication failed. Nearly all of the civil and police officials perished. The town of Dowluctor was utterly destroyed. The loss in cattle cannot be estimated. The crops suffered greatly, but it is hoped that enough remains to prevent a famine. The entire flooded region looks like a waste. Still the condition of the survivors just after the catastrophe was better than was to have been expected. The farmers of that region are the most thrifty in Bengal; the provisions are mostly kept buried in the ground; hence, though they were damaged by water, they can still be used for food. Wherever Sir R. Temple went he found the people drying grain in the sun. Until harvest-time, the cocoanuts will be of some assistance. Prior to the calamity, the harvest promised to be very bountiful; as it is, it will be a fair one. About sixty relief-stations were established. The official journal says: "Wherever the storm-wave struck, not a third part of the population, it is believed, survives. The islands have only a fourth of their former inhabitants. The odor of the decaying carcasses is intolerable, and a general outbreak of cholera is hourly expected." From an official communication, it appears that there perished in Chittagong during the storm over 3,000 souls, and between October 31st and December 31st, 4,399 persons died of cholera. Since New-Year's cholera has raged fearfully. In the district of Noakholly there died in October 43,544 persons, and in the following three months 30,263. Indeed, with the exception of the islands of Hattia and Sundney, the deaths from cholera everywhere have exceeded those caused by the inundation. On these two islands the number of deaths in October was 34,708; later it was only 7,139.

Thus, in the course of eighty-seven years, half a million of human beings have lost their lives by cyclones, without counting the mortality from pestilence and famine.—*Das Ausland.*

OUR SIX-FOOTED RIVALS.

I.

LET us suppose that, having no previous acquaintance with the subject, we were suddenly informed, on good authority, that there existed in some part of the globe a race of beings who lived in domed habitations, aggregated together so as to form vast and populous cities; that they exercised jurisdiction over the adjoining territory, laid out regular roads, executed tunnels underneath the beds of rivers, stationed guards at the entrance of their towns, carefully removed any offensive matter, maintained a rural police, organized extensive hunting-expeditions, at times even waged war upon neighboring communities, took prisoners and reduced them to a state of slavery; that they not merely stored up provisions with due care, to avoid their decomposition by damp and fermentation, but that they kept cattle, and in some cases even cultivated the soil and gathered in the harvest. We should unquestionably regard these creatures as human beings who had made no small progress in civilization, and should ascribe their actions to reason. If we were then told that they were not men, and they were in some places formidable enemies to man, and had even by their continued molestations caused certain villages to be forsaken by all human occupants, our interest would perhaps be mixed with some little shade of anxiety lest we were here confronted by a race who, under certain eventualities, might contest our claim to the sovereignty of the globe. But when we learn that these wonderful creatures are insects some few lines in length, our curiosity is cooled; we are apt, if duly guided by dominant prepossessions, to declare that the social organization of these beings is not civilization, but at most *quasi*-civilization; that their guiding principle is not reason, but "instinct," or *quasi*-intelligence, or some other of those unmeaning words which are so useful when we wish to shut our eyes to the truth. Yet that ants are really, for good or evil, a power in the earth, and that they seriously interfere with the cultivation and development of some of the most productive regions known, is an established fact. A creature that can lay waste the crops of a province or sack the warehouses of a town has claims upon the notice of the merchant, the political economist, and the statesman, as well as of the naturalist.

Many observers have been struck with the curious mixture of analogies and contrasts presented by the Annulosa and the Vertebrata. These two classes form, beyond any doubt, the two leading subdivisions of the animal kingdom. To them nineteen-twentieths of the population of the dry land, both as regards individuals and species, will be found to belong, and even in the world of waters they are largely represented. At the head of the Vertebrata stands the order of the Primates, culminating in man. At the head of the Annulosa the corresponding place is taken by the Hymenopterous insects. It is very remarkable—as first pointed out, we believe, by Mr. Darwin—that these two groups of animals made their appearance on the earth simultaneously. But along with this analogy we find a contrast. Man stands alone among the Primates as a socially organized being, possessing a civilization. Among the Hymenoptera the lead is undoubtedly taken by the ants, which, like man, have a brain much more highly developed than that of the neighboring inferior groups. But there is no one species of ant which enjoys a preëminence over its congeners anything at all approaching in its nature and extent to man's superiority over the gorilla or the mias. What may be the cause of this contrast we know not. Perhaps it is merely due to the tendency of the Annulosa to branch out into a scarcely numerable host of forms, while the vertebrate structure, less plastic, lends itself more sparingly to variation. Perhaps, on the other hand, lower human or higher ape forms than any now existing have been extirpated, as the traditions of many ancient nations would seem to admit.

At any rate, while the superiority of the ants as a group to the remaining Hymenoptera, to all other insects, and to the rest of the annulose "sub-kingdom," is undisputed, we are unable to decide which species of ant is elevated above the rest of the Formicide family. Possibly more extended and more systematic observations may settle this interesting question. According to our present knowledge the claims of the agricultural ant, of Western Texas (*Myrmica barbata*), seem, perhaps, the strongest. This species, which has been carefully studied by Dr. Linceceum, for the space of twelve years, is, save man, the only creature which does not depend for its sustenance on the products of the chase or the spontaneous fruits of the earth. As soon as a colony of these ants has become sufficiently numerous they clear a tract of ground, some four or five feet in width, around their city. In this plot all existing plants are eradicated, all stones and rubbish removed, and a peculiar species of grass is sown, the seeds of which resemble very minute grains of rice. The field—for so we must call it—is carefully tended by the ants, kept free from weeds, and guarded against marauding insects. When mature, the crop is reaped and the seeds are carried into the nest. If they are found to be too damp they are carefully carried out, laid in the sunshine till sufficiently dry, and then housed again. This formation of a plot of cleared land—or, as Dr. Linceceum not very happily terms it, a pavement—is a critical point in the career of a young community. Any older and larger city which may lie within some fifty or sixty paces looks upon the step as a *casus belli*, and at once marches its armies to the attack. After a combat, which may be prolonged for days, Providence declares in favor of the largest battalions, and the less numerous community is exterminated, fighting literally to the last ant. Where a colony is unmolested it increases rapidly in population, and undertakes to lay out roads: one of these, from two to three inches in width, has been traced to a distance of 100 yards from the city. These ants are not very carnivorous, nor do they damage the crops of neighboring farmers. Persons who intrude upon the "pavement" are bitten with great zeal, but otherwise the species may be regarded as harmless. One creature alone they seem to tolerate on their "pavement"—the so-called small black "erratic" ant—which, as Dr. Lincecum conjectures, may be of some use to them, and which is therefore allowed to build its small cities in their immediate neighborhood. If it becomes too numerous, however, it is got rid of, not by open war, but by a course of systematic and yet apparently unintentional annoyance. The agricultural ants suddenly find that it is necessary to raise their pavement and enlarge the base of their city. In carrying out these alterations they literally bury the nests of their neighbors under heaps of the small pellets of soil thrown up by the prairie earth-worms, and continue this process till the erratic ants in sheer despair remove to a quieter spot.

Concerning the government either of the agricultural ants or of other species, our knowledge is of a very negative character. The queens, or rather mothers, of the city are indeed treated with great attention, but their number is quite indefinite, and, unlike female hive-bees, no jealousy exists between them. How their migrations, their wars, their slave-hunts, are decided on, or even how the guards on duty are appointed, and the visiting parties selected who go round to inspect the works, and who sometimes insist on the destruction and rebuilding of any badly-executed portion, we are utterly ignorant. The outer manifestations of ant-life we have to some extent traced; but its inner springs, its directing and controlling powers, have eluded our observation.

It has been remarked, in the *Quarterly Journal of Science*, that ants, unlike man, have solved the problem of the practical organization of communism: this is literally true. In a formicary we can detect no trace of private property; the territory, the buildings, the stores, the booty, exist equally for the benefit of all. Every ant has its wants supplied, and each in turn is prepared to work or to fight for the community as zealously as if the benefit of such toil and peril were to accrue to itself alone. If the principle—so common among men—that there is no harm in robbing or defrauding a municipal body, or the nation at large, crops up in an ant-hill at all, it must evidently be stamped out with an old-fashioned promptitude. But, to understand why the ant has succeeded where man has failed, we must turn to certain fundamental distinctions between human and ant society; or, perhaps, speaking more generally, between the associations of vertebrate and those of annulose animals. A human tribe or nation—and, in like manner, e. g., a community of beavers or of rooks—is formed by the aggregation, not of single individuals, but of groups, each consisting of a male, a female, and their offspring. The social unit among vertebrates, therefore, is the family, whether permanent or temporary, and whether monogamous or polygamous. In numberless cases the family exists without combining with other families to form a nation, but we greatly doubt if there exists a single case of a vertebrate nation not formed of and resolvable into families.

Among the Annulosa this is reversed. The family among them scarcely exists at all. Rarely is the union of the male and the female extended beyond the actual intercourse, all provision for the future young devolving upon the latter alone. Among the rare exceptions to this rule, we may mention the burying-beetle, and some of the dung-beetles, both sexes of whom labor conjointly to find and inter the food in which the eggs are to be deposited. Generally speaking, moreover, the young insect never knows—never even sees—its parents, who in most cases have died before it has emerged from the egg. Among non-social insects the earwig and a few other Orthoptera form the chief exceptions. Where a regularly organized society, a nation, or tribe, exists among annulose animals, it is not formed by the coalescence of families to a higher unity. The family, if it can be said to exist at all, is conterminous and identical with the nation. This absence of a something whose claims are felt by all ordinary men to be stronger than those of the state has rendered the successful organization of the "commune" feasible among ants, and among other social Hymenoptera, such as bees, wasps, etc. With them the state has no rival, and absorbs all the energies which in human society the individual devotes to the interests of his family. We thus see that theorists on social reform have been, from their own point of view, logically consistent in attacking the institution of marriage and the whole system of domestic life: they have sought to abolish the great impediment to the commune, and to approximate man to the condition of our six-footed rivals, and to constitute society not as heretofore of molecules, but of atoms.

But it is not enough to show that the failure of communism among mankind and its success among certain Hymenopterous insects are due to the existence and the power of the family in the former case, and to its absence in the latter. We have yet to inquire into the wherefore of so important a distinction. Vertebrate society, where it exists at all, is founded on family life, because every vertebrate animal is sexual, and as such is attracted to some individual of the opposite sex by the strongest instinct of its nature, that of self-preservation alone excepted. Invertebrate society, where it exists in perfection, as among the Hymenoptera, is not formed by a union of families, because the great majority of Hymenopterous individuals (in the social species) are non-sexual, neuter, incapable of any private or domestic attachments, and devoted to the community alone. To attempt, without the existence of such an order, to introduce the social arrangements of the ant—i. e., communism—among mankind is as futile and as irrational as the endeavor to fly without wings: the very primary conditions for success are wanting.

It may not be amiss to examine a little further in the same direction. Among men there is a great diversity both in intellect and in energy. The more highly-endowed individual, if he does not leave his children in a better position, materially speaking, is likely to transmit to them his own personal superiority. In this manner the theoretical equality assumed as one of the bases of communism is in practice annihilated. Among ants nothing of this kind can prevail. The workers and the fighters are sexless. If any individual is superior to its fellows in strength or in intelligence—and we have every reason to believe that such must be the case—it has no posterity to whom its acquisitions could be bequeathed or its personal superiority handed down. Hence the formation of an aristocracy is impossible, and whatever benefit may result from the labors of such an exceptional individual flows to the entire community. In the converse manner the formation of a pariah, a criminal, or a pauper class, is frustrated, and the public is not burdened with useless or dangerous existences.

It is indisputable that this arrangement, joined to the brief term of insect-life, must greatly retard the progress of the ant in civilization. It has been remarked that were human life longer our development in knowledge and in the arts would be much more rapid. Take our present condition: by the time a man has completed his education, general and special—has fully developed his own mental faculties and mastered the position of the subject he has selected—he will be rarely less than five-and-twenty years of age. By the time he is fifty, as a rule, his power of origination begins to decline, and the remainder of his life is spent more in completing and rounding off the work of his younger days than in making fresh inroads into the unknown. Did our full vigor of intellect extend over a century, instead of over a fourth of that duration, we should undoubtedly effect much more. On the other hand, a shortening of our time of activity would have a powerfully retarding effect on the career of discovery and invention. Can we, then, wonder if the short-lived ant and bee sometimes appear to us stationary in their civilization? But this very brevity of the career of each individual acts decidedly in favor of the preservation of social equality. If either ant or man is disposed to rise or to fall, then the shorter the time during which such rise or fall is possible the better will the uniform level of society be preserved. To prevent misunderstanding we must remark that castes with a corresponding difference of duties, and, according to some authorities, with a diversity of honor also, do occur in the ant-hill; but within each caste all are on an exactly equal footing.

If we compare the zoölogical rank of our "six-footed rivals" with our own, we must, from one point of view, concede them a higher position. The more perfectly developed is any animal the more do we find it possessed of an especial organ for the discharge of every function. In like manner it may be contended that, as a species rises in the scale of being, duties once indiscriminately performed by all the species are assigned to distinct individuals. Among the humbler groups of the animal kingdom the whole reproductive task is performed by all members of the species. In other words, hermaphroditism prevails. As we ascend to higher groups the sexes are separated, and the species becomes dimorphous. This arrangement prevails among all vertebrate animals, and among a large majority of annulose species. We find here already, however, one of those contrasts which so often prevail between these two great series of beings. Among vertebrates, and especially in mankind, the function of the female sex seems limited to the nurture—intra- and extra-uterine—of the young. Were man immortal and non-reproductive, woman's *raison d'être* would disappear. Among Annulosa the very reverse holds good; the females are as a rule larger, stronger, and more long-lived, while the task of the male seems limited to the fecundation of the ova. This being once performed, his part is played. Among butterflies, moths, and ants, his death speedily follows, while among spiders he is generally killed and devoured by his better-half. This predominance of the female sex seems to prepare the way for the phenomenon which we recognize among the social Hymenoptera. Here the species become no longer dimorphous, but polymorphous. In other words, in addition to the males and females, whose task is now exclusively confined to the mere function of reproduction, there are, as we have seen, one or more forms of females, sexually abortive, but so developed in other respects as to form the castes of workers and fighters, upon whom the real government of the ant-hill devolves, who provide for its enlargement, well-being, and defense.

It may, we think, be legitimately contended that the development of a distinct working order is a step in advance similar to that taken by the distribution of the sexual functions among two different individuals—that the polymorphic species is higher than the dimorphic, just as the dimorphic is higher than the monomorphic.

Of the development of a neuter order among vertebrate animals, and especially among mankind, we know nothing which can be fairly called a trace. But, in comparing the two civilizations, that of man and that of the ant, we must be struck with the fact that the former has from time to time imitated this peculiar feature. The attempts, however, whether made by the devotion of certain classes to celibacy or by actual emasculation, have been as unsuccessful as the sham elephants of Semiramis. Celibates retaining the sexual appetite, but deprived of its legitimate exercise, have always been a disturbing force in society. On the other hand, emasculation, instead of—as might have been perhaps, *a priori*, anticipated—increasing the powers of body and mind, enfeebles both. What would be the moral and social effects of the appearance of a neutral form of the human species analogous to the working bee or ant it is impossible to foresee; but we may venture to surmise that they would not be entirely desirable.[1]

It may be suggested that the institution of caste among so many human races is an adumbration of the natural castes existing among social insects, each devoted to some especial function.

The remarkable intelligence of ants has from very early ages made a profound impression on man. Cicero considered them possessed of "mind, reason, and memory."[2] To the present day those who watch the formicary, not in order to defend prepossessions, but to arrive at truth, come to the same conclusion, unpopular though it may be. We sometimes wonder whether ants, like men, consider themselves the sole reasonable beings on the globe, prove their position by sound *a priori* arguments, and accuse those who take a different view of "skepticism" or "agnosticism."

When it is no longer possible to meet with a flat denial all instances of correct inferences drawn and of happy contrivances adopted by brutes in general and by ants in particular, the writers who still claim reason as the exclusive prerogative of man bring forward a curious objection: they urge that we should likewise collect proofs of animal folly and stupidity, and seem to think that these latter instances would nullify any conclusion that might be drawn from the former. That instances are numerous where some animal fails to draw an inference—very obvious, in our view—or to adopt some very simple expedient, we do not deny, and that their conduct hence seems strangely checkered, we admit. What, e. g., can seem more inconsistent than the following cases? Sir John Lubbock, to test the intelligence of ants, placed a strip of paper so as to serve as a bridge or ladder for some ants which were carrying their pupæ by a very roundabout way. The slip was, however, purposely left short of its destination by some small fraction of an inch. It would have been very easy for the ants either to have dropped themselves and their burden down this short distance, or to have handed the pupæ to the other ants below, or to have piled up a small amount of earth from below, so as to meet the slip of paper, and thus make the descending road continuous. They adopted, however, none of these expedients, but continued to travel the roundabout way.

[1] It is very remarkable that among the Termites, which, though improperly called "white ants," belong to a different order of insects, neuters exist. These, however, do not appear to be imperfectly developed females. It would thus seem that among insects social organization necessitates a class of sexless individuals.

[2] "Mens, ratio, et memoria."

On the other hand, Mr. Tennant tells us that *Formica smaragdina*, in forming its dwellings by cementing together the leaves of growing trees, adopts the following method: A line of ants, standing along the edge of one leaf, seize hold of another, and bring its margin in contact with the one on which they are posted. They then hold both together with their mandibles, while their companions glue them fast with a kind of adhesive paper which they prepare. If the two leaves are so far apart that a single ant cannot reach from one to another, they form chains with their bodies to span over the gap. The same author also informs us that certain Ceylonese ants, when carrying sand or dry earth for the construction of their nests, glue several grains together so as to form a lump as large as they can carry, and thus economize time and labor.

Mr. Belt, in his "Naturalist in Nicaragua" (page 27), gives the following account of the manner in which the *Ecitons*, or foraging ants of Central and South America, deal with what may be called engineering difficulties: "I once saw a wide column trying to pass along a crumbling, nearly perpendicular slope. They would have got very slowly over it, and many of them would have fallen, but a number having secured their hold and reaching to each other remained stationary, and over them the main column passed. Another time they were crossing a water-course along a small branch, not thicker than a goose-quill. They widened this natural bridge to three times its width, by a number of ants clinging to it and to each other on each side, over which the column passed three or four deep; whereas, except for this expedient, they would have had to pass over in single file, and treble the time would have been consumed."

Again, in *Eciton legionis*, according to Mr. Bates, when digging mines to get at another species of ant whose nests they were attacking, the workers were divided into parties, "one set excavating and another set carrying away the grains of earth. When the shafts became rather deep the mining parties had to climb up the sides each time they wished to cast out a pellet of earth, but their work was lightened for them by comrades who stationed themselves at the mouth of the shaft and relieved them of their burdens, carrying the particles, with an appearance of foresight which quite staggered me, a sufficient distance from the edge of the hole to prevent them from rolling in again."

What, then, are we to learn from these somewhat inconsistent cases? Are we to conclude that Sir John Lubbock, Mr. Belt, Mr. Bates, and Mr. Tennant, must be careless and incompetent observers? Assuredly not. Are we to believe that ants are stupid, irrational creatures, and that when they do anything right it must be regarded as an accident or ascribed to that convenient phantom, instinct? Still less: the well-established cases which are on record agree badly with either of these suppositions. The true explanation of the difficulty is that, like all finite intelligences, ants are not equally wise on all occasions. Sometimes they hit upon the best expedient for evading or overcoming an obstacle, but sometimes, under circumstances not more complicated, they fail. This is doubtless the case with man himself. If contemplated by some being endowed with higher reasoning powers, would he not be pronounced a most curiously inconsistent mixture of sagacity and stupidity, now solving problems of no small difficulty, and now standing helpless in presence of others even more simple? That such is in reality the case with man is proved by the history of discoveries, and of their reception. Do we not always say when we hear of any great step, whether in scientific theory or in the practical arts, "How simple, how natural!" Yet, simple and natural as it is, all sorts and conditions of men lived for centuries without opening their eyes to it. To those who, on the score of incidental blunders and stupidities, deny the rationality of animals, we would hold up the ever-memorable "egg" of Columbus, and exclaim, "What, gentlemen, do you expect the ant to be be more uniformly and consistently intelligent than your erudite selves?"

Concerning the language of ants no small diversity of opinion has prevailed; but among actual observers the general conclusion is that these tiny creatures can impart to each other information of a very definite character, and not merely general signals, such as those of alarm. It has been found that ants fetched by a messenger for some especial purpose seem, when they arrive at the spot, to have some knowledge of the task which is awaiting them, and set about it at once without any preliminary investigation. The cases which we quote elsewhere from Mr. Belt are very conclusive on this point. In order to decide whether ants are really fetched to assist in tasks beyond the strength of any one of their number, Sir John Lubbock instituted a very interesting and decisive experiment. It is well known that if the larvæ of ants are taken out of the nest, the workers never rest till they have fetched them back. Sir John Lubbock took a number of larvæ out of his experimental formicary, and placed them aside in two parcels very unequal in number. Each of these lots was soon discovered by an ant, who at once fell to work to carry the larvæ back to the nest, and was soon joined by others, eager to assist. The observer reasoned thus: If these ants have come to the spot by accident, it is probable that the number who arrive at each lot will be approximately equal. On the other hand, if they are intentionally fetched to assist in removing the larvæ, the number in each case will most likely bear some proportion to the amount of work to be done. The result was, that the large heap of larvæ was visited by about three times as many ants as the small one. Hence the inference is plain that ants can call assistance to any task in which they are engaged, that they can form some estimate of the amount of labor that will be required, and can make their views in some manner known to their companions. The manner in which, when on the march, they are directed by their officers, and the promptitude and precision with which a column is sent out to seize any booty indicated by scouting-parties, show likewise a completeness and precision of language very different from anything we observe in quadrupeds and birds.

But as to the nature of this language, which Mr. Belt rightly calls "wonderful," we are as yet very much in the dark. Sounds audible to our ears they scarcely can be said to emit. Their principal organs of speech are doubtless the antennæ: with these, when seeking to communicate intelligence, they touch each other in a variety of ways. There can be no doubt that, with organs so flexible and so sensitive, an interchange not merely of emotions but of ideas must be easy.

But there is another channel of communication which deserves to be carefully investigated. We know that the language of vertebrates, or at least of their higher sections, turns on the production or recognition of sounds. What if the language of social insects should be found to depend, in part at least, on the production and recognition of odors? We have already full proof that their sense of smell is developed to a degree of acuteness and delicacy which utterly passes our conceptions of possibility, and to which the scent of the keenest hound presents but a very faint approximation. Collectors of Lepidoptera are well aware that if a virgin female moth of certain species is inclosed in a box, males of the same species will make their appearance from distances which may be relatively pronounced prodigious. As soon, however, as the decoy has been fecundated, this attraction ceases. This is only one among the many phenomena which testify to the wonderful olfactory powers of insects. So much, then, for the recognition of odors. Nor is their production among insects a matter open to doubt. Scents, distinctly perceptible even to our duller organs, are given off by many. The pleasant odor of the musk-beetle, and the offensive smells of the ladybirds, the common ground-beetles, the oil-beetles, the Spanish fly, and the "devil's coach-horse"—hence technically named *Gœrius olens*—are known to every tyro in entomology. The next question is, Are these odors at all under the control of the insect, and capable of being produced, suppressed, or modified at will? We have noticed many instances where the odors of insects became more intense under the influence of anger or alarm. A peculiarly pungent odor is said to issue from a beehive if the inmates are becoming excited.

The possibility of a scent-language among insects must therefore be conceded. Mr. Belt thinks that the *Ecitons* mark out a track which is to be followed by their comrades by imparting to it some peculiar odor. He says: "At one point I noticed a sort of assembly of about a dozen individuals that appeared in consultation. Suddenly one ant left the conclave, and ran with great speed up the perpendicular face of the cutting without stopping. It was followed by others, which, however, did not keep straight on like the first, but ran a short way, then returned, and then again followed a little farther than the first time. They were evidently scenting the trail of the pioneer, and making it permanently recognizable. These ants followed the exact line taken by the first one, though it was far out of sight. Wherever it had made a slight *détour*, they did so likewise. I scraped with my knife a small portion of the clay on the trail, and the ants were completely at fault for a time which way to go. Those ascending and those descending stopped at the scraped portion, and made short circuits until they hit the scented trail again, when all their hesitation vanished, and they ran up and down it with the greatest confidence."

That among groups like the *Ecitons*, in which the sense of sight is imperfect, or even totally wanting, enhanced delicacy of scent and touch must be required in compensation, may be taken as self-evident. With the language of ants, and especially with a possible scent-language, is connected the faculty by means of which denizens of the same city recognize each other under circumstances of great difficulty. In the battles which take place between two nations of the same species, how, save by scent, do the tiny warriors distinguish friend from foe? We are told by some older observers that if an ant is taken from the nest, and restored after the lapse of several months, it is at once received by its companions and caressed, while a stranger ant introduced at the same time is rejected, and generally killed. To a great extent this has been confirmed by recent investigators. The returned exile was not indeed caressed, but was quietly allowed to enter the nest, while a stranger was at once greeted with hostile demonstrations. It has been maintained that this power of recognition is destroyed by water, and that ants will treat a comrade as an enemy if he has received a drenching. This, however, is evidently a mistake. To prevent rain from penetrating into the nests of the agricultural ant, the guards block up the doorways with their bodies, and are often drowned at their posts. But their companions are not thereby prevented from recognizing them, as they try to bring the dead bodies to life.—*Quarterly Journal of Science.*

HISTORY OF THE DYNAMICAL THEORY OF HEAT.[1]

BY PORTER POINIER.

I.

A RECAPITULATION of the various conjectures which have been advanced in explanation of so ever-familiar a sensation as that of warmth or heat, would neither prove particularly feasible nor interesting; for doubtless during the vast period of time which has elapsed

[1] Introduction to an unpublished work on Thermo-Dynamics.

since the enunciation of atomic doctrines by the old Greek philosophers—and from their great suggestiveness—the speculations of reflective minds have wandered over wellnigh every imaginable hypothesis, and approximated with greater or less minuteness to the views which are admitted now, and which we think to be supported by experiment. Thus, as a case in point, we may refer to Galileo,[1] whose resource of observation could have scarcely been superior to Archimedes's, and who would seem to have conceived of an increase of heat as only a more elementary condition of material substance, in which the more or less considerable destruction of molecular bonds allowed the individual particles of a body to move among themselves with a more unconstrained vibration.

But very few among the countless suppositions which we might thus succeed in raking up, however curious or predictive in themselves, would have the slightest bearing on our present subject. Developed only to the extent demanded by the superiority of the scholastic mind, they would be found in general mere arbitrary, whimsical assertions; untried and unsupported by critically-devised experiments. With the reformation of philosophy does our historical sketch then properly begin, and, moreover, with Lord Bacon as its founder; for, in illustrating the proper method of establishing a philosophical doctrine, he forever identified himself with the dynamic theory, by showing that the most comprehensive explanations were afforded by considering heat to be an intestine motion of the constituent particles of a body. Systematically reviewing the known properties and effects of heat—the only practicable course open to him—he concluded in the following memorable and oft-quoted passages:[2]

> "Atque hæc sit Prima Vindemiatio, sive Interpretatio inchoata de Forma Calidi, facta per Permissionem Intellectus.
>
> "Ex Vindemiatione autem ista Prima, Forma sive definitio vera Caloris (ejus qui est in ordine ad universum), non relativus tantummodo ad sensum talis est, brevi verborum complexu: *Calor est motus expansivus, cohibitus, et nitens per partes minores.*"

We find, therefore, in older writings, the first considerable support of this doctrine attributed to Bacon; and it must be conceded that to the power and vividness with which he portrayed his conception of this agent was due in a great measure the tenacity with which it was afterward, from time to time, brought forward and upheld.

The subsequent supporters of this view, though not perhaps most numerous, comprised by far the most distinguished and profound philosophers of their time, their writings furnishing many remarkable anticipations of heat-theory as now received.

[1] "Opere di Galileo Galilei," tom. ii., p. 505, *et seq.*

[2] "Novum Organum," lib. sec., aphorism 20. Spedding and Ellis's translation, vol. iv., p. 154.

Newton,[1] quite singularly, while rejecting the wave-theory of light, gave his assent to the analogous ideas respecting heat; and, in so far as we may judge, conceived the warmth excited in a body when exposed to light or radiant heat to be due to the little shocks which luminous or radiant material might produce in it.

Huyghens, Hooke, Locke, and Cavendish, among others, were also favorably inclined to the Baconian view;[2] the works of Hooke particularly containing many and strong expositions of the vibratory notion, and his comments on the mechanical and chemical production of heat being urged often with as great clearness, and as subtile a perception of occult natural causes, as any which we now possess.[3]

But the adaptation of the known "laws of motion" to these operations, whereby heat might in many instances have been directly correlated to the energy expended in producing it, was not until long after definitely proposed; and though, in 1744, Boyle,[4] perhaps as intelligently as any one before him, had attributed the heating of a hammered body to the transfer of the "motion" of the hammer to the ultimate particles of the body struck, yet the idea of the indestructibility of energy in all cases, and of course, therefore, in the mechanical excitation of heat, would not seem to have been expressly urged before the time of Rumford and Sir Humphry Davy.

In the mean while, however, a new doctrine was brought forth, assigning to heat a material existence and chemical properties. First

[1] Newton's "Optice," queries at the end of treatise, especially Nos. 6, 8, 12, 18, 23, and 31.

[2] The ideas of Huyghens on this point would seem to have resembled somewhat those of Galileo, already quoted. *See* "Exposé de la Situation de la Mécanique Appliquée," par Combes, etc., p. 200. Paris, 1867. And Locke quite uniformly made use of Bacon's hypothesis. *See* particularly his essay on the "Conduct of the Human Understanding, Elements of Natural Philosophy," chap. xi., where he says:

"Heat is a very brisk agitation of the insensible parts of the object which produces in us that sensation whence we denominate the object hot; so what in our sensation is heat, in the object is nothing but motion. . . .

"On the other side, the utmost degree of cold is the cessation of that motion of the insensible particles which to our touch is heat."

[3] Hooke's "Micrographia," obs. xvi., 12th particular. "Posthumous Works," p. 49. "Lectures on Light," p. 116.

[4] "And now I speak of striking an iron with a hammer, I am put in mind of an operation that seems to contradict, but does indeed confirm our theory: namely, that if a somewhat longer nail be driven by a hammer into a plank or piece of wood, it will receive divers strokes on the head before it grow hot; but when it is driven to the head, so that it can go no further, a few strokes will suffice to give it a considerable heat; for while at every blow of the hammer the nail enters further and further into the wood, the motion that is produced is chiefly progressive, and is of the whole nail tending one way; whereas, when that motion is stopped, then the impulse given by the stroke being unable either to drive the nail further on or destroy its entireness, must be spent in making a various, vehement, and intestine commotion of the parts among themselves, and in such an one we formerly observed the nature of heat to consist."—(Boyle, "On the Mechanical Origin of Heat and Cold," "Complete Works," vol. iv., p. 236, *et seq.*, exp. vi.)

advocated, it is thought, by Boerhaave[1] and Lémery,[2] it received in 1787 the unrestricted name "caloric" from the French Academy.

According to these hypothetic notions, singularly cramped and superficial, as compared with the more fruitful ideas of Bacon, caloric, or the matter of heat, was thought to be a highly-elastic, imponderable fluid; which, distributed among the constituent molecules of bodies, in quantities varying with the temperature in the same, or the "capacity" in different kinds of substance, occasioned all the known phenomena of heat: the sensation, through an occult property of its own; expansion and repulsion, by the entrance of its own substance among the molecules of the bodies heated; a change of state whenever the effective action of any particular set of molecular forces should thus happen to be overcome; and in radiation passing from one body to another with vast swiftness. Being, moreover, an unchangeable material, a definite created quantity of it was considered to exist at all times in the universe.

The idea of a substance unaffected by the force of gravity did not appear so very improbable in those days, while the then frequent separation of some new or more elementary gas, and the astonishing effects directly traceable to their action, quite naturally suggested an analogous causation in thermal phenomena.

The discovery by Black, of latent heat,[3] seemed also to supply the necessary induction for its quantitative treatment; so that toward the beginning of the present century, and upon chemical considerations merely, the hypothesis of caloric had succeeded in supplanting quite effectually the ideas of Bacon.

The explanations which it gave of the mechanical excitation of heat were not so plausible, however; certain phenomena appearing utterly incongruous with the idea of an unalterable material supply of heat-substance, and its continued production of friction—a phenomenon which has been since said to have furnished the key to the whole science of thermo-dynamics—serving eventually to completely overturn it. In explaining such phenomena, therefore, those who still chose the material hypothesis were compelled to overlook some very significant objections; while, still supposing it to be a vibratory mo-

[1] "De Igne, Elementa Chemiæ," i., 116.

[2] "Sur la Matière du Feu," "Histoire et Mémoires de l'Ac. Par.," 1709, pp. 6, 400.

[3] We know, however, that these discoveries did not fail to be correctly interpreted at the time, for Cavendish, in a foot-note to some "Observations on Mr. Hutchinson's Experiments," etc., "Philosophical Transactions," 1783, p. 312, remarked:

"I am informed that Dr. Black explains the above-mentioned phenomena in the same manner; only instead of using the expression, 'heat is generated or produced,' he says, 'latent heat is evolved or set free;' but as this expression relates to an hypothesis depending on the supposition that the heat of bodies is owing to their containing more or less of a substance called the matter of heat, and as I think Sir Isaac Newton's opinion, that heat consists in the internal motion of the particles of bodies, much the most probable, I choose to use the expression 'heat is generated.'"

tion, the additional phenomena of latent or specific heats were not at all irreconcilable or difficult of explanation.

Thus Lavoisier and Laplace, in their famous "Mémoire sur la Chaleur" of 1780, though still retaining and defending the ideas of caloric, admitted the frictional excitation of heat to be "favorable" to the dynamical hypothesis. But it is, on the other hand, to be remembered that the earlier experiments devoted to the study of this point had been by no means unmistakable in their indications, directed as they had been rather to the detection of some suspected influence of the rubbing surfaces than to the investigation of any possible relation between the heat produced and the energy expended in producing it.

The material hypothesis was, therefore, the prevailing one, when about the year 1797 Count Rumford,[1] while engaged in superintending the construction of cannon at the military arsenal at Munich, became impressed by the considerable generation of heat accompanying their boring. And as he thought upon the explanation of the phenomenon consistent with the then prevailing ideas as to the intimate nature of heat, it seemed to him impossible that an apparently *unlimited* supply of any substance could be separated from so inconsiderable a quantity of borings. The doubt increased when, upon making the determination, he found the specific heat of this *débris* to be the same, apparently, as that of the mass of metal from which it had been separated: for in some obscure manner the "capacity" for heat of any body, or the total quantity of it which it might hold in any particular state, was considered to be intimately connected with, if not entirely defined by, its specific heat.

But, though he quoted this experiment as sufficiently conclusive that the heat set free by friction could not have been produced at the expense of any caloric latent in the metal, he undertook the following more elaborate investigation to determine all the circumstances which might possibly exert an influence on its production: and it appears, both from his method of procedure and the arguments with which he supplemented his results, that he had fully comprehended the philosophical consequences of each rival theory.

In view of the preëminent importance of these first conclusive and well-understood experiments, both with respect to the establishment of the dynamic theory upon an experimental basis, and the undoubted claim of their author to be considered as its founder, we here give as detailed an account of his investigations as may be thought admissible in a work intended merely for didactic purposes; and we conceive a full statement upon this most important point to be the more desirable, from the fact that the completeness with which he then demolished the material hypothesis, and the maturity of his views respecting the dynamical nature of heat, do not of late seem to

[1] "Inquiry concerning the Source of the Heat which is excited by Friction," "Philosophical Transactions," 1798, p. 80. "Complete Works," Am. Ac. ed., p. 400.

have gained the unqualified recognition which they most certainly deserve.

Taking the casting of a brass cannon, solid and rough as it came from the foundery, and with the cylindrical mass of metal *a* (Fig. 1), called the *verlorner Kopf*, still adhering to the muzzle, Rumford caused to be turned upon the superfluous end a smaller cylinder, *b* (Fig. 2),

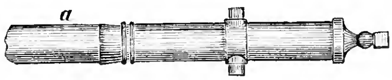


FIG. 1.

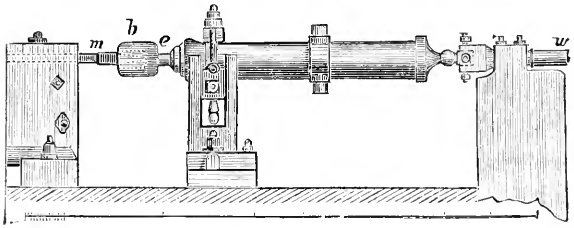


FIG. 2.

$7\frac{3}{4}$ inches in diameter and 9.8 inches long, and which remained connected to the cannon proper by the neck, *e*, 2.5 in diameter and 3.8 inches long.

The whole mass being then secured in the apparatus used for boring (Fig. 2), a cavity 7.2 inches long and 3.7 in diameter was bored in *b*, in the direction of its axis, so that a metal bottom, 2.6 inches thick, remained between the borer and the neck. In this also a small round hole, *c d* (Fig. 3), was radially bored for the insertion of a thermometer. The cylinder, neck, etc., are represented upon a somewhat larger scale in Fig. 3.

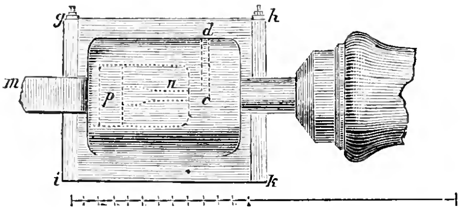


FIG. 3.

The borer used to create friction upon this metallic bottom was a flat piece of hardened steel, 0.63 inch in thickness, four inches long, and nearly as wide as the cylindrical bore in which it turned, $3\frac{1}{2}$ inches; so that the area of contact with the bottom was about 2.33 square inches. This borer was securely held in place against the bottom of the cylinder, and kept from turning by an iron bar, *m*; and thus disposed for the experiment the apparatus is represented in Fig. 2.

In Rumford's first determination the borer was forced against the bottom with a pressure of about 10,000 pounds, and the cylinder was rotated at the rate of thirty-two turns in a minute, by the labor of two horses. To prevent also as far as possible any loss of heat by radiation, the exposed parts were protected by thick coverings of flannel.

At the beginning of the experiment the temperature throughout, as well as that of the surrounding air, was 60° Fahr.; at the end of thirty minutes, when 960 revolutions of the cylinder had been made, the temperature, as indicated by a thermometer introduced into the small hole, had risen to 130°.

Collecting the metallic dust—or, as he described it, scaly matter—which had been detached, he found upon a careful weighing that it amounted to but 837 grains, or 54.2 grammes. Its inadequacy to account for the large excitation of heat fully impressed him, and he exclaims:

"Is it possible that the very considerable quantity of heat that was produced in this experiment (a quantity which actually raised the temperature of above 113 pounds of gun-metal at least 70° of Fahrenheit's thermometer, and which, of course, would have been capable of melting six pounds and a half of ice, or of causing nearly five pounds of ice-cold water to boil) could have been furnished by so inconsiderable a quantity of metallic dust, and this merely in consequence of *a change* of its capacity for heat?

"As the weight of this dust (837 grains, Troy) amounted to no more than $\frac{1}{948}$ part of that of the cylinder, it must have lost no less than 948° of heat, to have been able to raise the temperature of the cylinder 1°; and consequently it must have given off 66,360° of heat to have produced the effects which were actually found to have been produced in the experiment!

"But without insisting on the improbability of this supposition, we have only to recollect that from the results of actual and decisive experiments, made for the express purpose of ascertaining that fact, the capacity for heat of the metal of which great guns are cast *is not sensibly changed* by being reduced to the form of metallic chips in the operation of boring cannon; and there does not seem to be any reason to think that it can be much changed, if it be changed at all, in being reduced to much smaller pieces by means of a borer that is less sharp.

"If the heat, or any considerable part of it, were produced in consequence of a change in the capacity for heat of a part of the metal of the cylinder, as such change would only be *superficial*, the cylinder would by degrees be *exhausted*; or the quantities of heat produced in any given short space of time would be found to diminish gradually in successive experiments. To find out if this really happened or not, I repeated the last-mentioned experiment several times with the utmost care; but I did not discover the smallest sign of exhaustion in the metal, notwithstanding the large quantities of heat actually given off.

"Finding so much reason to conclude that the heat generated in these experiments, or *excited*, as I would rather choose to express it, was not furnished *at the expense of the latent heat*, or *combined caloric* of the metal, I pushed my inquiries a step farther, and endeavored to find out whether the air did, or did not, contribute anything in the generation of it."

In this, his Experiment No. 2, the only modification consisted in fitting the steel borer with an air-tight piston, packed with oiled leather, by which any circulation of air from without to the interior was prevented. But in the use of this device the oiled leather itself, by its friction with the sides of the borer, produced considerable heat, so that, to obviate any possible objection as to this point, Rumford had recourse to his third and most celebrated experiment.

In this, the friction cylinder was made to rotate in a water-tight box, which, being filled with water, completely submerged all the heat-producing parts. Here, therefore, the only supply of caloric, if any, lay in the water, which itself was to be heated by the friction; for had any caloric been abstracted by the heated water from the ambient air, there would have necessarily been a flow of heat from a cool body to a warmer, which every one admitted to be contrary to experience. The apparatus, therefore, having been arranged, the box was filled with water at the temperature of 60° Fahr., and the machinery put in motion.

With reference to what followed, Rumford remarked:

"The result of this beautiful experiment was very striking, and the pleasure it afforded me amply repaid me for all the trouble I had had in contriving and arranging the complicated machinery used in making it.

"The cylinder, revolving at the rate of about thirty-two times in a minute, had been in motion but a short time, when I perceived, by putting my hand into the water and touching the outside of the cylinder, that heat was generated; and it was not long before the water which surrounded the cylinder began to be sensibly warm.

"At the end of one hour I found, by plunging a thermometer into the water in the box (the quantity of which fluid amounted to 18.77 pounds, avoirdupois, or two and a quarter wine-gallons), that its temperature had been raised no less than 47°; being now 107° of Fahrenheit's scale.

"When thirty minutes more had elapsed, or one hour and thirty minutes after the machinery had been put in motion, the heat of the water in the box was 142°.

"At the end of two hours, reckoning from the beginning of the experiment, the temperature of the water was found to be raised to 178°.

"At two hours twenty minutes it was at 200°; and at two hours thirty minutes it ACTUALLY BOILED!

"The quantity of heat excited and accumulated in this experiment was very considerable; for, not only the water in the box, but also the box itself (which weighed 15¼ pounds), and the hollow metallic cylinder, and that part of the iron bar which, being situated within the cavity of the box, was immersed in the water, were heated 150° Fahr., namely, from 60° (which was the temperature of the water and of the machinery at the beginning of the experiment) to 210°, the heat of boiling water at Munich."

The total quantity of heat generated may be estimated with some considerable degree of precision as follows:

Quantity of ice-cold water which, with the given quantity of heat, might have been heated 180°, or made to boil. In avoirdupois weight. lbs.

"Of the heat excited there appears to have been actually accumulated:

"In the water contained in the wooden box, 18¾ pounds, avoirdupois, heated 150°, namely, from 60° to 100° Fahr. . . . 15.2

"In 113.13 pounds of gun-metal (the hollow cylinder), heated 150°; and, as the capacity for heat of this metal is to that of water as 0.1100 to 1.0000, this quantity of heat would have heated 12½ pounds of water the same number of degrees 10.37

"In 36.75 cubic inches of iron (being that part of the iron bar to which the borer was fixed which entered the box), heated 150°; which may be reckoned equal in capacity for heat to 1.21 pound of water . . . 1.01

"N. B.—No estimate is here made of the heat accumulated in the wooden box, nor of that dispersed during the experiment.

"Total quantity of ice-cold water which, with the heat actually generated by friction, and accumulated in two hours and thirty minutes, might have been heated 180°, or made to boil 26.58

"As the machinery used in this experiment could easily be carried round by the force of one horse (though, to render the work lighter, two horses were actually employed in doing it), these computations show further how large a quantity of heat might be produced, by proper mechanical contrivance, merely by the strength of a horse, without either fire, light, combustion, or chemical decomposition; and, in a case of necessity, the heat thus produced might be used in cooking victuals.

"But no circumstances can be imagined in which this method of procuring heat would not be disadvantageous; for more heat might be obtained by using the fodder necessary for the support of a horse as fuel. . . .

"By meditating on the results of all these experiments, we are naturally brought to that great question which has so often been the subject of speculation among philosophers, namely:

"What is heat? Is there any such thing as an *igneous fluid?* Is there anything that can with propriety be called *caloric?*

"We have seen that a very considerable quantity of heat may be excited in the friction of two metallic surfaces, and given off in a constant stream or flux *in all directions* without interruption or intermission, and without any signs of diminution or exhaustion.

"Whence came the heat which was continually given off in this manner in the foregoing experiments? Was it furnished by the small particles of metal, detached from the larger solid masses, on their being rubbed together? This, as we have already seen, could not possibly have been the case.

"Was it furnished by the air? This could not have been the case; for, in three of the experiments, the machinery being kept immersed in water, the access of the air of the atmosphere was completely prevented.

"Was it furnished by the water which surrounded the machinery? That this could not have been the case is evident: 1. Because this water was continually *receiving heat* from the machinery, and could not at the same time be *giving to* and *receiving heat from* the same body; and, 2. Because there was no chemical decomposition of any part of this water. Had any such decomposition taken place (which, indeed, could not reasonably have been expected), one of its component elastic fluids (most probably inflammable air) must at the same time have been set at liberty, and, in making its escape into the atmosphere, would have been detected; but, though I frequently examined the water to see if any air-bubbles rose up through it, and had even made preparations for catching them, in order to examine them, if any should appear, I could perceive none; nor was there any sign of decomposition of any kind whatever, or other chemical process, going on in the water.

"Is it possible that the heat could have been supplied by means of the iron bar, to the end of which the blunt steel borer was fixed, or by the small neck of gun-metal by which the hollow cylinder was united to the cannon? These suppositions appear more improbable even than either of those before mentioned; for heat was continually going off, or *out of the machinery*, by both these passages, during the whole time the experiment lasted.

"And, in reasoning on this subject, we must not forget to consider that most remarkable circumstance, that the source of the heat generated by friction, in these experiments, appeared evidently to be *inexhaustible.*

"It is hardly necessary to add that anything which any *insulated* body, or system of bodies, can continue to furnish *without limitation*, cannot possibly be *a material substance;* and it appears to me to be extremely difficult, if not quite impossible, to form any distinct idea of anything capable of being excited and communicated in the manner the heat was excited and communicated in these experiments, except it be motion."

From this quotation we see, then, that Rumford, with a sagacity indeed consummate, had seized upon the most notable circumstance presented by these experiments, against the materiality of heat. Italicizing the word inexhaustible—a far more significant proceeding than the use of any acids would have been—he showed most incontestably that, to still further reconcile the doctrine of caloric with experience, it would be necessary to admit the creation of it—a substance—in the production of heat by friction. But, even against so absurd a proposition, he proceeded to prepare, when he subjected to a comparative investigation the *quantities* of energy expended and heat produced in such an operation.

In his "Experiment No. 3" he made, as may have been already noticed, nearly all the observations and corrections necessary for an entirely trustworthy estimate of the "mechanical equivalent of heat;"[1] and, although never literally employing such a term, he subsequently stated, in reviewing still other experiments undertaken at

[1] Its value from the *data given* may be calculated as follows:

Considering the shape of the borer, and its contact with the bottom of the cylinder, we see that the moment of friction may be represented by the expression—

$$4\,f\,p \int r^2 \sin^{-1} \frac{a}{r}\, d\,r,$$

where f denotes the coefficient of friction, p the total pressure between the rubbing surfaces, r the variable distance from the axis, of any rubbing particle, and a the half-width of the borer: when, moreover, the superior value of r alone is substituted.

The integral indicated is—

$$4\,f\,p \left\{ \frac{r^3}{3} \sin^{-1} \frac{a}{r} + \frac{ar}{6} \sqrt{(r^2 - a^2)} + \frac{a^3}{6} \log \frac{r + \sqrt{(a^2 - a^2)}}{a} \right\},$$

about this period,[1] that the heat so generated "*is exactly proportional to the force with which the two surfaces are pressed together, and to the rapidity of the friction:*" in other words, that the production of heat is "exactly proportional" to the work expended in producing it.

First drawing attention to the absurdity of an apparatus containing or creating an indefinite supply of a material substance; then proving by experiment that the quantities of heat excited in a given time were proportional to the expenditures of an entirely different magnitude—work: he must be credited not only with the first conclusive, but with the most weighty argument initially available, against the existence of caloric, or in favor of the dynamic origin of heat.

OPEN AIR AND HEALTH.[2]

BY DR. PAUL NIEMEYER.

I SPARE the reader the diffuseness of an introduction, by telling him of a scene in an omnibus, which hinged on the question whether the conductor should open or shut the windows. On the left was

in which the substitution of Count Rumford's data,

$$p = 10{,}000 \text{ lbs.}, \qquad a = 0.3 \text{ inch}, \qquad r = 1.75 \text{ inches},$$

gives for the approximate moment of friction of the borer, in foot-pounds,

$$800\,f.$$

So that, making thirty-two revolutions per minute, a quantity of work, 160,800 f, would be expended during the same interval.

On the other hand, the heat excited in two hours and thirty minutes, and which, dynamically, was to be regarded the equivalent of the work expended, according to Count Rumford's estimate, was sufficient to raise the temperature of 26.58 pounds of water 180° Fahr., or 4,784 heat-units. The production of one heat-unit, therefore, corresponded to the expenditure approximately of an amount of work—

$$5041\,f,$$

For $f = 0.15$, this would give 756

" $f = 0.20$, " " " 1008

as the equivalents in mechanical units or foot-pounds of one British thermal unit.

Prof. Tait, availing himself of the remark let fall by Rumford, that "the machinery used in this experiment could easily be carried round by the force of one horse," and assuming 30,000 foot-pounds as the value of a horse-power per minute, thus derives 940 foot-pounds as the mechanical value of a rise of temperature of 1° Fahr. in one pound of water. (*See* "Historical Sketch," p. 9.) But Prof. Thurston regards this calculation as unfair to Rumford, quoting Rankine's estimate of the admissible value of a horse-power, 25,920, from which the value of the equivalent, 812, results. This critique also seems the more allowable, since Rumford neither made corrections for the work expended in friction in "the complicated machinery used" in the determination, nor for "the heat accumulated in the wooden box, nor for that dispersed during the experiment."—(*See Journal of the Franklin Institute*, 3, lxvii., p. 203.)

[1] "Kleine Schriften," 1805, vol. iv., p. 41. "Complete Works," Am. Ac. ed., vol. ii., p. 209.

[2] Translated from the German, by J. Fitzgerald, A. M.

seated a corpulent lady with full face, shrill voice, and labored respiration. The lady on the right was of lean, slender, dried-up figure; on entering the omnibus she had coughed; after taking her seat she held her handkerchief to her mouth and fairly changed color when the one opposite, wheezing, took her place and called out for "Air, air!" exclaiming that she would surely be smothered if the window were to remain closed. "But I," objected the other, "should get my death of cold if the window were opened." The conductor, who for some time stood undecided what to do, received this piece of Solomonic advice from one of the passengers: "Open the window," said he, in a deep voice, "and then one of them will die; then close it, and the other will die, and so at last we shall have peace."

This ending of the scene I state for completeness' sake only, and I add to it, by way of transition to the subject of the present essay, a conversation with a farmer which grew out of the occurrence.

On expressing to this sun-bronzed young man my regret that, in this self-styled "age of intelligence," the fear of colds and of draughts should be steadily increasing, and that it should really be producing the very effects it is meant to guard us against, namely, coughs and colds, he fully agreed with me, but took credit to himself for having risen above such notions. "We farmers," said he, "no longer believe that rust in grain comes from cold; for we know that it results from the development of noxious germs which, emitted by barberry-bushes and decaying stalks, are carried about by the wind."

This idea was of interest to me; for the farmer's account of the origin of "rust" put me in mind of certain throat and lung complaints that, developing unnoticed, gradually lead to positive disease, and the causes of which we physicians are daily more and more clearly tracing to inhalation of impure, vitiated air; hence, instead of speaking of consumptive lungs or tuberculous lungs, we should, rather, speak of "decayed" lungs or "dust" lungs. Stone-cutters are not assured by life-insurance companies, because it is known that the stone-dust settles in their lungs, undermining them, producing ulcerations and reducing the average life of the men to thirty-six years. Other "dusty occupations," so to speak, are less dangerous, but of certain callings and of certain classes of working-men we often hear it said that they are seldom free from "dry" cough. The reader, though he or she may have little to do with dust, will perhaps have taken home from the ball a very fair case of "dust-lung" caused by the dust of the dancing-floor. If they will not believe this, let them examine their expectoration the day after the ball. He who has good lungs may without fear inhale dust; he will dance most of it out again; but not so a delicate girl, whose lungs are compressed in a tight corset: when with dust-laden mucus she spits blood, do not say she has "taken cold." No, it is heating that has caused it.

Heating, too, and not cold, far less "trouble with teeth," is to blame when the first-born child of inexperienced young married people becomes feverish, or has a cough, and these symptoms are only aggravated when the innocent victim is treated with "teas" and mixtures, kept in an overheated room, and loaded down with bedclothes.

That our children were intended by Nature to live in fresh, open air, and that the old wives' regimen of keeping warm, living in-doors, and of warm drinks, is the cause of the fearful mortality of young children, is a truth that was not unknown one hundred years ago, but which must still be repeated over and over again.

The reader will allow me to recite the case of a patient of mine. A year ago, during his honey-moon, I congratulated him, and told him that a dry cough with which he was troubled was curable, provided he took care to live in the open air as much as possible, inuring himself to cold, sleeping in well-ventilated chambers, free from dust, etc. But this advice was hardly relished by the young pair. In October they hired rooms in a house that had just been built; its "dampness" they remedied by keeping up fires steadily; the windows were hardly ever opened, as the house stood on a windy corner, and the husband was growing more and more sensitive to cold; for this reason, too, he seldom went out-of-doors. In November he took to the bed, was again about, but he gradually declined, to the last hoping to recover.

Different was the course followed by Mr. H——, who, emaciated and troubled with a cough, had a hæmorrhage after contracting a "severe cold." He went into the country, took as much exercise as he could in the open air, and returned home with only a slight cough. At home he every morning took a warm bath with affusions of cold water, avoided rooms with bad air, etc. In six months he was free from his cough, appeared to be well nourished, and no longer had any fear of taking cold.

If the reader will dispassionately compare these two cases, he will agree with me that the first patient, who had never had hæmorrhage, fell a victim to the action of foul air, while H—— used to say, "I must give to my diseased lungs, above all things, fresh air, as the prime necessary of life." Animals never take cold, even in winter; therefore among men it must be a result of wrong habits if air does any harm. We know that gold-fishes quickly perish when fresh water is not provided for them; and when we were boys we used to consider it cruelty to animals if we made no openings for ventilation in the boxes in which we kept cockchafers.

Now, these openings answer to the windows in our houses; doors are meant to be closed, windows to be opened. It has long been held that closed windows are the principal cause of consumption. I would make the proposition more general, by substituting "defective ventilation" for "closed windows." It is very pleasant to be sheltered by four walls against wind, rain, and cold; but, now that we employ window-glass, coal for heating, and iron stoves, and rent is becoming higher, while rooms, especially sleeping-rooms, are growing smaller, we have all the greater reason to keep open ventilating apertures, since our lungs cannot live with less than six hundred cubic feet of fresh, pure air per hour. The man who has but once made trial for one week of sleeping with the window open will never give up the practice.

I once spoke to a lady about this matter, but she replied by telling me the story of a "thoughtless person" who, having left the window open through the night, awoke in the morning blind. She had also read in some newspaper that a man had a stroke of apoplexy produced by the same cause. I was amazed. But, calling to mind that this lady's husband had served in the army, I remarked: "Your husband lay for so long in the open air in the rain-drenched trenches at Strasburg; did he ever write to you that he had taken cold, or that any of the men had ever overnight been struck blind, or had met with any other misfortune? Did he ever contract a catarrh? Did he ever write for licorice, and not rather for tobacco? Your brother-in-law tramped in the deep snow to Besoul, your cousin learned at Le Mans what is the meaning of a fall of freezing rain, and thousands of our countrymen have had like experiences; still, coughs and rheumatism were not frequent, and most of the men came back strong and healthy!"

More rational opinions are gradually making their way, and, in one particular at least, a beginning is being made of a revolution, namely, the system of treatment followed in "climatic" sanitariums, and establishments for the cure of disease by air, difference of elevation, etc. The proprietors of such places, it is true, speak of the "specific" virtues of their climate; but, inasmuch as chemistry shows that atmospheric air all over the earth has the same constitution, the specific virtue must reside in the special purity of the air—a thing wanting in cities, but found in all villages, provided they do not possess large factories. Further, it is an error to suppose that in the south—Florida, Colorado, or in the Tyrol, or by the lake of Geneva—it is as warm as in a hot-house. In those regions, too, it is now and then cold; yet it is easier to be out-of-doors there, for usually the sun shines and the landscape is beautiful. But, since we cannot send all the sick to the south, we must devise some substitute at home, the benefits of which may be enjoyed even by the poorest. Then, too, when we consider that the majority of those who have spent the winter in a southern clime return as—embalmed corpses, because it is only when it is too late that people make up their minds to make the costly voyage, there is reason to expect better results from timely recourse at home to "air-cure." With the means of treatment at hand, disease might be nipped in the bud, and lung-complaints in general would be rarer.

And this result we may hope to attain. That pulmonary consumption is only an acquired disease we know from the fact that it first appears in the apices of the lungs—a portion of the organ which is not affected by hereditary pathological processes. The diathesis only is hereditary, and this diathesis consists simply of a general debility, which, however, can be overcome. But the thing that is transmitted hereditarily is habits of life—the avocation descending from father to son.

MacCormac tells of a family in which father, mother, and six children, died of consumption; the seventh son alone survived, he having quit the paternal house and calling, and gone to sea. Many instances of a like kind might be cited. This case is easily understood when we consider that here the parents and the six children who died had followed a sedentary trade; that they lived in narrow quarters, the air of which was quickly vitiated by the large number of persons breathing it; that they slept in a dusty room, with windows closed, lest they should take cold. They fell sick one after another; but the seventh son, who quit the unhealthy locality, had exercise, inhaled fresh, pure air, became vigorous and healthy, and escaped from consumption.

This simple explanation appears strange to those who believe in "tuberculosis." If this disease has grown to be the curse of modern society, the scholastic interpretation of it has to bear no small part of the blame. The doctrine of the heredity of consumption leads to the belief that the consumptive patient is fated to die of his complaint, and that his death is merely a question of time. He himself often draws the conclusion that the best thing for him to do is to enjoy life as best he may while it lasts. On the other hand, we must condemn the heedlessness of those who, so long as danger is not proximate, fear the expenditure of time and money. These same people, when hæmorrhage suddenly appears, quite lose their heads, adopt the most preposterous methods, whose only result is to cause new hæmorrhages, and to produce a regular case of consumption: whereas many of the old physicians recommend horseback exercise as the best cure for those suffering from hæmorrhage of the lungs, we now often see patients shut up in a hot, dusty room, not allowed to talk, and almost forbidden to breathe.

It is a peculiarity of consumption that it may appear in association with all diseases in which recovery is slow. In the first place, it accompanies inflammation of the lungs, unless the patient, while recovering, is permitted to breathe plenty of pure air. But it also makes its appearance in typhus, diabetes, and meningitis, when the patient is kept for a long time in a close room. So, too, delicate persons—those supposed to tend toward consumption—will all the sooner become indeed "tuberculosed," the more they are coddled, protected against cold, and treated with warm drinks and so-called "invigorants." Pulmonary hæmorrhage is in itself not a symptom of "tuberculosis," but it is made so by wrong treatment.

The foregoing practical considerations will enable the reader better to appreciate the theoretical observations which follow.

The lungs, like all mucous surfaces, secrete mucus even in their healthy state; this collects while we remain quiet, but is thrown out when we move. Every adult person clears his throat in the morning. One who has been sitting for a long time must cough when he goes out-of-doors. Bodily movement is the best "solvent" for a cough. When one's life is sedentary, mucus collects first of all in the apices of the lungs, and it is more difficultly broken up there by bodily movement, because the apices are the uppermost parts of the lung, and the impetus of the cough must drive the expectorated mucus around the corners of the lung. The apices are a veritable receptacle for mucus, which, if not removed, dries up, grows hard, and causes ulceration. In one hundred autopsies we find as many as ninety cases where the apices are more or less shrunken, scarred, and obstructed, and this without reference to the cause of death.

The apices, furthermore, are regular dust and gas traps, especially the right apex, which usually is the first to be affected by consumption, because the air-passage leading to it is wider and less crooked than that leading to the left apex. All impurities inhaled into the lungs, and especially all dust, first make their way to the apices, and there settle, unless they are kept in motion by bodily exercise. Elimination, too, is more difficult in the apices than in the inferior lobes. In coughing, the latter are aided by the abdominal pressure; while the apices, on the contrary, have to depend on their own contractility, which is weaker in proportion as they have been out of exercise, or as their cell-walls have grown together. Heavy clothing, which, like the yoke for carrying water, bears on the collar-bone, diminishes the power of respiration in the apices; a modern winter-overcoat weighs as much as eight or nine pounds. If, in addition to this, we have the usual two turns of a comforter around the neck, then the neck is bound fast, and we have all the conditions necessary for producing a diseased condition of the apices. Under such circumstances it would require considerable exertion in coughing to clear the apices. Hence the troublesome dry cough, which often ends in vomiting, yet does not loosen the mucus in the lungs. No benefit is to be got in such cases from lozenges, drops, extracts; the most that can be expected from such remedies is that they may moisten the throat rendered dry by the effort of coughing. But then they fill the stomach with phlegm. For small children such substances are an actual poison, producing sour stomach, diarrhœa, and fever.

Continued hard coughing in time injures the texture of the lungs, and leads, often with bloody expectoration, to decay of the apices, and, finally, to true pulmonary consumption, concerning the rational treatment of which we add a few words:

As a general rule, where a cough is habitual, whatever the age of the patient, recourse should at once be had to those means of cure which usually are resorted to only at the last moment, and then without any hope of good results. But, unfortunately, most people think only of the present moment. They want a son to complete his schooling as early as possible, and to go to earning money. But what is the gain if the young life, after a few years, ends its earthly career? Better, therefore, that a year or two should pass without remunerative employment, while in the mean time care is taken of the bodily health and strength, the affected lungs are invigorated, and the spirits are renewed. In the first case we have dead capital, in the second capital which bears interest.

The person whose lungs are affected must once for all give up dancing, for dancing as now practised is not "motion," but only destruction of the pulmonary apices by dust and vapor, fatigue of the body through want of sleep and privation of fresh air.

With this one exception, "caution" as usually understood is bad. Let the one who is threatened with consumption look on himself not as one doomed to die, but only as a pulmonary invalid. He should consider that, while it is a misfortune that the pulmonary apices are from their position exposed to disease, we nevertheless have plenty of lung-cells which can be made to do duty in place of them. Still, if these are not daily strengthened by careful treatment, they are in danger of being infected by the others, and of becoming diseased like them. By timely and continuous exercise, it is possible to restore even the diseased cells, and to cure the consumption, or at least to stay its further progress. If one can find the means of visiting Florida, Colorado, or Southern Europe, it is well to do so. But if this is not possible, one must find the means of an air and movement cure at home. That this is possible, the reader will see from the following analysis of the means of cure:

1. Lung-Ventilation.—The patient must with scrupulous conscientiousness insist on breathing fresh, pure air, and must remember that the air of closed rooms is always more or less bad, impure. No man, however uncleanly, would drink muddy, dirty water. Unfortunately, for detecting impurities of air, the only organ we have is the nose, and in most persons the nose is of so obtuse a sensibility that it is of no service. Besides dust, injury to the lungs is caused principally by the products of respiration (carbonic acid and watery vapor), which act as poison on the lungs and the blood. A party which occupies a room for hours, breathing the same air, might be compared to a party of bathers drinking the water in which they bathe. The man who on the street cuts off from his lungs the "cold" air, is like a ruminant. If this literally true comparison were universally accepted and acted on, the number of cough-complaints would be reduced one-half.

The patient must keep the window of his bedroom open. Night-air is fresh air without daylight; he who fears night-air is like a child who dreads darkness; the light in the room after the lamp is extinguished is also night-air. In close, crowded, heated rooms, the patient suffering from lung-complaint respires consumptively. In winter artificial heat may be employed, but the window must be opened above, and thus we have at once both warmth and ventilation. In the city night-air is always wholesomer than day-air, being both purer and stiller.

If it be objected that "what suits the blacksmith does not suit the tailor," I reply that may be true of a plate of sauerkraut. But here the case is just the reverse. The blacksmith who has no trouble with his lungs can stand vapor-dust, heat, fatigue; but the one who has pulmonary disease risks his life if he has not always abundance of fresh, pure air.

So far of the What?—lung ventilation. Next, of the Why?

On rising, let the patient drink fresh milk (not coffee), which will be relished all the more if one wakes with an inclination to cough. Then let him approach the open window, brandish the arms over the head—which enables the lung apices to inhale air more easily—and for a few minutes fetch as deep inspirations of air as possible. He must frequently take such deep inspirations in the open air.

If the lungs do not become free, let him introduce into them—not into the stomach—something to act on the dry mucous membrane—as the vapor of water or of camomile-tea.

If the cough is caused rather by a "scratchy" feeling in the throat, if it is spasmodic, let him swallow or gargle some substance that will quiet the nerves. Cold water is best—in summer ice-water; in some cases cooled fennel-tea is of service, but not sirup or any hot drink.

2. Skin-Ventilation.—This is of no less importance for warding off simple coughs, as well as for preventing the transition to consumption. With its millions of pores, the skin is on the one side the main sewer for carrying away superfluous fluids, and on the other it is the principal factor in cooling the body, in colds, in overheating, and in fevers. We will now consider skin-ventilation from this point of view under the two heads of—*a.* Elimination of fluids; *b.* Reduction of temperature:

a. Elimination of Fluids.—Like the external skin, the inner skin, the mucous membrane, exudes moisture, sweats. The mucous membranes, having no covering, are always moist. The mucous membrane of the lungs exhales watery vapor. This vapor comes from the serum of the blood, i. e., from that portion of the blood in which the corpuscles are suspended, and which, after the corpuscles have been filtered out, resembles water. The external skin under ordinary circumstances gives off about twice as much watery vapor. But, in proportion as this elimination is checked by defective skin-ventilation, the water of the blood (serum) has to be eliminated internally through the mucous membranes. Cooling, i. e., the sudden action of comparatively low temperature on the warm surface of the skin—for instance, when one sits in a draught of air—may check transpiration, and so cause the fluids to tend inward in such volume as to overtax the capacity of the mucous membrane of the lungs or the intestines, more rarely of the kidneys, the result being catarrh. But catarrh and coughing are two different things: as for "dry cough," it can never arise from cold. That it results from the inhalation of impure, vitiated air, the reader knows already. It is true that obstruction of the breathing-apparatus, as "rattling" in infants, and hawking and hoarseness in grown persons, results from retention of serum; but that this obstruction is not connected with taking cold must be admitted, at least in all cases where the patient has not quit his chamber, or even his bed. As a matter of fact, no one takes a cough from a cold wall or from an open door. The conclusion to be drawn from all this is, that the coughs, hoarseness, and sore-throats, from which those persons suffer in winter who are ever on their guard against colds, are produced, not at all from cold, but from its contrary, overheating of the skin, whose evaporation is feebler the nearer the external temperature approaches that of the body. In this case there is a suppression of the action of the skin, but it is produced not by cold but by improper warming—or, as it is more properly called, by pampering. A hot bath, a cold pack, or a good, lively walk, will work wonders in "loosening" a hard cough. At first, it is true, the patient will cough harder than ever; but this effect is not due to the "cold wind," but to the fact that the accumulated mucus, once started, is expelled *en masse*. The oftener the patient resorts to the bath, to the pack, and to walking, the less frequent are the fits of coughing, and the freer and easier does he breathe.

b. Reduction of Temperature.—The body's temperature is normal when in the armpit it is about 95° Fahr. Food and drink are stimulants, and the skin is the radiating surface which gives off the surplus heat. If this elimination is not sufficiently active, the body becomes overheated, and this manifests itself by shivering. Overheating is the result when one eats and drinks much, at the same time parting with but little heat. The chill so produced is usually called "inward cold," but this is an error: it is overheating. That this is so is shown from the fact that when on the morning after a "social evening," during which we were overheated, we feel chilly, we have only to take a walk until perspiration is set up; we then feel warm again in spite of a considerable cooling off. And this, by-the-way, is the very best cure for the "Katzenjammer." We live in a climate where it is far easier to heat the body than to cool it. Hence one of my counsels against catching cold is, that the weakly, coughing reader of sedentary habits should not overheat himself with strengthening food, so called (meat, eggs, beer), else he might take an "inward cold," or even a fever.

But a person may contract a genuine (external) cold by unwise precaution against draughts — by neglecting the skin-ventilation. Under this head of unwise precaution we must class the habit of wrapping up the body when it is in a state of perspiration. On the contrary, coat and waistcoat must then be opened so that the shirt may dry quickly, and the underclothing, including the stockings, must be changed. But what does he do who on reaching the top of a mountain, with a wet shirt, buttons up his coat about him, puts on his overcoat, and over all his plaid? He applies a wet poultice at the wrong time.

Prof. Tyndall, in his "Glaciers of the Alps," tells us that, on being overheated during his rambles in the Alps, he at once took a bath, or poured water over his body. "*Probatum est*," say I, from personal experience.

"Yes," some one will say, "you are inured to that sort of thing." To be sure I am! But what hinders you from being inured also? Just go out on the ice during this glorious winter weather, put on a pair of skates: you will return bright and fresh; you will throw open the windows, and be indignant at yourself for ever having shut yourself up in such a steaming atmosphere. The next day take a simple bath—not a Russian or a Turkish bath at all—and you will rid yourself of still another part of your phlegm.

3. Muscle-Ventilation.—Muscular fibre respires too, i. e., gives off carbonic acid and takes up oxygen. To this end it must diligently contract and then relax; in short, it must work, or, if the reader prefers the expression, it must practise gymnastics. Whether one takes his exercise at home or abroad, makes no difference. They whose lungs are affected would do well to climb hill-sides, for in such exercise the apices of the lungs are most called into play; in climbing the hands may rest on the hips. Muscle-exercise is not to be separated from lung-exercise. If bodily movement be neglected, deleterious fluids accumulate, which I call "suffocation-blood" and "fatigue-blood." The former contains carbonic acid, which makes one always drowsy, and causes one to go about his day's work with a feeling of lassitude no matter how long he has slept. This feeling of weariness grows steadily worse. "Fatigue-blood" accumulates in the muscles as a result of drinking wine and beer; even simply bending the body causes inconvenience; one feels quite unstrung and wants to recline on a lounge or a bed, whereas what he ought to do is to take a brisk run in the open air, or a little exercise in a gymnasium. In this way the skin is ventilated and the serum worked off.

My essay cannot exhaust all the topics named in its title: the most it can do is to awaken attention, free the reader from certain erroneous ideas, and lead him to believe that the simplest remedy is always the most natural and the best. If any one will put his faith in recipes, I would remind him of the history of the sale of indulgences. We look back with indignation to Tetzel's scandalous work, but how many people still think they can purchase health by gorging themselves with medicines! Consumptives form no small portion of this class. The treatment here recommended costs no money, but demands only will, self-conquest, and perseverance. The treatment is not so complicated as it may appear; it is simply a movement and an air cure, or, more briefly, an "attempering" cure, for effeminacy is the source of all colds, coughs, and consumption, and hardening is the only protection and remedy against them.—*Der gemeinnützige Gesundheits-Almanach.*

THE TIDES.

By Professor ELIAS SCHNEIDER.

II.

A PART of the theory of the tides presented in our text-books has been pronounced absurd in my first article. It is also a matter of amazement that the effect of centrifugal force is entirely ignored in these text-books. That the propelling force arising from this cause should be utterly disregarded in an explanation of the tides is very remarkable. And yet the existence of such a force is so easily demonstrated that nothing else seems necessary to prove it to be one of the causes of the tides, than what was presented in my first article. I will, however, give additional force to my reasoning by citing the results of actual experiment.

It may be shown that there is an actual difference in the amount of centrifugal force felt at any part of the earth's surface during different times of the twenty-four hours of one axial rotation; and also at different times of the earth's revolution around her centre of motion. Theory implies that when any portion of the earth's surface is moving toward that point in her orbit where such surface makes the most rapid sweep around the centre of motion, the greatest amount of centrifugal force must be felt at such surface; and that, when this part moves toward that point of the earth's orbit where it makes the slowest sweep around the centre of motion, the least amount of centrifugal force must be felt. Now, it is very evident that any portion of the earth's surface which is most remote from the centre of her motion, whether that centre be the sun or the centre of gravity between herself and the moon, makes the most rapid sweep, and that consequently her waters must feel the greatest amount of centrifugal force at that time.

Now, let us see what experiment tells us on this subject: A box has been made of proper dimensions, free within from all outside disturbance or motion of air. In this box is placed a steel frame, which moves like a gate on a very delicate hinge, so as to avoid all possible friction. A weight of nearly twenty pounds rests on this gate at about four feet from the hinge. The hinge, whose lower part is a mere point, or delicate pivot, and the weight, are in the same line, parallel with the meridian. The weight is free, as nearly as can be, to obey the power of its own inertia. In consequence of this it moves laterally once every twenty-four hours west and east, whenever the centrifugal force is increasing and decreasing.

From noon to midnight the earth's surface is moving toward that point where its motion is more rapid, and consequently it begins to feel an increasing amount of centrifugal force. This is indicated by the apparatus, for the weight, which rests on the gate, by virtue of its inertia, lags behind and makes an apparent motion westward. This motion is, of course, not real. The earth's surface moves eastward faster than the weight, and hence the weight appears to move westward. From midnight to noon the centrifugal force felt by the earth's surface diminishes, for it is then moving toward that point where its motion eastward is less rapid. This is also indicated by the apparatus, for the weight, having gradually acquired the same velocity eastward, remains stationary at midnight a very short time. But, soon after midnight, when the earth's surface begins to feel less centrifugal force, this weight, by virtue of its inertia, resists the change of motion, and therefore moves eastward as far as it moved westward before midnight.

This movement of the weight is greatest when new-moon occurs at midnight, for the earth then feels not only the centrifugal force produced by her revolution around the sun, but, in addition, that produced also by her revolution around the centre of gravity between herself and the moon.

The motion of the weight westward begins soon after mid-day, and reaches its highest acceleration at about 8 P. M.; the motion eastward begins soon after midnight, and reaches its highest acceleration at about 7 A. M.

I hope soon to make a new apparatus, which shall have a longer distance between the hinge and weight, and from it more marked results can be derived.

When a body moves in a curve around a centre, it feels the effect of two forces: the one, which I call centrifugal, is the impulse which puts the body in motion; the other, which I call centripetal, is the power which draws toward the centre and keeps the body from moving in a direct line. These are the only forces acting upon a body moving in a curve. The former is sometimes called tangential, but I prefer to call it centrifugal, for it is the only force which drives from the centre. There *is* no force acting directly *from* the centre. That which is often called centrifugal is really centripetal force, for the tension of the string in the following experiment is not caused by any force acting on the body *from* the centre, but it is caused by a force drawing the body out of its rectilineal course, and *toward* the centre, compelling it to move in a curve.

Suppose the body E (Fig. 1) moves with a certain velocity in the curve $E\ C\ D$, and that the string $E\ S$ feels a known tension, just equal to its strength. Now, double the velocity, and the strength of the string must be increased fourfold to keep it from breaking, for the force drawing the body toward the centre must then be four times as great to keep it moving in the curve. Or, suppose the body moves from A toward B with a known velocity, and that on reaching E it is acted upon by the string. The body is then made to take a curvilinear motion, and the string feels a tension drawing the body not directly from but toward the centre, and equal to a force necessary to keep the body from moving in a straight line. It may be remarked that, as action and reaction are equal, the tension is felt both ways. But the reader can easily see what I mean.

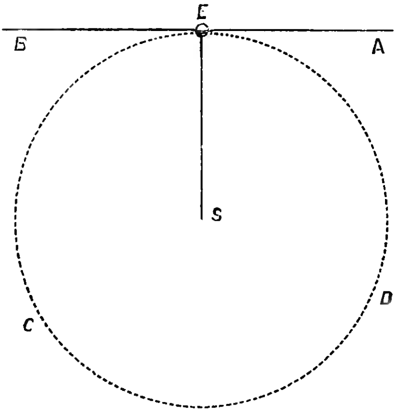


FIG. 1.

This law of motion can be still better illustrated by a reference to one of the satellites of the planet Neptune. The mean distance of this satellite is nearly equal to the distance of our moon from the earth. We may assume these distances to be exactly equal. Then, as at the same distance the centripetal force must increase as the square of the velocity, to keep the body moving in the curve, and as the velocity of this moon of Neptune is about four and a half times greater than that of our moon, the centripetal force, or the force of gravity produced by Neptune on this moon, must be $(4.5)^2$ about twenty times as great as is the centripetal force or the gravitating power our earth produces on its moon. In other words, the planet Neptune is about twenty times as heavy as our earth, for weight is nothing else than the measure of gravity.

The preceding statements are sufficient to show what is meant by centrifugal and centripetal forces. Let us now see how these act on bodies moving in large and small curves, and how the waters on the earth's surface are driven by centrifugal force toward a line tangent to her orbit. Since the length of the orbital curve of the earth is very great, and therefore not much deflected from a straight line, the waters are driven very little above the usual surface, no matter how rapidly the earth herself may move in this curve. The centrifugal force or original impulse felt by the whole earth is very great, but that felt by her waters is hardly visible or sensible in mid-ocean. For the tide-waves cannot get above the line tangent to the curve of the earth's orbit. The following illustration will show this:

Let *A B C* (Fig. 2) represent a part of the curve of the earth's orbit, in its motion around the central sun, and *B D* a line tangent

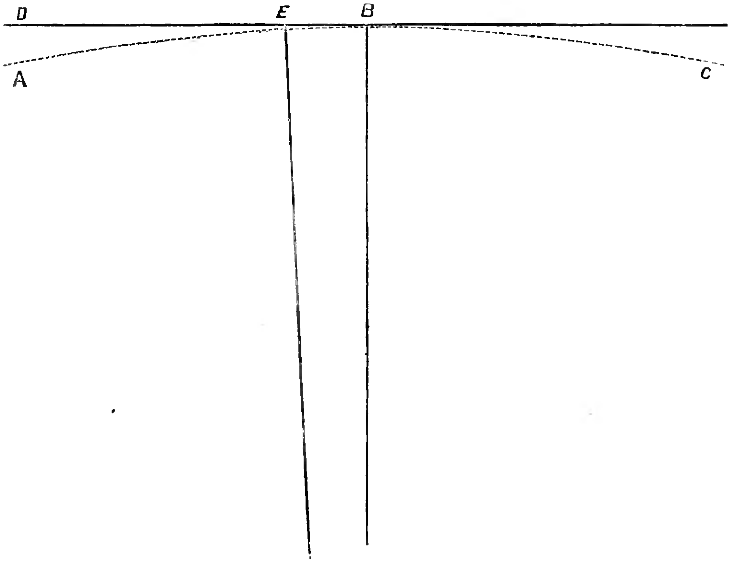


FIG. 2.

to the curve at the point *B*. Now it is very evident that no tide-wave produced by centrifugal force can get higher above the curve of the orbit than this tangent line, and the distance between the curve and the tangent, as at *E*, is very small. The part of the earth's surface most remote from the sun has indeed a greater tendency to continue moving on in the straight line of the original impulse than any other part. The particles of water have a small degree of cohesion, and they will therefore continue to move a short distance along this tangent, but only a little above the usual surface of the earth.

The curve in which the surface of the earth moves around the centre of gravity between herself and the moon is much more deflected from a straight line. Here also the tide-wave can rise no higher than to the line tangent to this curve. The distance of the point *G* (Fig. 3) from the curve is, however, much greater than the point *E* in Fig. 2 from its curve. The motion of the surface of the earth at *H* around the point C, the centre of gravity between herself and the moon, is only about sixty-five miles an hour; while the surface at B (Fig. 2) moves with a velocity of 68,000 miles an hour around the sun. Nevertheless, as the waters are driven toward these respective tangents by the effect of centrifugal force, the tide-wave must be greatest where the distance between tangent and curve is the greater.

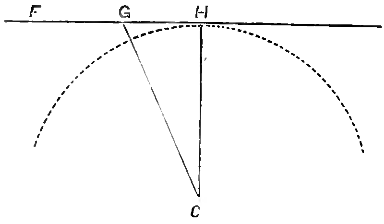


Fig. 3.

Let us now proceed to prove by mathematical demonstration the falsity of the theory of the tides found in our text-books.

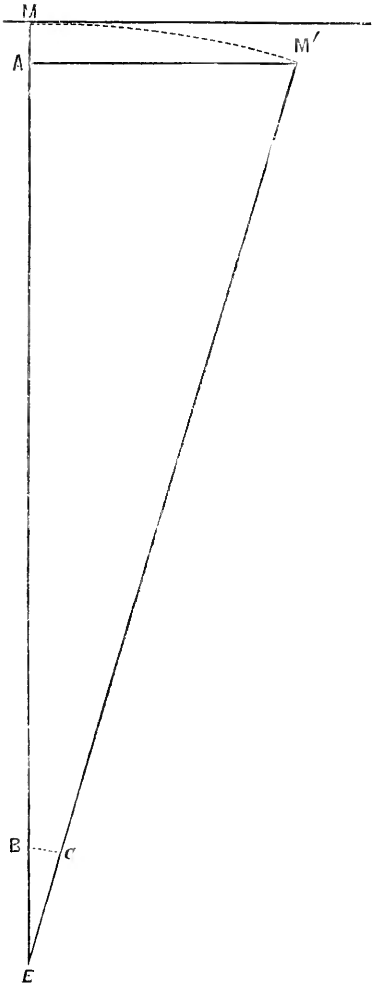


Fig. 4.

Herschel, in his "Outlines of Astronomy," uses the following language: "That the sun, or moon, should by its attractions heap up the waters of the ocean under it seems to them (objectors) very natural. That it should at the same time heap them up on the opposite side seems, on the contrary, palpably absurd. The error of this class of objectors . . . . consists in disregarding the attraction of the disturbing body on the mass of the earth, and looking on it as wholly effective on the superficial water. Were the earth, indeed, absolutely fixed, held in its place by an external force, and the water left free to move, no doubt the effect of the disturbing power would be to produce a single accumulation vertically under the disturbing body. But it is not by its whole attration, but by the difference of its attractions on the superficial water at both sides, and on the central mass, that the waters are raised; just as in the theory of the moon the difference of the sun's attractions on the moon and on the earth (regarded as movable, and as obeying that amount of attraction which is due to its situation) gives rise to a *relative* tendency in the moon to recede from the earth in conjunction and opposition, and to approach it in quadratures."

This language gives about the clearest presentation we have of the pulling-away doctrine. But there *is* no "tendency in the moon to recede from the earth in conjunction and opposition, and to approach it in quadratures." On the contrary, the tendency of the moon's motion is just the reverse—namely, to approach in conjunction and opposition, and to recede in quadratures. And if so in regard to the moon and earth, it must be still more so in regard to the earth and her waters under this influence alone, as can be demonstrated.

I am sustained in my position by the best of authority. "Thus our moon moves faster, and, by a radius drawn to the earth, describes an area greater for the time, and has its orbit less curved, and therefore approaches nearer to the earth in the syzygies than in the quadratures. . . . The moon's distance from the earth in the syzygies is to its distance in the quadratures, in round numbers, as 69 to 70." The authority I quote is Newton's "Principia."

Let us make a calculation, and apply it to the earth and her waters. The moon performs its revolution in $27^{d}\ 7^{h}\ 43\frac{4}{9}^{m}$, which is equal to $2{,}360{,}606\frac{2}{3}$ seconds. The seconds of time in which the moon makes one revolution around the earth is to one second of time as 1,296,000 seconds in a whole circle is to a fractional part of one second of a circle, which we will call x. Hence $x = \frac{1296000}{2360606\frac{2}{3}} = .54901141+$, which is the fractional part of one second of the circle of the heavens the moon describes in one second of time. The semicircumference of a circle whose radius is one equals 3.14159265389+. Hence one second of this semicircumference equals $\frac{3.14159265389}{648000} = .0000048481368110+$, and the fractional part .54901141 + of one second of this semicircumference is equal to .0000026616824264 8+.

Let $E\ M$ and $E\ M'$ represent the moon's distance from the earth, $M\ M'$ the arc which the moon describes in one second of time, and $A\ M'$ the sine of this arc. Let $E\ M'$ equal 240,000 miles, the moon's distance, in round numbers, from the earth, and $E\ C$ equal one mile. The arc $B\ C$, being very small, may be regarded as equal to its sine. The length of this arc we have already found. From similarity of triangles we have the following proportion: $A\ M' : B\ C :: E\ M' : E\ C$, or, by substituting the figures, $A\ M'$: .00000266168242-648 :: 240000 : 1. Therefore $A\ M' = .6388037823552+$, which is the sine of the arc passed over by the moon in one second of time. The cosine $E\ A$ is equal to

$$\sqrt{\overline{E\ M'}^2 - \overline{A\ M'}^2} = \sqrt{(240000)^2 - (.6388037823552)^2} + =$$

239999.9999991498535+, which, subtracted $E\ M$, gives $A\ M = .00000$-08501464+, and this fractional part of a mile, reduced to inches, gives

.053865275 +, the fractional part of an inch as the distance the moon falls from a tangent to its orbit in one second of time. Multiply this by the square of 60, and we get, when reduced, 16.159 + feet, the distance the moon descends in one minute, which is equal to 15.1 + Paris feet, the result obtained by Newton in his "Principia."

The distance the earth falls, in one second of time, toward the sun is about .12144 + of an inch, and the distance the moon falls toward the sun in one second, when in opposition, is about .12084 of an inch. This, added to the distance the moon falls toward the earth in one second, makes .17470 +. Now, .17470 — .12144 = .05326. Hence the moon, when in opposition, moving faster toward the earth than the earth does toward the sun, by .05326 fractional part of an inch in a second, these two bodies have a tendency to get nearer to each other in this position. The same can be proved when the moon is in conjunction.

Now let us see how this same law affects the waters of the ocean. The earth moves toward the sun .12144 part of an inch in a second. The waters of the earth, on the side turned away from the sun, are only 4,000 miles farther from the sun than the centre of the earth. Gravity toward any body diminishes as the square of the distance increases. Hence these waters, influenced by the gravitating power of the sun alone, and not hindered by any intervening object, would fall toward the sun .12143 part of an inch in one second. Hence the earth has a tendency to move away from the waters with a velocity of .00001 part of an inch in one second—that is, if these waters were not influenced by the gravitating power of the earth, and only by that of the sun, the earth would be "pulled away" from its waters at the rate of only the 100,000th part of an inch in one second. But it must be remembered that the waters gravitate, in addition to this, toward the earth at the rate of 16.15 + feet in one second, and therefore these waters are *depressed* by gravity, and not elevated. The same may be proved in regard to lunar tides.

I close by saying that I am an earnest seeker of truth, and nothing but a sincere desire for truth has impelled me to write these two articles. Any person attempting to prove me in error, with the same good motive, will be kindly welcomed.

MODERN SUPERSTITIONS.

MOST people accept it as a fact that superstition went out with the advent of steam, the telegraph, and the penny-post. A little honest observation, however, will assure us that there still exist a number of pitiable though petty superstitions. Among certain classes there are lucky and unlucky days in their calendar. They will not attempt an important task on Friday. The horseshoe still hangs behind or over the door in the Highlands, and in some places much less removed from the centres of civilization. East-coast fishermen will yet occasionally burn, or otherwise destroy, a boat from which the lives of any of the crew have been lost, no matter how seaworthy or valuable the boat may be. A hare crossing the path of one of these hardy sons of the sea will cause him to forego an intended journey or voyage. To rustic and fisherman alike a concourse of magpies is an evil omen. As for dreams, the belief that they are the forecasts of events is perhaps the strongest of all the forms of their superstition. We might multiply examples, but have said enough to suggest that the follies of their great-grandfathers have still no slight fascination for the ignorant, in spite of the strides which intelligence has made.

But have superstitious beliefs quite left the more intelligent ranks of society? On the very subject of dreams itself is there not a sneaking credulity which goes far to prove the contrary? True, any one of us is quite able to account in a natural way for his or her dreams. Nevertheless, the lady who chides her children for repeating the interpretation which the housemaid has put upon their sleeping vagaries, and sagely instructs them on the subject of imperfect digestion and its effects upon the brain during sleep, is not ashamed to impart to her husband any morning the particulars of her own shocking dreams, or to piously express the hope that something untoward is not about to happen. Her better-half pooh-poohs the matter, doubtless, as becomes his superior dignity, but is visited none the less with a vague sense of uneasiness when he remembers that he himself had a vision of losing a tooth or seeing a house on fire. Having courageously quizzed his wife at the breakfast-table on the folly of *her* augury, and bidden her and the children good-by for the day, he inwardly deplores the unlucky omen of having to turn back for his forgotten umbrella or pocket-book!

How many curious but innocent little customs too are still current, and with the sanction of the wisest! An old slipper is still cast after a bride: it is considered necessary to christen a new ship with a bottle of wine: a fine day is still royal weather: and so on. These and many others most of us would indeed be sorry to see extinct. They are not only harmless, but, in their very departure from strait-laced common-sense, give an agreeable and perhaps even healthful relief to the prosiness of ordinary life. To sacrifice them to the strict letter of reason, would be to sacrifice much of the sentiment of life, to banish imagery from poetry, to take the perfume from the rose, to guide into a Dutch canal the current of human affections, which left free will gush and eddy, prattle and murmur by rock and meadow, carrying music and health throughout its living course.

Would that modern superstitions never took less innocent shapes!

Having discarded the ghostology of olden times, many people, and among these some men and women of considerable culture, have set up for themselves a novel system of intercourse with the unknown world. Brownies and fairies, with all the fine romance that surrounds the history of their doings among human folks, are dismissed with contempt. Spiritualism has swept all these ethereal puppets off the boards of ordinary life. To substitute what? We might at least look for an improved exhibition and more interesting "characters;" but the truth is, that nothing could be less satisfactory than the modern attempt at demon-craft. There is something so clumsy and inartistic in the whole get-up of the "spiritual" drama, that it is less surprising to find it very generally scouted than to see it obtain even a partial notoriety.

Ignorance is the parent of superstition, without a doubt; and the one never exists apart from the other. There is, however, a second wise saw that tells a great deal of the truth about the origin of that world-old bugbear of the human mind, namely, "The wish is father to the thought." What we strongly desire to be, we are next door to believing to be. The appetite of man's vanity is unappeasable, and in catering for it his fancy plays tricks with his reason. He longs for intercommunion with the unknown, and indulges the wish by creating fictitious agents for that purpose. Tokens, signs, omens, and auguries, are also outgrowths of the various forms of desire and vanity. We believe we shall have luck if we turn the money in our pocket when looking at new moon. Men have *waited* in all ages for the appearance of some favorable sign before beginning any enterprise of importance. If the sun shines on our wedding-day, how auspicious! Palpably in each case because we desire these things to be! But having set up omens with such an object, we, in the cleft-stick of our own superstition, are bound to believe their absence, or converse, the foreshadowers of evil.

In many ways modern credulity frees itself from such mechanical trammels as those we have mentioned, to take a form and complexion from the age, losing meanwhile not one jot of its vigor. To dream three times of a hidden treasure and set about, Whang-the-Miller-like, to lay bare the foundations of one's house, is an exploit not to be thought of by the veriest wiseacre of our day; but the desire to obtain wealth easily and rapidly being, if anything, more active and rampant, the belief in some magical means for attaining it is the most natural thing in the world. An El Dorado is required, and lo! an El Dorado is implicitly thought to exist. The projectors of a bogus company for "utilizing the clippings of old moons," or "extracting starch from granite chips," are the good fairies whom by propitiating with a portion of our substance we hope to enlist in our behalf, and obtain a thousand-fold return. Where such a superstition exists, and it is broadcast, any scheme, however absurd, any swindle, no matter how transparent, will serve for a bait to catch the unwary and over-eager fish. Nothing is so purblind as undue acquisitiveness. The ancient Highlander with his keen eye to the main chance and happy facility for "attaching" whatever came in his way, found a beautiful horse in rich trappings, browsing ownerless in his path, and, following the instinct of his desire rather than the prudence which tradition should have taught him, rashly mounted. In an instant he was borne aloft, then plunged forever beneath the dark waters of a tarn on the back of the wily and terrible water-kelpie. We, too, have our illusory steeds in this so vaunted age, and neither the teachings of history nor the bitterest experience seems able to prevent the speculator from vaulting into the saddle, and forthwith launching into perdition.

Charms are things of the past, or believed in merely by the vulgar; that is to say, those pretty and fanciful conceits which led our ancestors to attach a healing or sanitary virtue to certain objects and ceremonies are now almost extinct. A spray from the rowan-tree is no longer a safeguard against an epidemic, nor the hand of majesty a cure for scrofula. Ladies do not now believe that the presence of a piece of cold iron on their couch, "*while uneasy in their circumstances*," will secure a happy consummation; nor is a child's caul in much request in these days as a protection against fire and drowning. True, we have got over these beliefs pretty thoroughly. But is the desire for infallible remedies and potent protectives done away with also? Not in the least; and though science is doing its best to provide honest substitutes in a natural measure, the public is not satisfied with its efforts. Quacks are the modern magicians, and quack medicines the charms of latter days. Those who are bald, for instance, will not accept their fate while a single well-puffed elixir with a Greek name remains untried. There is something saddening, if not sickening, in the evident success which attends the pretenses to cure chronic and irremediable diseases, to effect miracles in short with the most trumpery of means and execrably silly devices. Our forefathers were imposed upon, no doubt, but there was method in their madness. The "simples" with which spae-wives and charlatans professed to cure ailments were in many cases effective and now recognized drugs, and were at the worst perfectly harmless; while the rites with which they were administered, if quite apart from the purpose, yet appealed gracefully to the imagination. Nowadays, however, the "simples" are the patients and not the medicines! The old story. Childlike, the age cries for something that it cannot get, rejecting the good that is within reach.

In a recent number of this *Journal*, we had occasion to refer to the amazing credulity of Americans on the subject of professional "mediums." The worst of it is, that the extent to which this has been laid bare is insignificant compared with that which really remains unexposed. The desire to work with supernatural tools in effecting the paltriest and meanest of human ends, would seem to have divided a people of accredited shrewdness into the two classes of rogues and dupes. But, as we have seen, we, too, have been singed at the same fire. There are, moreover, other if minor superstitions in our midst that suggest the propriety of beginning the task of reformation at home. An occasional glance, for instance, at the stock advertisements of leading journals, will convince any one how wide-spread is the infatuation that believes in spurious offers of advantageous employment. Some of these have, under our own observation, been repeated with little variation for more than twenty years; and we have no doubt that the wily advertisers are able to calculate to a fraction the number and gullibility of their dupes. We have from time to time drawn attention to swindles of this class, as well as to those tempting offers of "Money to lend," which appear with equal regularity in newspaper columns. We are afraid, however, that friendly warning and experience are alike unavailing to stem the mischief. The spread of education itself would appear unable to outstrip the spread of imposture or the eager credulity that supports it; for superstition merely shifts its ground from time to time, without losing appreciably its original dominion over the human mind.—*Chambers's Journal.*

SKETCH OF PROFESSOR RANKINE.

PROF. W. J. MACQUORN RANKINE was born in Edinburgh, July 5, 1820, and on Christmas-eve, in 1872, he died, before he had completed his fifty-third year; but in that comparatively short life he had won higher distinction and done more good work than it falls to the lot of most men to compass.

He pursued his ordinary school studies in the Burgh Academy of the town of Ayr, the high-school of Glasgow. When very young he entered the University of Edinburgh, where he devoted himself to natural philosophy and natural history, including zoölogy, geology, mineralogy, and botany. He was a born mathematician, and received little aid from professional instruction in the branch of science in which he subsequently displayed such great genius. Throughout his educational course he received valuable aid from his father, who was a retired lieutenant of the British Army.

His powers were developed at an early age. Before he was twenty he had written two essays on subjects in pure physics. At eighteen he adopted the profession of civil engineering, and was the pupil of Sir John Macneil for three or four years, a great part of which was spent on engineering works in Ireland. Subsequently, he was employed for several years on railways and similar works in

Scotland; and in 1850, forming a partnership with Mr. John Thomson, C. E., he settled in Glasgow.

Meanwhile he had been busy in purely scientific pursuits not connected with his calling, and the value of his work was generally recognized. He was elected to various learned societies, and in 1853 was made a fellow of the Royal Society of London. The same year he became a member of the British Association, in which he subsequently held several important positions. During the Dublin meeting of the Association in 1857, the honorary degree of LL. D. was conferred upon him by the university of that city as a mark of the eminence he had gained as a physical investigator. He was then but thirty-seven years old.

In 1855 he was made Regius Professor of Civil Engineering and Mechanics in the University of Glasgow, a position which he held with distinction for seventeen years. He was an able instructor, his aim being to develop the understanding of the student by the cultivation of natural knowledge, and to beget those habits of close observation and persistent and exact verification which are so essential to the scientific worker in any field.

Prof. Rankine was the first President of the Institution of Engineers of Scotland, and in 1861 was made President of the Philosophical Society of Glasgow, contributing many papers to the Proceedings of that Society, and on a wide range of topics. The honors he won in his profession, and in thermo-dynamics, were rivaled by his achievements in naval architecture, to which his attention was for some time given.

His writings were exceedingly voluminous. His published treatises and manuals included, among others, "Manual of Applied Mechanics," "Manual of the Steam-Engine and Other Prime Movers," "Civil Engineering," "Useful Rules and Tables," "Cyclopædia of Machine and Hand Tools," "Manual of Machinery and Mill-Work," besides a very long catalogue of papers on physics, especially thermodynamics, applied mechanics, etc. His style was a model of scientific writing—elegant, exact, lucid in explanation and apt in illustration. In short, his was a mind of the first order, his original investigations were of the highest value, and his excellent influence as an instructor in moulding the minds of his students will be far-reaching.

His early death was the penalty of overwork, and was preceded by an impairment of vision and a derangement of the heart's action that were very distressing. He yielded to the demand for bodily rest when it became imperative; but it was too late. His is another name added to the long list of those who, understanding perfectly the limits of human endurance, seem to think that their case is exceptional, that their organisms can be continuously overworked with impunity, and so go on, heedless of the dumb protests of the abused body, until the ruin is utter and irrevocable.

EDITOR'S TABLE.

LANGUAGE IN EDUCATION.

THE agitation for a reform in the Civil Service, as it is called, should it result in the establishment of that measure, may be expected to produce effects not now much anticipated or cared for. The essence of the reform is to consist in getting better men for office-holders than American politics has hitherto afforded—certainly a most laudable thing. But the mode of arriving at the better qualified men is to be by "examinations," that is, by the educational test. Before candidates can be examined, however, and decided upon, it will be necessary to arrange the standards by which they shall be judged, and one of the important effects of the system will be to bring to inexorable judgment those preliminary standards on which the whole policy must rest. One of the reasons why the superstitions and absurdities of education are so tenaciously persistent, is the difficulty of bringing the results of so-called culture to direct practical test or verification; but the examiners who frame the catechism by which candidates for office are to be sifted and accepted or rejected, cannot fail to do something toward the removal of this difficulty. In deciding what qualifications are desired, they will give judgment upon the method that has produced them.

The English have tried Civil Service reform sufficiently long to begin to connect cause and effect, and take account of the validity and worth of its standards. They began the system of Civil Service examination in 1853 by drawing up scales of the valuation of different kinds of knowledge as expressed numerically by marks, so that proficiency in the various branches could be added up and indicate the "standing," as is done in many schools. This scheme, of course, represented current ideas, and the Indian Civil Service Board decided that "in the two great ancient languages there ought to be an examination not less severe than those examinations by which the highest classical distinctions are awarded at Oxford and Cambridge." This was for those who aspired to civil positions in India; and how the knowledges were rated comparatively may be inferred from the following examples:

Greek	750
Latin	750
French	375
German	375
Natural sciences	500

This marked predominance of dead over living languages, and the still more striking predominance of language over science, could not fail ultimately to bring the whole question under critical scrutiny, and has led to a reëstimate of the educational value of lingual studies. We publish part of a paper read by Prof. Bain before the British Social Science Association, which deals with this important subject, and our readers will find it valuable as a contribution to education, regardless of the Civil Service interest, while it illustrates what must be the effect of that reform in bringing educational questions into a new aspect. The overshadowing predominance of language forces an inquiry which proves that it is of the very lowest possible use as a means of mental culture.

SAVINGS-BANKS AND STATE CONTROL.

THE recent scandalous revelations concerning the management of savings-banks and similar institutions of trust have, of course, provoked much discussion, and, equally of course, much loose talk.

The obvious fact that many of the men who have been chosen, or have assumed, to take care of the savings of the frugal have proved to be wholly unworthy shows, it is often argued, an alarming decadence in the moral tone of the community, which is variously ascribed according to political or religious bias. There are not wanting those who assert that the whole social organism is unprecedentedly corrupt, and that the facts which have transpired are but a faint precursor of what is to come. But it is by no means clear that any such doleful view of the situation is warranted. The morals of trade may be loose enough, but it is not readily to be admitted that they are deteriorating.

It is true that the early history of savings-banks in this country shows no such dark picture. Previous to 1862, failures were rare; the banks were, as a rule, safely managed by fit men. A high order of financial or executive ability is not required for the management of a savings-bank, but integrity and common-sense are; the right paths are straight and well beaten—what is needed is a steadiness of purpose to resist the temptations that lead away from them. During the last fifteen years the number of these institutions has largely increased, and the process of natural selection does not seem to have developed safe officials as fast as they were wanted.

Nor is it alone that it has been necessary to put many new and untried men in places of trust. A higher degree of rectitude has been needed to bear the strain imposed by the speculation and recklessness of a period of inflation than was sufficient in the less trying days which preceded this era—this has not always been found. The prudence of any given man or class is not a fixed quantity, it is subject to fluctuations; it is weakened by the spirit of confidence and rashness that always marks a period of rising prices, and strengthened by the heroic treatment of adversity which is sure to come in with the reaction.

Of the details of the mismanagement which has led to disaster, and of the rules for properly conducting such institutions, it is not our present purpose to speak; but there is one idea which seems to be fundamental in all the remedies proposed that deserves attention.

State control in some form is the sole corrective which, in the opinion of those whose views find expression, is available; and there is something sublime in the faith apparently felt in government management, even by those who are loudest in their denunciations of office-holders — the only agents through whom a state can do its work.

The recommendations all assume one of two forms:

1. That a system of post-office savings-banks, similar to those now operating in England, be established; or—

2. That more thorough state inspection be instituted with a view to maintaining and purifying the present system.

Opinion is still divided in England as to the ultimate success of the scheme for post-office banks, but it has, so far, worked too well to permit unqualified condemnation. This success, however, has been wrought under conditions that do not obtain in the United States.

In the first place is the wide difference in the Civil Service of the two countries. Without going into comparisons it is safe to say that, until our much-talked-of reform shall have made some progress, it may be as well to go slow in committing savings-deposits to the custody of an irresponsible, ever-shifting set of officials, chosen without any reference to their natural fitness or training for the discharge of such a trust. We already hear much of their delinquencies, and it is certain that the proposed system would add to their temptations and the risk of defalcation.

Secondly, the difficulties in working the system are greatly enhanced in this country by the wide territory over which it must extend, to at all meet the requirements of the people.

Thirdly, the banking branch of the Post-Office Department could not be made self-sustaining, and at the same time pay a rate of interest that would draw deposits. It is not likely that 3½ per cent. would be satisfactory when there are perfectly sound banks that can pay five per cent.; and yet 3½ is probably more than the Department could afford to pay. Following the rule of the English system, and the only safe one, it must invest its deposits in Government securities, on which it cannot now realize more than four per cent. Out of the half per cent. margin must come all expenses and the loss of interest on unused balances. The Department could not even take the very necessary precaution of keeping a cash reserve against deposits, and though it may be said that the degree of confidence would be so great as to preclude a run, and so no reserve would be needed, it will be found that if the Government, through any of its departments, goes into banking, it will be amenable to the rules that govern banking operations. It could be readily shown, if space permitted, that the Department would be a constant dealer in bonds, buying on a high market, and selling on a low one—a process not conducive to profit—and it is highly probable that from these various causes the chronic deficit of the mail-service would be increased by the losses incurred in the banking department, a result which could not be defended on any tenable ground.

Next, as concerning State inspection. It is certainly remarkable that a system which has been tried so fully and failed so utterly, should still be so implicitly relied on; that men, who pride themselves on being practical, and who never fail to have their little fling at theorists, should cling to a theory that has broken down whenever tested.

Official examination has had a very thorough trial in this country; it has been a feature of the national banking system since its organization in 1864; the history of these banks has, as a whole, been creditable, but scores of them have failed, many disgracefully, and the worst of them in localities where it might be expected that the examinations would be most thorough; while the life-insurance companies and savings-banks of New York have long been objects of legislative solicitude and official care, with results that do not need to be told here.

The theory of State intervention in such matters is fallacious; private enterprise, if left to itself, would compass the desired end much better than any governmental machinery. The indorsement which the State gives to a new institution, by granting a charter and nominally assuming a supervisory control, endows it with an air of respectability and solidity which it could not otherwise command, and which is for the most part illusive. If depositors understood that their sole reliance was the character of the men they were dealing with, and that the only supervision would be such as they chose to exercise, they would soon come to select the guardians of their savings with greater care, and scan their acts more closely.

The State has a legitimate function which it has very imperfectly fulfilled in this connection; it *is* competent to enforce the performance of contracts; to visit punishment upon negligent or dishonest officials; to secure prompt and inexpensive justice to the sufferers in event of failures. This has not been done, but instead, contracts have been shamelessly broken with impunity; felony has been openly compounded; and the proceedings of winding-up defunct banks have been dilatory and extravagant—conducted with a disregard of the interests of the depositors that differs from common swindling only in having the sanction of the courts. If the State had performed the duties which manifestly belong to it, there would be less clamor now for it to step out of its proper sphere to manage financial corporations.

It is true that the public has been marvelously credulous. Any adventurer who could raise money enough to put up a sign and make large promises would find some trusting fools to leave their money with him, and it almost seems that they should be protected against themselves; but efforts which aim to protect people from the consequences of their own folly, however amiable they may be, are rarely successful; it is best in the end to let people reap the reward of their stupidity.

Unfortunately, the average depositor in savings-banks labors under disadvantages in being without facilities for getting information or training which would help him to form an intelligent judgment on it when obtained; but this is one of the unpleasant concomitants of ignorance from which there is no way of escape except through the acquirement of knowledge. The public does not seem very apt in gaining this sort of knowledge; but only as it is mastered will a better condition of things be reached. The teachings of the last few years have been very thorough, and it is to be hoped that confidence will be more intelligently placed in the future than it has been in the recent past; that new candidates for it will find that more strenuous and legitimate measures are needed.

A good deal is said about the philanthropy of this class of institutions; but analysis would doubtless show that the altruistic element in them is the merest trace. They are formed by men who are selfish enough to desire to make them as large and prosperous as may be; it will not need a great prolongation of the present state of feeling to teach them that the way to success is to offer the highest guarantees of good management and security, and see to it that these guarantees be real.

As to the best methods of convincing the public of their trustworthiness, that may safely be left to the managers themselves; the utmost publicity and fullness in the statements of condition, and the greatest freedom for the inspection of accounts and securities by depositors, or those in their interest, would contribute much to that end.

LITERARY NOTICES.

The Question of Rest for Women during Menstruation. By Mary Putnam-Jacobi, M. D. The Boylston Prize Essay of Harvard University for 1876. Pp. 232. New York: G. P. Putnam's Sons, 1877. Price, $3.50.

It is fortunate for that group of physiological and social conditions involved in what is termed the "Woman Question" that it has been investigated in one of its most important aspects by an author not only specially prepared by education and training to do it justice, but one, so to speak, "to the manner born." The motive of Dr. Putnam-Jacobi's book seems to be to close the discussion opened by Dr. Clarke in his "Sex in Education," rather than to make a direct answer to his argument. That it does not close this discussion, and furnish an authoritative canon to measure the value of the "question of rest for women," is the fault partly of the material gathered, and partly of the method of handling the facts. There is no difficulty in the way of doctors, male or female, collecting facts relating to women sick; but, when facts are needed concerning women well, the innate delicacy of the sex is in arms against the statistician. This is evident when we state that, of 1,000 circulars calling for information regarding the sexual history of women in different occupations, but 268 were answered.

The second section of the book deals with the facts obtained in reply to this circular. These facts relate to the condition of health of childhood, and of parents or sisters; the age of going to and leaving school; the number of hours of study, of exercise; the nature of the study or occupation; pain during menstruation; the need and length of rest during the continuance of that function, and the time when rest first became necessary. The strength is measured by exercise, and several other conditions naturally suggested by the questions are given. These facts are tabulated under groups distinguished by either the total absence of pain or its presence at various periods. The author makes ingenious but legitimate use of her figures, hampered by the small number of individuals subjected to analysis. The number is sufficient, however, to foreshadow what is probably the amount of disability entailed upon women by the need of rest. Too much stress appears to be laid upon the mere presence of pain and the incapacity to work resulting from it, as if this were the only source of disability. Women are sometimes obliged to take rest from the nervous depression and mental disturbance which attend the exercise of the ovarian function; but it is possible that it is the better way, when the interpretation of the causes of incapacity is left to the average individual, that some well-understood term like "pain" be adopted. The section on statistics being long and complicated, we must overlook the steps of the process, and confine ourselves to the results.

Out of the number of women interrogated (286 cases), 94, or 35 per cent., declare themselves always free from discomfort (pain?) during menstruation; by adding to this number 46, who only suffered slightly, or occasionally during that period, this proportion is raised to 59 per cent.; on the other hand, 128 women, or 47 per cent., suffered seriously from pain; in them menstruation was, therefore, a morbid process. "In all such cases," remarks the author, "rest during the existence of such pain is as desirable as during the occurrence of any other." Of the 162 painful cases, including all degrees of pain, 53 per cent. had been so from the beginning; and in 47 per cent. the habit had been acquired. The relation of the age at which schooling began and the time spent in school to this catamenial pain is not very evident, as this condition is very nearly alike in all the groups. Of the painful group 18 per cent. received very little education, while in the normal group none are so specified. Of the first only eight per cent. pursued advanced studies beyond the age of twenty-two against 16 per cent. in the latter. Dr. Putnam-Jacobi is led to the conclusion from her figures, which are unfortunately too limited to afford even a guess at the real truth, that the highest education given to women is the most favorable to menstrual health; the least favorable being the ornamental education. In the matter of physical education, it was found that those who never suffered pain exercised more than the other class; but all classes were found to exercise too little during childhood and girlhood. The tables show that the family history exerts a greater influence over the menstrual life than occupation. The figures prove that two-thirds of those who suffered periodical pain inherited some special or general constitutional defect. Physical vigor, as measured by the capacity for exercise, was shown among those free from pain in the ability to walk an average of five miles; the average for those who habitually suffered pain was three and a quarter miles; and for the cases of slight or acquired pain four miles. "Capacity for exercise was nearly always in inverse proportion to the habit of pain." The tables show that persons without occupation suffered from painful menstruation in much larger proportion than those who were occupied. One would infer from this that the author, in a measure, traced this result to the want of occupation; while we should reverse the conditions of cause and effect, and explain the lack of occupation by the incapacity resulting from the periodical pain. The conclusion is also reached from the fact that marriage is opposed to the existence of habitual periodical pain. And, lastly, "as regards rest—the most important question for our purpose—we have seen that the above data do not suffice to inform us of its influence;" and thus, so far as the main theme of the book is concerned, the author leaves the "question of rest for women" in just the condition in which she found it.

The third section, occupying fifty pages, is a review of the various theories of menstruation, and shows considerable research.

The next section is devoted to what the author calls experimental research upon six persons in the form of daily tabulated statements of pulse, temperature, dynamics, and the excretion of urea, before, after, and during ovulation. The general results to be gathered from the tables are, that excretion of urea is increased previous to the hæmorrhage over the usual amount, although there were many exceptions to this rule, individual peculiarities generally governing the results. The number of cases observed, however, was too small to afford conclusions. The same objection may be made against the dynamometer and temperature tests. Physiological experiments of this nature always require a sufficient number of subjects to reduce individual peculiarities and accidental conditions to a minimum in the mean results. The state of the circulation is given a very careful study by means of the sphygmograph before, during, and after menstruation, from which observations the author concludes that there is an increase in the tension of the arteries seven to nine days preceding menstruation, to be lowered, as a rule, a few hours after the beginning of the hæmorrhage, reaching its minimum after its cessation. This increase in intermenstrual arterial tension, being similar to that observed in pregnancy, leads the author to this remarkable conclusion—"that in all these respects the intermenstrual, and especially the premenstrual, period represents a pregnancy in miniature." From the facts gathered in this experimental chapter, "it should follow," the author says, "that reproduction in the human female is not intermittent, but incessant; not periodical, but rhythmic; not dependent on the volitions of animal life, but as involuntary and inevitable as are all the phenomena of nutritive life." From what we know of the author, we believe the phraseology of the above will be materially altered in the next edition. Aside from the unscientific use of words, and the strained meaning put upon the word *rhythmic*, the author confounds reproduction with the conditions essential to reproduction. It conflicts also with reasoning to which this is designed to be the natural conclusion. For instance, on page 98, speaking of the Graafian vesicles, she says that, "as the process of their development is gradual, the periods of rupture are necessarily intermittent;" and, as if to preclude all idea of rhythmic action, she says, further, it "is one of the most irregular of physiological phenomena."

We shall end our notice by a few remarks on the conclusions with which the author closes the book.

Menstrual pain, instead of being the result of want of rest, depends upon—1. "Imperfect power of resistance in the nerve-centres." This presupposes an inherent tendency to pain in all women during this act, its expression depending on the power of repression, although this alternative is evaded by the author. 2. Organic defects; and, lastly, acquired pain, which may depend upon conditions common to both sexes in the genesis of disease; upon causes mainly due to parturition, and thus peculiar to women; or "from two causes, very much more frequently operative in women than men, namely, ill-arranged work and celibacy." Whether this work is "ill-arranged" with reference to time or not, the author does not inform us. The conclusion is natural that this ill-arrangement is due to the need of intervals of rest, since work and rest are natural antitheses. The evil effects of celibacy are insisted upon in several places. The author even rises to the heights of impassioned prose, when she says that "many others never obtain the opportunity to bear a single child, for which, nevertheless, every fibre of their physical and moral being is yearning." While we cannot express ourselves so poetically, we concur in the idea; but it is not a little singular that, since the motive of the book is to demonstrate woman's capacity for continuous work during certain periods, the derangements due to matrimony receive no attention. The fifth and last conclusion is that "there is nothing in the nature of menstruation to imply the necessity, or even the desirability, of rest for women whose nutrition is really normal." Yet, upon the previous page, in speaking of the presence of pain in 46 per cent. of women, it is traced among other things to "work that is either absolutely excessive, or excessive relative to woman's constitution, by being prolonged too much during a single session, or else which is insufficiently relieved by recreation." It is impossible to read this last section of the book without coming to the conclusion that the author in many instances is reasoning against her convictions.

The author does not seek to evade the fact that 46 per cent. of women suffer a greater or less degree of pain during this time, and yet it has not the slightest bearing upon woman's efficiency to work while thus suffering to say, as the author does, that this pain is not directly dependent upon the need of rest. If we recognize in pain the ideal curse of humanity, we may form a notion of what a woman must undergo who, under the lash of necessity or duty, carries her burden of pain to her daily tasks. It matters not whether the pain is evaded, or mitigated or not by rest, it is a panacea instinctively sought. It accords also with the universal experience of medical men that pelvic pain, or hyperæmia, is quieted by rest, and this is as true of menstrual pain as of any other condition. Such a fact as this cannot be reasoned away by arguments drawn from speculative physiology.

But we must recognize in this book a new departure in the literature of the question. It is something new, as well as a grand stride in the right direction, for the advocates of woman's immunity from anything like physical restraints to labor to investigate facts and to couch this investigation in scientific language. The faults of the book are mainly those of hasty preparation, both in the collection of data and the arguments based upon them. We are satisfied that, with a wider range of facts and greater deliberation in handling them, many of the hasty generalizations which we have pointed out would not have occurred. The book shows hard and honest work, and demonstrates the great capacity of Dr. Putnam-Jacobi for scientific investigation.

Fifteen-Cent Dinners for Working-men's Families. By Juliet Corson. Pp. 40.

This little tract is designed to show the working-man's wife how she may provide for her household a sufficiency of good, wholesome food at a cost easily within the means of the poorly-paid day-laborer. An edition of 50,000 copies has been published by the author for gratuitous distribution, and it would be an act of humanity to aid in circulating the book among the class who have need of the information it contains. The poorer class of people are, in proportion to their means, far more wasteful than the rich, and the information here conveyed cannot fail to be highly profitable to them.

Report on the Telegraphic Determination of Differences of Longitude in the West Indies and Central America. By Lieutenant-Commander F. M. Green, U. S. Navy. Washington: Government Printing-Office, 1877.

Navigators, geographers, and others, are constantly demanding improved values of the geographical coördinates of places on the earth's surface, as the demands of their pursuits become more and more exacting. When the longitude of a slow-sailing vessel was obtained by observations of lunar distances a large uncertainty in the resulting datum was inevitable, and was expected and allowed for. Modern practice in steamers, where every additional hour's run means the expenditure of valuable fuel, etc., and where an uncertainty as to the ship's position is subsequently paid for by the owner in the expenses of the voyage, demands something more than the approximate longitudes of prominent seaports, which before were sufficient.

This want has been long felt, and the establishment of secondary meridians has been attempted in many places and by various nations. In 1866 a committee of the French Bureau des Longitudes was directed to prepare a plan for fixing a certain number of fundamental secondary meridians, separated by convenient distances, all round the world; and, in March, 1867, their report having been submitted to the Minister of Marine, its immediate execution was directed. A commission of eminent French naval officers was organized to superintend the preparation for this work and its performance, and five or six parties of skillful observers were, after several months of preliminary study and practice, dispatched with their instruments to various parts of the world to make observations of moon-culmintaions to determine the difference of longitude between their respective stations and the meridian of Paris. At that time, the present wide extension of submarine cables could not be foreseen. This commission fixed several points in the West Indies, and from these longitudes were counted by French and other navigators. Other points in this region were established by other nations; and frequent discrepancies arose, for which there was no remedy, except an entirely new and independent determination by the accurate method of telegraphic longitudes.

In view of the importance of the commerce of the United States with the West Indies, the Hydrographer of the U. S. Navy determined to undertake this task, and accordingly a plan for its completion was prepared and the execution of this plan was confided to Lieutenant-Commander Green. This plan was very comprehensive, and included the determination of the latitude of each of the following stations, together with its longitude from the U. S. Naval observatory of Washington, which was already telegraphically connected with Greenwich.

The stations selected were: 1. Key West; 2. Havana; 3. Santiago de Cuba; 4. Kingston (Jamaica); 5. Aspinwall; 6. Panama; 7. San Juan (Porto Rico); 8. St. Thomas; 9. St. Croix; 10. St. Johns (Antigua); 11. St. Pierre (Martinique); 12. Bridgetown (Barbados); 13. Port Spain (Trinidad).

Station 1 was already connected with Washington through the labors of the Coast Survey. It is to be noted that stations 2 and 3 furnish a basis for an accurate survey of Cuba, that 5 and 6 furnish starting-points for the whole sea-coast of Mexico and Central America, and that 6, in connection with the longitude of Santiago de Chile (already determined in position by two American astronomers, Gilliss and Gould), will furnish a basis for the survey of the west coast of South America. The north coast of South America is fixed by the stations 5 and 13 (already the Hydrographic Office has published the results of chronometer expeditions, between these points, made under its direction by Commander Ryan, U. S. N., in 1877). On station 8 many longitudes, previously determined, depend; and the other stations amply suffice to fix the Windward and Virgin Islands. Thus the comprehensive plan of the expedition, together with that of the expedition sent out by the Hydrographic Office in 1877, under the same distinguished officer, will practically suffice to fix nearly the whole eastern and northern sea-coast of South America, and will furnish bases for the establishment of the coast-line of Mexico and much of the West coast of the Southern Continent. The expedition of 1877 contemplates the junction of station 13 with Lisbon, Madeira, Cape Verd, Para, Rio, Montevideo, and Buenos Ayres.

The work necessary to the final fixing of the positions of these thirteen stations was done in 1874–'76, and is described in detail in the report before us.

Full descriptions of the instruments (with plates), the methods of observation and reduction, etc., are given in this volume, to which we refer for particulars which would be out of place here. Suffice it to say that the results are of the same grade of excellence as those attained in similar work of the highest class all over the world. A special point of excellence is the absolute uniformity of programme at each of the stations in each of the expeditions, and this contributed in no small degree to the excellence of the results. This expedition reflects great credit upon the navy and upon all concerned in its planning and execution, and is especially noteworthy as being the first expedition of the kind undertaken by naval officers of any country in foreign ports. It is to be hoped that this important service to navigation and geography will be followed by other similar work hardly less needed.

Influence of Civilization on Duration of Life. By Charlton I. Lewis. A Discourse at the Annual Meeting of the American Public Health Association, October, 1876. Cambridge: Riverside Press.

The doctrine of the survival of the fittest is now widely recognized as the key to all progress toward the perpetuation and perfection of the species, at least so far as the lower orders are concerned, and up to a certain point in the development of humanity.

But with the foundation of societies an opposite doctrine has been introduced. Instead of the pitiless destruction of the weak and the infirm, which marks the operations of the law of natural selection, they are fostered, cared for, and allowed to propagate their kind. "Society preserves for the progenitors of the future alike the weak, the strong, the diseased, and the healthy. If, then, this blind law of natural selection is the one key to progress, man must degenerate." One school of statistical writers maintains that this result does actually appear.

But Mr. Lewis shows conclusively that, while "civilization does largely sacrifice one principle of progress — the law of evolution by survivorship — it introduces another still more potent principle"— longevity. The outcome of careful breeding for a few generations, with a view to improvement in this direction, would produce a people who would live to a patriarchal age. The idea of such stirpiculture as this is repulsive to our present habits of thought. It is probable that the idea will never be realized, but there is a tendency toward something of that kind.

Mr. Lewis truly says that the subject leads us to the door of a world of restless thought and speculation.

The paper is extremely interesting and suggestive.

Elementary Lessons in Physical Geography. By Archibald Geikie, LL. D., F. R. S. London and New York: Macmillan & Co., 1877. Pp. 375. Price, $1.75.

One of the best of the "Science Primer Series" was that of Dr. Geikie on "Physical Geography," which in the present volume is expanded into the form of a text-book for rather more advanced scholars.

The author is undoubted authority on this subject, and may be fully trusted, and his material is well arranged for the purposes of teaching. The illustrations are taken close at hand, and not only show the way in which effects, with which we are familiar, have been produced, but teach the collateral lesson that Nature's processes are uniform; that the most stupendous results of far-away lands or past time have been wrought by the same methods that are in operation here and now. This is a lesson that scientific men were slow to learn, and it has not hitherto been sufficiently taught in our text-books. It is something gained when a boy, watching the little streams of a summer shower making their way through a sand-bank, knows that he is looking on the same forces at work that make and waste a continent.

The book is freely illustrated with good woodcuts, and with maps showing the distribution of atmospheric pressure, temperature, volcanoes and earthquakes, ocean-currents, etc.

Geological and Geographical Survey of Colorado and Adjacent Territory (1875). Pp. 834. Washington: Government Printing-Office.

It would be impossible, within the narrow compass of a book-notice, to summarize the contents of this valuable report; indeed, the space at our disposal would be insufficient even to give a simple list of the many wonderful natural curiosities and interesting ancient ruins here for the first time described and pictured. Then, in addition to the reports of the geologists and togpographers, we have an elaborate monograph on the American bison, by J. A. Allen; and a voluminous report by Dr. A. S. Packard, Jr., on the Rocky Mountain locust and other insects injurious to the field and garden crops of the Western Territories.

Fur-bearing Animals. By Elliott Coues. Pp. 362. With numerous Figures and Plates. Washington: Government Printing-Office.

Dr. Coues has for some time been engaged in preparing a systematic history of the North American mammals, both living and extinct, and the present volume is offered as a specimen of the method of treatment to be adopted in that work. The group of animal forms described in this monograph, the family *Mustelidæ*, he divides into five sub-families, namely, *Mustelinæ* (wolverene, marten, weasel), *Mephitinæ* (skunk), *Melinæ* (badger), *Lutrinæ* (otter), *Enhydrinæ* (sea-otter). The material on which the author bases his systematic classification is sufficiently voluminous, namely, the collections made by Hayden's Survey, of which he is the naturalist, and those of the National Museum at Washington. The purely scientific and technical aspects of the subject-matter are, of course, discussed with all requisite detail, and there is no doubt that the work will be prized by naturalists as a substantial contribution to zoölogical science. But, at the same time, the interests of a larger circle, viz., the educated though unscientific public, have not been overlooked. Indeed, what may be called the "popular" aspects of the subject in hand, namely, the life-histories of the species, and their economic and other practical relations, are considered at length.

Narrative of the Expedition of the Polaris. Edited by Rear-Admiral C. H. Davis. Pp. 696. Washington: Government Printing-Office.

The story of the gallant Captain Charles Francis Hall is here told in simple, unaffected style; indeed, as it would appear, for the most part in the very words of Hall himself, and of his companions in danger and misfortune. The volume is of quarto size, on heavy calendered paper, elegantly printed, and adorned with a steel-plate portrait of Captain Hall, a vignette of the Polaris, some forty full-page wood engravings, numerous smaller engravings, and six maps. It is, indeed, a fitting monument to the genius and intrepidity of Captain Hall and the modest heroism of his officers and crew.

PUBLICATIONS RECEIVED.

Natural Law. By Edith Simcox. Boston: Osgood. Pp. 373

History of the Ottoman Turks. By Sir E. S. Creasy. New York: Holt & Co. Pp. 574. $2.50.

The World's Progress. G. P. Putnam, editor. New York: Putnam's Sons. Pp. 1028. $4.50.

Freethinking and Plain Speaking. By Leslie Stephen. New York: Putnam's Sons. Pp. 362. $2.50.

Outlines of Modern Chemistry. By C. Gilbert Wheeler. New York: A. S. Barnes & Co. Pp. 231. $1.75.

History of Materialism. By F. A. Lange. Boston: Osgood & Co. Vol. I., pp. 350.

Through Rome On. By Nathaniel R. Waters. New York: C. P. Somerby. Pp. 352. $1.75.

The Religious Feeling. By Newman Smyth. New York: Scribner, Armstrong & Co. Pp. 171. $1.25.

Our Common Insects. By A. S. Packard, Jr. Boston: Estes & Lauriat. Pp. 225. $1.50.

Tables for the Determination of Minerals. By Persifor Frazer, Jr. Philadelphia: Lippincott & Co. Pp. 119. $2.

Smithsonian Report for 1876. Washington: Government Printing-Office. Pp. 488.

Village Improvements and Farm Villages. By George E. Waring, Jr. Boston: Osgood & Co. Pp. 200. 75 cents.

Steam-Engineering. By J. W. Nystrom. New York: Putnam's Sons. Pp. 185. $2.50.

Browne's Phonographic Monthly. New York: D. L. Scott-Browne. Vol. I., pp. 144. $2 a year.

Chemistry: Theoretical, Practical, and Analytical. Parts 21-25. Philadelphia: Lippincott & Co. 50 cents each.

Metallurgical Review. New York: D. Williams. Vol. I., No. 2, pp. 96. $5 a year.

Report of Steamboat Inspection in Canada. Ottawa: Maclean, Rogers & Co. print. Pp. 346.

Anales del Museo Nacional de México, tom. I., entrega 1ª. México: Cárlos Ramiro print. Pp. 46. With Plate.

Catalogue of the Missouri State University. Jefferson City: Regan & Carter print. Pp. 160.

Preservation of Wood as adapted to Shipbuilding. By C. E. Munroe. Claremont, N. H.: Manufacturing Co. print. Pp. 16.

Immediate Fulfillment of Prophecy. By Captain J. E. Cole. New York: O'Keefe print. Pp. 53.

Proceedings of the American Philological Association. Hartford: Case, Lockwood & Brainard Co. print. Pp. 52.

Latimer Collection of Antiquities. By O. T. Mason. From "Smithsonian Report for 1876."

Immortality of the Soul. By C. Skelton, M.D. Trenton, N. J.: Naar, Day & Naar print. Pp. 27.

Overturning the World. By Dr. G. M. Ramsey. New York: P. F. McBreen print. Pp. 27.

Iodates of Cobalt and Nickel. By F. W. Clarke. From *American Journal of Science.* Pp. 7.

Calendar of the University of Minnesota. Minneapolis: The University. Pp. 104.

International Conference on Education. Washington: Government Printing-Office. Pp. 92.

The Membrana Tympani as a Phonautograph. New York: W. Wood & Co. With Heliotype. Pp. 6.

Meteorological Researches for the Use of Coast Pilots. Part I. With Charts. Washington: Government Printing-Office. Pp. 49.

Should Comparative Anatomy be included in a Medical Course? By Dr. B. G. Wilder. New York: Appletons. Pp. 35.

Four Great Eras in Modern Astronomy. By Jacob Ennis. Cambridge: Wilson & Son print. Pp. 21.

The Force that put all the Heavens in Motion. By Jacob Ennis. Pp. 23.

Standard Public Time. By Jacob Ennis. Cambridge: Printed for the Observatory. Pp. 12.

Official Circular No. 8 of Johns Hopkins University. Pp. 12.

Cable-making and Suspension Bridges. By W. Hildenbrand. New York: Van Nostrand. Pp. 121. 50 cents.

POPULAR MISCELLANY.

The United States Pharmacopœia, as is well known, has been issued in revised editions every ten years, since its first appearance in 1830. These revisions have been made under the authority and direction of "the National Convention for revising the Pharmacopœia," consisting of delegates from medical and pharmaceutical colleges; the real work, however, has mainly rested in the hands of a few persons, who have at the same time published the very remunerative "Dispensatory of the United States." The fifth edition of the United States Pharmacopœia, issued three years after the convention met in 1873, did not, however, meet with the former approval, and was left without its customary commentary, inasmuch as the authors of the Dispensatory failed to prepare in time a new edition supplementing the new Pharmacopœia. Suggestions for an earlier revision of the Pharmacopœia than in 1880 have since been advanced; and a new departure advocated in the method and scope of the revision. Dr. Edward R. Squibb, of Brooklyn, submitted to the American Medical Association an elaborate plan for a new and completer work, to be prepared by experts, under the control of that Association. This plan, however, was abruptly rejected by the American Medical Association at its recent meeting in Chicago, mainly on the ground that the work of pharmacopœial revision is not appropriate to that body. The American Pharmaceutical Association, too, of which Dr. Squibb is also a member, and to which his plan had been presented, objected to it on account of the unequal share accorded to pharmacy in the management of the work.

The plan to obtain a better Pharmacopœia at an earlier date, and under new management, would practically have failed for the present, if it were not for the judicious and prompt action and energy of Dr. Frederick Hoffmann, of New York, who carried the subject, when dropped by Dr. Squibb, into the American Pharmaceutical Association at its recent annual meeting at Toronto. He offered the resolution, that the American Pharmaceutical Association elect a Committee to prepare a complete Pharmacopœia which may be submitted to the criticism of the medical and pharmaceutical professions, and may be proposed to the above-mentioned National Convention for revising the Pharmacopœia. This resolution passed unanimously; and the result was, that a committee was appointed for this purpose, which has agreed upon a plan of its work and has selected the experts to accomplish it. Dr. Hoffmann, of New York, has taken charge of the chemical part of the new Pharmacopœia, Prof. Maisch, of Philadelphia, of the department of pharmacognosy; and Mr. Rice, of New York, represents pharmacy. This committee has promptly entered upon its labors, and expects to submit the results to the American Pharmaceutical Association in the fall of 1879. It remains to be seen whether the Association will then present the work of its expert-committee to the National Convention, supposed to meet in 1880; and whether the latter will accept this gratuitous offer: or else, whether the American Pharmaceutical Association, encouraged by the character and value of the work, and by the sentiments of its members and the profession at large, will choose independently to publish its Pharmacopœia. By such action it would realize a desideratum which Dr. Squibb vainly aimed to accomplish, and would relieve the profession from the old National Convention for revision of the Pharmacopœia, and this itself from any further labors, by presenting in time a new and adequate standard which by its intrinsic merits might at once command the approval and acceptance of the professions.

Salicylic Acid as a Remedy for Rheumatism.—The value of salicylic acid as a medicine in the treatment of rheumatism has been under discussion for some time, the weight of authority plainly inclining toward an affirmative solution of the problem. As a specimen of the favorable results obtained by the use of the drug, we quote the observations of Dr. L. P. Yandell, Jr., as stated in his "Report on Materia Medica" to the Kentucky State Medical Society. Dr. Yandell's report treats of a number of recently-introduced drugs; it is published in the *Louisville Medical News*. His experience with salicylic acid may be briefly stated as follows: First, in the City Hospital of Louisville, nine cases of acute articular rheumatism were treated with this drug, and a "perfect cure" effected; in every instance the disease was arrested within three days, and in several cases relief was obtained in from eight to twelve hours. The drug did not appear to have any antipyretic effect. The patients took the acid in ten and twenty grain doses, in capsules, at varying intervals. In the same hospital three cases of chronic rheumatism were treated with salicylic acid without any good results. In his private practice Dr. Yandell has used this drug in five pronounced cases of acute rheumatism with entire success; and in another case this drug, combined with quinine, broke up the disease. The author writes that salicylic acid is best given in milk; it gives the milk a sweetish-sourish taste; a little tickling and sense of slight constriction may be felt about the throat, and an insignificant cough is not uncommon. He adds: "Salicylic acid is the first and only remedy that has proved itself at all reliable in the control of acute rheumatism in my hands. Salicylate of soda has shown no superiority over salicylic acid."

Notes on Fish-culture.—The one great difficulty met with in hatching the striped bass is, according to an intelligent correspondent of *Forest and Stream*, the fact that spawners of this species are very rarely found. About four years ago, we are informed, a few ripe "rock-fish" (striped bass) were found in the Roanoke River, North Carolina, and about 100,000 young fish were hatched from their spawn. One reason assigned for the diminution of this fish is the fact that they are marketed before they reach maturity. Prof. Baird favors the enactment of a law prohibitng the marketing of these fish when less than twelve inches long. Striped bass frequently attain a weight of sixty and eighty pounds; and it has been held that they do not spawn until they attain a weight of about twenty pounds. The same correspondent cites, as an evidence of the success of salmon-propagation, the recent capture of a nine-pound salmon in the Delaware. The fish was a California salmon—a variety with which the Delaware, Potomac, Susquehanna, and other rivers, were supplied a few years ago. It is supposed they return in five or six years, though difference in the temperature of the water, currents, and other conditions, may accelerate or retard the return. Over 400,000 eggs of California salmon were shipped last fall to New Zealand, where they nearly all arrived in excellent condition.

Florida Lizards.—During a sojourn in Waldo, Florida, Mr. Henry Gillman has studied the characters and habits of a great variety of lizards, and, in a brief communication to the *American Naturalist*, states some of the results of his observations. One point which he has been enabled to determine is the possession by the lizards of Florida of the power of "chameleonization," or of changing color. The author states positively that the lizards of Florida possess this power in a remarkable degree. Thus, he has seen a small, yellowish-brown lizard, on quitting the ground, instantly assume the dull gray-hue of a weather-beaten fence-rail, along which it glided. Passing under some olive-tinted foliage, it next adopted that color, which was succeeded by a bright green, as the animal reached and rested under the grass and leaves of like shade. The original yellowish-brown color was again assumed on the lizard returning to the ground. Each of these changes was almost instantaneous, and the entire series could not have occupied much more than one-quarter of a minute of time.

International Scientific Service.—Of Prof. Grote's paper, mentioned in our October number, on an International Scientific Congress, and read at the meeting of the American Association, we find a very good abstract in the *Polytechnic Review*, from which journal we quote the essential points of the paper. The author referred to the excellent work done by national scientific associations, such as the British Association and the American Association, but said that there is urgent need of a still broader organization—of an international congress of scientific men. Foremost among the problems which Science is striving to solve is that of the origin of our species. The elucidation of this question concerns the whole race, and no merely national organization possesses the means of exploring the whole field. Then, the various scientific explorations in Africa, Australia, and the polar regions, need coöperative assistance to realize the best results from the outlays, while the new knowledge they bring is the common inheritance of all enlightened nations. Now, where all participate all should contribute. Prof. Grote's plan of an international scientific service contemplates the appointment of commissioners by the civil governments of the world. The deliberations of this body "would be the wisdom of the age; its recommendations would be respected by the legislative powers of the consenting and represented nations. Under its auspices all extra-limital astronomical, geological, and biological expenditures would be fitted out, and directed to those places which would be most fruitful for any particular purpose. The difference in the mental faculties between different nations would prevent the loss in such a body of any possible suggestion which the human mind could offer."

At the same meeting a paper was read by Profs. Grote and Pitt on new fossils in the collection of the Buffalo Society of Natural Sciences, from the water-line group. The free ramus of the chelate appendage of *Pterygotus Cummingsi* (G. and P.) was described by the aid of drawings. The crab-like animal was over five feet in length, and lived in the shallow waters of the Silurian sea where Buffalo now stands. Its remains were deposited in the sedimentary lime-beds which are now being worked for manufacturing purposes.

Prof. Loomis on Rain-Areas.—The *American Journal of Science* for July contains the seventh paper of a series by Prof. Loomis, in which he investigates the phenomena of storms, their origin, development, and movements. It was shown in a previous paper that the form of a rain-area, that is, of a storm moving over the country, is usually elliptical: this elongated form is more obvious in storms which move along the coast than in those which move farther inland. The area of low barometer in a storm is not at the centre of greatest rainfall. Sometimes the rain centre is northward, or southward, or eastward, or westward, of the area of low barometer. North of latitude 36° the distance of the area of greatest rainfall from the centre of low pressure is in a majority of cases less than 250 miles, but in some instances three times that distance, the average being 300 miles. When extensive rainfalls occur there is a marked tendency to the formation of several centres of precipitation, and heavy rains may occur at various localities in a storm-area. This fact suggests that during the progress of a storm there occur local causes of great precipitation.

The tables show that heavy rainfalls are not of long duration over extended areas, and the conclusion from this fact is, that the causes which produce rain do not increase in force from the rainfall, but diminish and become exhausted. This result cannot be attributed to a want of supply of vapor, as the inflowing winds continually carry vapor into the storm-area, and this is especially true in the case of storms moving along the Atlantic border. What seems to be implied is, that an exhaustion occurs of the forces which impart that movement to the air requisite to precipitation.

The centre of great rain-areas occurs along the Atlantic border four times more frequently than inland, nor is this general fact changed in the region of the Great Lakes. Very extensive rainfalls are most frequent in autumn and winter, and occur most frequently in mornings and afternoons, and are least frequent during evenings, the difference in this respect being very marked. It is observed, too, that the "heaviest rainfalls are seldom accompanied by very high winds."

"There seems," says Prof. Loomis, "no room to doubt that areas of low barometer occur during periods of twenty-four hours with little or no rain, and travel nearly eastward with an average velocity of about twenty miles an hour." From this fact it is concluded that rainfall is not essential to the formation of areas of low barometer, and is not the principal cause of their formation nor of their progressive motion. The barometer is frequently low during the hazy weather of October, when the Indian summer prevails, a period usually of little rainfall.

Taste-Perceptions.—An interesting inquiry has been made by Vintschgau and Höingschmied to determine how much time is requisite to perceive different taste-sensations. We have already, in No. 39 of the MONTHLY, given the results obtained by these investigators in their earlier researches; but since then they have studied the subject more thoroughly, attacking more complex problems, as will be seen from the following account of their labors, which we take from the *English Mechanic*. In these experiments by pressure of a brush saturated with a concentrated solution of a savory substance on the tongue, an electric circuit was closed, which was only opened by the person when he made a signal on first perceiving the taste. The time during which the current flowed was marked by a rotating cylinder, and represented the "reaction-time" of a given taste. First, the "reaction-time" of four different substances was ascertained. This experiment was then so modified that not merely the sensation of taste had to be answered to, but the tongue of the person was touched now with water, now with a savory solution, without his knowing beforehand which was to be applied; he had to decide which had touched his tongue, and gave the signal only when it was the savory matter. In a final series of experiments there were always two savory substances used: when the person perceived the one, he gave the signal with one hand; when he perceived the other, with the other hand. Here the person had not only to perceive the sensation, but to distinguish the one taste from the other, and then to make the right choice of the hand to give the signal. The results are stated in the table below, where the first vertical series gives the names of the savory substances; the second, the time in seconds between the application of the substance and giving of the signal; the third, the reaction-time when the savory substance was applied interchangeably with water, and must be distinguished from this; the fourth, fifth, sixth, and seventh, the reaction-time in comparison with common salt, acid, sugar, and quinine, respectively:

SUBSTANCES	Simple Sensation.	COMPARISON WITH				
		Water.	Salt.	Acid.	Sugar.	Quinine
Comm'n salt...	0.1598	0.2766	......	0.3338	0.3378	0.4804
Acid....	0.1676	0.3315	0.3749	......	0.4081	0.4096
Sugar...	0.1639	0.3840	0.3688	0.4373	......	0.4224
Quinine.	0.2196	0.4129	0.4388	0.5095	0.4210	......

"If we take as a basis," say the authors, "the reaction-times when the tongue was touched with a savory substance alone, and compare therewith the reaction-times which were obtained in the experiments whether with water, or with another savory substance, we find that the following law generally holds: If we experiment with distilled water and a savory substance, or interchangeably with two savory substances on the tongue-tip, then the time of recognition of the one (in experiments with water), or of the two (in experiments with savory substances), is longer, the longer the reaction-time of one of the savory substances on simple application." The converse of this law, however (which is only in general valid), does not hold good.

An Underground Pneumatic Clock-Regulator.—The inhabitants of modern cities who are accustomed to receive their supply of water and illuminating gas through pipes laid under the streets, and who are prepared to welcome the introduction of a system of steam-heating on a large scale, will next "get the time of day" from underground pipes. A plan of regulating clocks by means of compressed air has been devised by an Austrian engineer named Mayrhofer. Its principle will be understood from the following description, which we take from the *Boston Journal of Chemistry*: In the first place, tubes are laid to convey compressed air from a central station, in which is the "master-clock." A simple contrivance, connected with the tubes and the clock, lets off a puff of air every minute or half-minute, and the fingers of all the clocks in the system are in that manner pushed forward with unerring accuracy, in accordance with the time indicated by the standard timepieces in the observatory, so that exact uniformity can be maintained without difficulty in the time shown on any number of dials. The weather has no effect on the air, so far as the working of the pneumatic clocks is concerned, and, be it hot or be it cold, the little valve lets off its puff of air, and the clocks go accurately, in defiance of atmospherical influences. A small yearly charge is made for the clocks, and there is no further expense or trouble. The system has been in operation in Vienna for nearly four months, and has worked without a solitary hitch, so that the people are beginning to realize the idea that time can be "laid on" in their houses as readily as either water or gas.

Local Temperatures of the Blood.—From researches made by Claude Bernard, it appears that while the temperature of the blood in the aorta and its more important branches is uniform, that of the venous blood varies considerably in different regions of the inferior vena cava and its principal tributaries. At the junction of the extremities and the neck with the trunk of the body, the venous blood is colder than that in the great arteries; in the right heart it is considerably hotter. If we determine its temperature at successive points in the inferior cava, we find that at the junction of the iliac veins this is lower than the arterial temperature: on a level with the entrance of the renal veins, the two are about equal; on a level with the hepatic veins, the temperature of the venous exceeds that of the arterial blood by nine-tenths of a degree. It retains this superiority even after it has become mixed in the right heart with the colder blood returned through the superior cava. Accordingly, though the venous blood of the peripheral parts is colder than in the arteries, it acquires sufficient heat during its passage through the abdominal cavity, not merely to equalize the difference, but actually to give it a permanent advantage. This is so, not because the viscera are the source of animal heat, but simply because they are by their situation protected from the effects of radiation and evaporation. Heat is generated in all the tissues, muscles, nerves, nerve-centres, and glands. The rise of temperature, which may always be detected in a muscle when thrown into a state of contraction, is invariably preceded by a slight depression; and precisely the same phenomenon is exhibited by a gland when its secretory nerve is stimulated.

Electro-Plating.—We take from Van Nostrand's *Engineering Magazine* the following statement of the results obtained by Bertrand in experiments in electro-plating with aluminium, magnesium, cadmium, bismuth, antimony, and palladium. Aluminium was deposited on decomposing, with a strong battery a solution of the double chloride of aluminium and ammonium; a plate of copper forming the negative pole whitens gradually, and becomes covered with a layer of aluminium, which takes a good polish. The double chloride of magnesium and ammonium in an aqueous solution is readily decomposed by the battery, giving in a few minutes strongly-adherent and homogeneous deposits of magnesium on a sheet of copper. It polishes readily. The battery must be powerful. Cadmium is best deposited from the bromide to which a little sulphuric acid has been added; it is then very coherent and very white, and takes a fine polish. The sulphate, if acidulated, also gives an immediate deposit of metallic cadmium, very adhesive and capable of a good polish. Bismuth is deposited from a solution of the double chloride of bismuth and ammonium on copper or brass by the current from a Bunsen element; it is very adhesive, and might be used in decorating works of art. Antimony can be deposited from a solution of the double chloride of antimony and ammonium at common temperatures. Deposits of palladium are obtained with ease by means of the double chloride of palladium and ammonium, either with or without the battery. The solution must be perfectly neutral.

New Method of Artificial Respiration.—Dr. Benjamin Howard, late of the Long Island Medical College, recently gave at King's College Hospital, London, a demonstration of his "direct method" of producing artificial respiration. For the purpose of making his description of the method perfectly plain, Dr. Howard had a man to act the part of a person rescued from the water, and apparently dead from drowning. The first thing done was to rip away the wet clothing to the waist, making of it a large, firm bolster. "Quickly turning the face downward," said he, as he proceeded to explain the process, "the bolster beneath the epigastrium, making that the highest point, the mouth the lowest; placing both hands on his back immediately above the bolster, my whole weight is thrown forcibly forward, compressing the stomach and lower part of the chest between my hands and the bolster for a few seconds, two or three times, with very short intervals." Thus the lungs are relieved of water and the stomach emptied. Then "quickly turn the patient on his back, the bolster again making the epigastrium and anterior margins of the costal cartilages the highest point of the body, the shoulders and occiput barely resting on the ground. Seize the patient's wrists, and, having secured the utmost possible extension of them behind his head, hold them fast to the ground with your left hand. With a dry pocket-handkerchief between the right thumb and forefinger withdraw the tongue, holding it at the extreme right corner of the mouth. If a boy be at hand, both wrists and tongue may be confided to his care. In this position two-thirds of the entrance to the mouth is free and the tongue is immovably fixed forward; the epiglottis is precluded from pressure and partial closure; the head is dependent; the free margins of the costal cartilages are prominent, and there is a high degree of fixed thoracic expansion. The epigastrium being highest, the movements of the diaphragm are not embarrassed by the abdominal viscera.

"To produce respiration, you kneel astride the patient's hips, rest the ball of each thumb on the corresponding costoxyphoid ligaments, the fingers falling into the lower intercostal spaces; now, resting your elbows against your sides, and using your knees as a pivot, throw the whole weight of your body slowly and steadily forward until your mouth nearly touches that of the patient, and while you slowly count three; then *suddenly* spring back to your first position on your knees, remain there while you might slowly count two; then repeat, and so on about eight or ten times a minute." The acting patient at the very first steps of the process gasped involuntarily, and as it was continued he came more and more under the control of the operator. After the operation had ceased, there were visible successive waves of involuntary respiration which the "patient" could not control.

Frank Buckland on the Berlin Gorilla.—Mr. Frank Buckland has made a visit to "Pongo," the young gorilla at the Westminster Aquarium, and observed with much pleasure the many great differences between monkey and man. First he notes the hands of the gorilla: the thumb, he observes, is exceedingly short, and "cannot be used with anything like the facility as in the human subject." Then, in the gorilla, the spaces from the knuckles to the first joint of the finger are united by a membrane, and become practically a continuation of the palm. The gorilla, too, uses its hand much more as a foot than as a hand. "The thumb of the foot," he adds, "has great powers of prehension; indeed, it may be said that the thumb proper is carried on the foot. The gorilla has no calf to the leg, and no biceps in the forearm: he cannot stand upright without supporting himself by means of some object. The back of the gorilla is almost square, something after the form of the flat saddle used in equestrian feats in circuses. The cause of this is, that the ribs come close down on the top of the hip-bone." So far as Mr. Buckland has been able to learn, the gorilla does not use a stick for the purpose of striking, neither does he ever strike with his hands. Two children, a boy and a girl, were permitted to play with Pongo, and as Mr. Buckland looked on he "could not help seeing what a vast line the Creator had drawn between them." Our author concludes by saying that Pongo's structure and manners confirm the idea that Darwin is wrong, and that human beings are not monkeys. This doctrine of the identity of man and monkey gives Mr. Buckland a great deal of trouble, and from the vehemence with which he combats it one is led to suppose that it must be prevalent in England. It is a little strange, however, that the adepts of this vile heresy have contrived to mask their teachings, for we have not seen this doctrine upheld in any of the publications of the day. Mr. Buckland asks: "Why not rest satisfied with the origin of our race thus revealed to us by the great Creator himself?—'So God created man in his own image, and in the image of God created he him; male and female created he them.'"

Topographical Surveys and Health.—Mr. James T. Gardner delivered, at the Boston meeting of the Public Health Association, an address on the "Relation between Topographical Surveys and the Study of Public Health," which abounds in suggestions of the highest practical importance. As an illustration of the author's mode of enforcing his arguments, we may take his remarks on "natural drainage." "This," we are informed, "results from combined action of configuration, character of soil, constitution of underlying rock, and the form of its surface. These four elements regulate natural drainage. Each must present favorable conditions, or deadly waters will accumulate on the surface or in hidden strata. *No plan of artificial drainage can be completely successful unless based on a thorough comprehension of the natural drainage system of the area under treatment.* The region above the Palisades on the Hudson furnishes excellent illustration of these statements. The plateau fronts the river eastward with a bluff 300 feet high, and westward slopes gently to the Hackensack Valley. . . . All topographical conditions of unusual health seem here present, and yet malarial diseases abound. The reason of this will probably be found in the configuration of the rock. The dense basalt underlying the thin soil absorbs almost no water. Its surface, originally nearly level, was worn by glacial action into low, swelling ridges and shallow rock-basins, many of which, having no outlet, hold stagnant water as great saucers would. If the rock were either fissured or porous the height of the plateau would insure perfect under-drainage."

With the Palisades plateau the author now contrasts the Helderberg plateau, also situated near the Hudson River. Here, "an escarpment 1,000 feet high bounds, on the eastern side, the table-land, composed of horizontal limestone resting on shales. From the more level parts water does not pass off by surface-streams. Low undulations divide these areas into many separate basins, each draining toward its own centre, where a funnel-shaped opening in the limestone receives the disappearing flow, whose future course is subterranean. These basins are from a few acres to 300 or 400 in extent. When one covers about five square miles a pond is formed at the point of central drainage, finding outlet through fissures of the limestone below. The plateau's elevation insures that these waters sink at once many hundred feet, or escape in springs along the cliffs." Mr. Gardner then proceeds to show how—as at Sandusky, Ohio—this same Helderberg limestone may, *under different topographical conditions*, become one of the most powerful producers of disease.

A Formidable Arachnidan.—Dr. B. F. Pope, U. S. A., contributes to *Forest and Stream* some valuable "Notes on the Natural History of Southwestern Texas," from which we take the following account of the "vinagrone" (*big vinegar*, so called on account of the pungent secretion it ejects), an arachnidan found in the vicinity of Fort Stockton. In general appearance it resembles a large scorpion, though belonging to a different family. From the head to the commencement of the tail the adult vinagrone is full two inches long; in breadth it measures about three-quarters of an inch. The thorax and head are amalgamated, while the thorax and abdomen are separated by flexible tissue. The legs are six in number, all attached to the thorax. The trunk and head are protected by a single dorsal plate; the abdomen has sixteen distinct dorsal and ventral laminæ, which overlap; they would form continuous rings, were it not that they are curiously separated laterally by elastic tissue. This division of the abdominal rings affords considerable flexibility, and gives the insect the appearance of bearing about him an old-fashioned bellows. From the terminal, dorsal, and ventral plates is given off a series of rings, which, after the third one, are fused into a stiff spike or tail, that is usually three-fifths of the length of the entire body, and covered with short bristles like the legs. This is not a sting, nor does it seem to be the duct through which the secretion is ejected. It appears to be used principally as a posterior feeler, and sometimes as an aid to locomotion.

From the head are given off two powerful brachials, each having four articulations. They resemble the arms of a scorpion, and terminate in sharply-curved pincers. The threatening manner in which they are opened and stretched out, when the insect is enraged or is seeking for its prey, almost makes one shudder. But the brachia are not its only means of offense. Beneath the frontal plate are two long, incurvated fangs. Connected with these are two sacs, that, by pressure, exude drops of greenish liquid over the fangs, and in them undoubtedly resides the true venom of the insect.

Of the bite of this animal the author writes: "We have no good proof that the bite of the vinagrone would be fatal to man, except perhaps as it might be supplemented by the shock of an excessive terror; but that it would be dangerous I think highly probable. As an experiment, I confined two of them in a small box with a large bat. The next morning the bat was dead, having been killed by them during the night, when it is supposed to be most agile and wary. I placed another unsavory specimen in a large bottle, in company with a large wasp and a tarantula. The vinagrone killed and devoured them both in short order."

In a later number of the same journal Dr. H. C. Yarrow writes that the vinagrone is quite well known to entomologists under the name of *Thelyphonus giganteus*, and that it is common in New Mexico and Arizona.

The Scandal of the Seal-Fishery.—Unless the governments of the countries which send out ships to the seal-fishery grounds speedily put some restrictions on the method now pursued, there will before long be no seals. In 1868 Dr. Robert Brown expressed his belief that, "supposing the sealing prosecuted with the same vigor as at present, before thirty years shall have passed away the seal-fishery, as a source of commerical revenue, will have come to a close." The Greenland seal-fishery is already "practically used up" and the sealers are now turning their attention to the coast of Newfoundland. A writer in *Nature* cites the London *Daily News*, to show what slaughter is made of the Newfoundland seals, and we learn that in one season four vessels secured 89,000 seals. To this add a like number of young ones left to die of starvation, and twenty per cent. as many mortally wounded and lost, and the aggregate amounts to over 200,000 seals! The writer in *Nature* suggests this subject of the destruction of the seal as a fitting one to occupy the minds of the advocates of the anti-vivisection laws, and the Society for the Prevention of Cruelty to Animals.

The Building-Stones of St. Lawrence County, New York.—From a statement by Mr. D. Minthorn, published in the *Engineering and Mining Journal*, it appears that in the northern portion of the State of New York may be found in abundance all the choicest varieties of marbles, granites, and other building-stones. Besides the common gray gneiss, he enumerates among the building-stones of St. Lawrence County several varieties, such as syenitic granite, many New England granites, a deep-green granite "mottled like the pedestals of Cheops." Then there are various pink, green, and dark-red porphyritic granites; and finally there are large masses of very compact gray and green granite, studded with garnets about half an inch apart. The varieties of marbles are very numerous, ranging from white limestone and dolomite and statuary marble to straw-colored, blue, drab, brown, black, yellow, and red variegated marbles; verd-antique also is represented; indeed, Mr. Minthorn is prepared to match any of the antique marbles with the products of the St. Lawrence County quarries. Adjoining the statuary-marble quarry is a deposit consisting partly of pagodite or Chinese figure-stone, and possessing sufficient hardness to take a polish, while at the same time it does not "chip out" when chiseled in sharp lines.

NOTES.

We have received from Conrad Meyer & Sons, of Philadelphia, a correction of the statement made by Mr. S. Austen Pierce, in our October number, that Jonas Chickering in 1837 "conceived the bold idea of constructing a [pianoforte] frame entirely of iron." The Messrs. Meyer now cite the official "report" of the jury of the Franklin Institute Exhibition of 1833, which mentions "an iron-framed square piano" exhibited by Conrad Meyer. Other testimony to the same effect is quoted by the Messrs. Meyer, who appear to make out a clear case of priority of invention. Having admitted this correction, we can afford no more space in the columns of the Monthly for the piano-frame controversy.

We have received from Mr. E. Berliner, Washington, a circular, with drawings, giving an account of certain of the author's discoveries and inventions in electricity. These are a contact telephone, an electric-spark telephone, and a method of telephonic transfer.

At New Cumberland, West Virginia, a fountain of natural gas is utilized for manufacturing fire-brick. This, says the *American Manufacturer*, is the first fire-brick ever burned without wood or coal. Fifty-five thousand bricks are made daily in nine kilns. The gas furthermore supplies fuel for three engines, ten furnaces in the drying-house, and several dwellings—the latter obtaining in this way both light and heat. There remains withal a large surplus of gas, which is unused, except from the top of an escape-pipe, for illuminating the country around.

The *Nation* is authority for the statement that the office of Director of the International Bureau of Weights and Measures in Paris has been offered to Prof. J. E. Hilgard, of the United States Coast Survey.

Died, at Bonn, on September 13th, at the age of eighty-nine years, Jakob Nöggerath, for about fifty years Professor of Mineralogy in the university of that town. The deceased was a most assiduous student of mineralogy and geology, and his contributions to scientific literature were very voluminous.

Mr. Henry Newton, geologist, attached to Jenney's Black Hills Exploring Expedition, died at Deadwood City, August 5th, at the early age of thirty-two years. Mr. Newton was a graduate of the Columbia College School of Mines; later, Assistant Professor of Geology in the same institution; then he joined the Ohio Survey under Prof. Newberry; finally, two years ago, he became geologist of Prof. Jenney's Expedition to the Black Hills.

Mr. R. A. Proctor, in excusing himself for not answering all the letters of inquiry he receives, gives the following account of his multifarious occupations: Seeing through the press three new works and four new editions, preparing two pamphlets, writing one translation of an 800-page book, and preparing four new works; writing articles for English and American magazines; lecturing occasionally; business correspondence with ten publishers; personal concerns; original research.

At a meeting of the Paris Academy of Sciences, a note by L. Laliman was read, in which the author stated that he had discovered an insect which preys on the Phylloxera. This insect, or rather its larva—for M. Laliman had not seen the perfect insect—devours phylloxeras with great avidity, and the author saw as many as ninety-five disappearing in the space of ten minutes. The larva was found in the interstices of the leaf-galls, and sometimes in the substance of the galls. M. Laliman thinks he has seen the egg of this insect; it occurs on the underside of the leaf; but he has not seen it hatched. A member of the Academy, M. Balbiani, remarked that the fact observed by Laliman is not altogether new. The larva seen by him belongs to the genus *Syrphus*, or to some allied genus. The larvæ of *Syrphus* all prey on Aphides.

An expedition, with aims similar to those of the "Woodruff Expedition," will sail from Havre, France, on the 15th of June, 1878. This expedition will be absent from France for eleven months. Of this time it is proposed to spend about six months and a half in excursions inland in America, North and South, the Pacific Archipelagos, Australia, Japan, China, British India, etc. The cost of passage is 17,000 francs per head.

Mr. Richard S. Floyd, one of the trustees of the "Lick Trust," on his return to California, after an extended tour of foreign travel, during which he collected all the information he could with regard to the construction of great telescopes, expressed his belief that the best telescope for the Lick Observatory would be a refractor of the largest size. The cost of a suitable instrument, with object-glass of forty inches, would not, he thinks, exceed $150,000. But, in addition to the great refractor, Mr. Floyd would have in the observatory a reflector about four feet in diameter, with both silvered glass and speculum-metal mirrors. This would cost about $20,000.

A service of plate was recently presented in London to Señor Manuel Garcia "in recognition of the great services he has rendered alike to science and humanity by his important discovery of the laryngoscope."

Advices from Australia announce the total and sudden disappearance of a group of guano-islands—the Barker Islands—situate in latitude 14° south, and longitude 125° east, just off the northwest coast of Australia. In April last Mr. Fisher, a capitalist of Tasmania, who had obtained from the government the right of working the guano-deposits, visited their site with three steamships, but found there only a "waste of waters," and had to return empty. The Barker Islands are not mentioned in the "Imperial Gazetteer," nor are they indicated in the atlases.

There was exported from China to Europe, in the year 1875, the enormous amount of about sixty tons of human hair. This hair is ostensibly the product of the sweeping of barber-shops, but there is little doubt that much of it represents "pig-tails" feloniously snipped from their wearers' heads.

The addition of cheese to the army and navy ration, in part substitution for salt meat, is advocated by a writer in the *Polytechnic Review*. The suggestion is a good one, the advantages of cheese being manifold: it is wholesome, highly nutritious, aids digestion, needs no cooking, and is easily handled and transported.

JOSEPH LE CONTE

THE

POPULAR SCIENCE MONTHLY.

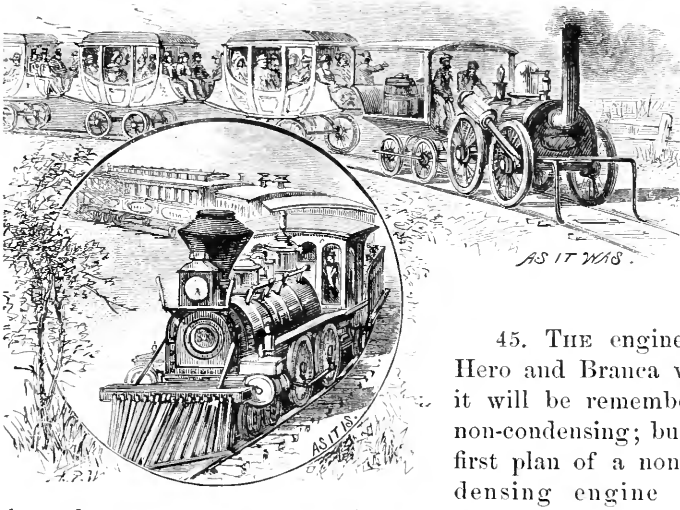
JANUARY, 1878.

THE GROWTH OF THE STEAM-ENGINE.[1]

By Professor R. H. THURSTON,
OF THE STEVENS INSTITUTE OF TECHNOLOGY.

III.

THE NON-CONDENSING ENGINE, AND ITS APPLICATION IN THE LOCOMOTIVE.



45. The engines of Hero and Branca were, it will be remembered, non-condensing; but the first plan of a non-condensing engine that could have been made of any really practical use is given in the "*Theatrum Machinarum*," of Leupold, published in 1720. His sketch is copied in Fig. 23. It is stated by Leupold that this plan was sug-

[1] An abstract of "A History of the Growth of the Steam-Engine," to be published by D. Appleton & Co.

gested by Papin. It consists of two single-acting cylinders, *r s*, receiving steam alternately from the same steam-pipe through a "four-way-cock," and exhausting into the atmosphere. We find no evidence that this engine was ever built.

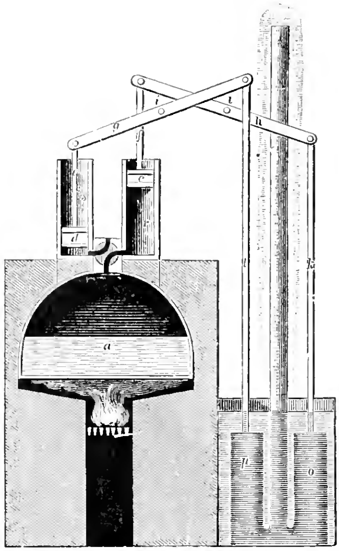


Fig. 23.—Leupold's Papin Engine, 1720.

When, during the last century, the steam-engine had so far been perfected that the possibility of its application to other purposes than the elevation of water had become generally recognized, the problem of its adaptation to the propulsion of carriages was attacked by many engineers and inventors.

As early as 1759, Dr. Robison, who was at the time a graduate of the University of Glasgow, and an applicant for an assistant professorship there, and who had made the acquaintance of the instrument-maker, James Watt, when visiting the workshop, called the attention of the latter, who was probably then more ignorant of the principles of the steam-engine than was the young student, to the possibility of constructing a carriage to be driven by a steam-engine, thus, perhaps, setting in operation that train of thoughtful experiment which finally earned for Watt his splendid fame.

46. Watt, at a very early period, proposed to apply his engine to locomotion, and contemplated using either a non-condensing engine, or an air-surface condenser. He actually included the locomotive-engine in his patent of 1784, and his assistant, Murdoch, in the same year, made a working-model locomotive which was capable of running at a rapid rate.

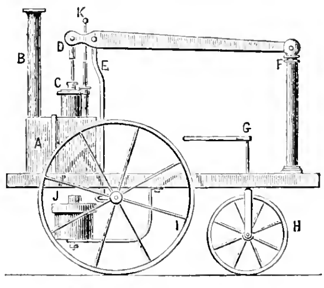


Fig. 24.—Murdoch's Model, 1784.

This model, now deposited in the Patent Museum, at South Kensington, London, had a flue-boiler, and a "grasshopper" engine. Its steam-cylinder was three-quarters of an inch in diameter, and had two inches stroke of piston (Fig. 24). The driving-wheels were nine and a half inches in diameter. It is reported to have run six to eight miles an hour, its little driving-wheels making from two hundred to two hundred and seventy-five revolutions per minute.

47. In 1765 that singular genius, Dr. Erasmus Darwin, whose celebrity was acquired by speculations in poetry and philosophy as well as in medicine, urged Matthew Boulton (subsequently Watt's partner, and just then corresponding with our own Franklin in relation to the use of steam-power), to construct a steam-carriage, or "fiery chariot," as he poetically styled it, and of which he sketched a set of plans.

A young man, named Edgeworth, became interested in the scheme, and in 1768 published a paper which had secured for him a gold medal from the Society of Arts. In this paper he proposed railroads on which the carriages were to be drawn by horses, *or by ropes from steam-winding engines.*

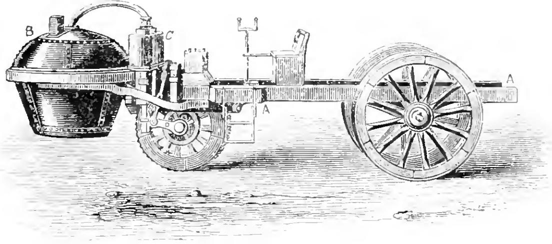


Fig. 25.—Cugnot's Steam-Carriage, 1770.

48. These were merely promising schemes, however. The first actual experiment was made, as is supposed, by a French army officer, Nicolas Joseph Cugnot, who in 1769 built a steam-carriage (Fig. 25), which was set at work in presence of the French Minister of War, the Duke de Choiseul. The funds required by him were furnished by the Comte de Saxe. Encouraged by the partial success of the first locomotive, Cugnot, in 1770, constructed a second which is still preserved in the *Conservatoire des Arts et Métiers*, Paris. This more powerful carriage (Fig. 25) was fitted with two non-condensing single-acting cylinders, thirteen inches in diameter. Although the experiment seems to have been successful, there appears to have been nothing more done with it.

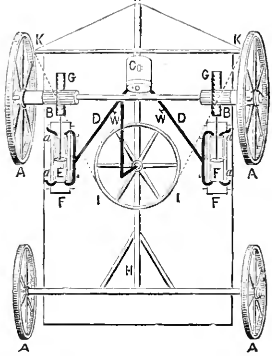


Fig. 26.—Read's Steam-Carriage, 1790.

An American of considerable distinction, Nathan Read, patented a steam-carriage, 1790,[1] of the form seen in Fig. 26, which is copied from his patent. The cylinders *F F* lie under the body of the carriage; the pistons *E F* drive racks *B G*, which turn the wheels *A K*. The steering-wheel *I* moves the large wheels *A K*, which lat-

[1] "Nathan Read and his Steam-Engine." New York: Hurd & Houghton, 1870.

ter, turning, carries the engines about with it. It is an ingenious and curious device.

49. "To Oliver Evans," says Dr. Ernest Alban,[1] the learned German engineer, "was it reserved to show the true value of a long-known principle, and to establish thereon a new and more simple method of applying the power of steam—a method that will remain an eternal memorial to its introducers." Dr. Alban here refers to the earliest successful introduction of the non-condensing high-pressure steam-engine.

Oliver Evans, one of the most ingenious mechanics that America has ever produced, was born at Newport, Delaware, in 1755 or 1756, the son of people in very humble circumstances.

He was, in his youth, apprenticed to a wheelwright, and soon exhibited great mechanical talent and a strong desire to acquire knowledge.

His attention was at an early period drawn to this possible application of the power of steam to useful purposes by a boyish prank. Placing a small quantity of water in a gun-barrel, and ramming down a tight wad, he put the barrel in the fire of a blacksmith's forge. The loud report which accompanied the expulsion of the wad was an evidence to young Evans of the great, and, as he supposed, previously undiscovered power of steam.

Subsequently, meeting with a description of a Newcomen engine, he at once noticed that the elastic force of confined steam was not there utilized.

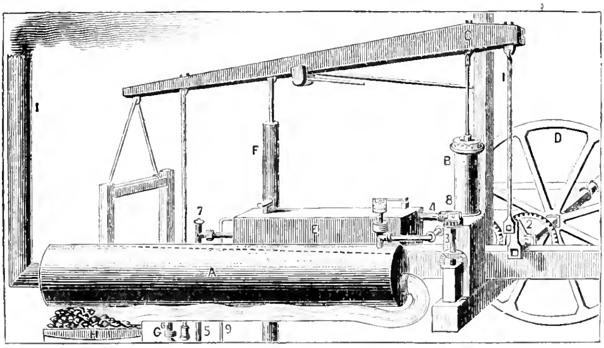


Fig. 27.—Oliver Evans's Engine, 1800.

He then designed the non-condensing engine, in which the power was derived exclusively from the tension of high-pressure steam, and proposed its application to the propulsion of carriages.

50. About the year 1780 Evans joined his brothers, who were millers by occupation, and at once employed his inventive talent in

[1] "The High-Pressure Engine investigated," Dr. Ernest Alban, London, 1847.

improving the details of mill-work, and with such success as to reduce the cost of attendance one-half, and also to increase the fineness of the flour made.

In 1785 he applied for, but was refused, a patent for a steam-carriage.

In 1800 or 1801, Evans, after consulting with Prof. Robert Patterson, of the University of Pennsylvania, and getting his approval of the plans, commenced the construction of a steam-carriage, to be driven by a non-condensing engine.

He soon concluded, however, that it would be a better scheme, pecuniarily, to adapt his engine, which was novel in form and of small first cost, to driving mills; and he accordingly changed his plans, and built an engine of six inches diameter of cylinder and eighteen inches stroke of piston, which he applied with perfect success to driving a plaster mill.

51. This engine (Fig. 27), which he called the "Columbian engine," was of a peculiar form.

The beam is supported at one end by a rocking column; at the other it is attached directly to the piston-rod, while the crank lies beneath the beam, the connecting-rod being attached to the latter at about the middle point.

The head of the piston-rod is compelled to rise and fall in a vertical line by the "Evans parallelogram," a kind of parallel motion very similar to one of those designed by Watt.

52. Subsequently, Evans continued to extend the application of his engine and to perfect its details, and, others following in his track, the non-condensing engine is to-day fulfilling the predictions which he made seventy years ago, when he said:

> "I have no doubt that my engine will propel boats against the currents of the Mississippi, and wagons on turnpike-roads, with great profit. . . .
>
> "The time will come when people will travel in stages moved by steam-engines, from one city to another, almost as fast as birds can fly—fifteen or twenty miles an hour. A carriage will start from Washington in the morning, the passengers will breakfast at Baltimore, dine at Philadelphia, and sup at New York the same day. . . .
>
> "Engines will drive boats ten or twelve miles an hour, and there will be hundreds of steamers running on the Mississippi, as predicted years ago."

53. In 1804 Oliver Evans completed a flat-bottomed boat (Fig. 28), to be used at the Philadelphia docks, and, mounting it upon wheels, drew it by its own steam-engine to the river-bank. Launching the craft, he propelled it down the river, using its steam-engine to drive its paddle-wheels. Evans's "*oructor amphibolis*," as he named the machine, was the first road-locomotive that we find described after Cugnot's time. Evans asserted that carriages propelled by steam would soon be in common use; and offered a wager of three hundred

dollars that he could build a "steam-wagon" that should excel in speed the swiftest horse that could be matched against it.

Evans's connection with steam-navigation will be referred to when considering that subject.

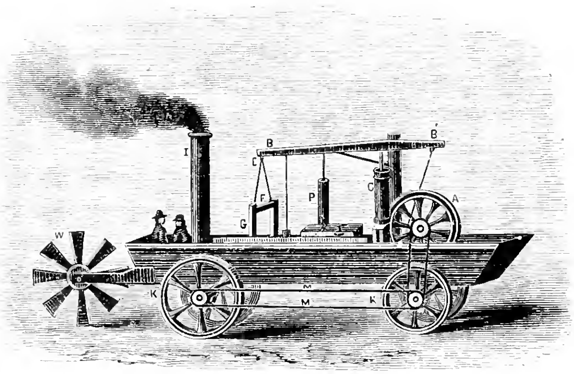


Fig. 28.—"Oructor Amphibolis," 1804.

To this brief sketch of Evans's inventions it can only be added that he devised the flue-boiler, now generally called the Cornish, and used it to furnish steam to his engines.

Richard Trevithick.

54. The earliest non-condensing engine brought into use in Great Britain seems to have been constructed by Richard Trevithick and

Andrew Vivian in 1802. It is stated, by friends of Oliver Evans, that he had, at an earlier date, sent Mr. John Sampson to England, and, by him, had forwarded drawings and specifications, which Trevithick and Vivian inspected, and to which, it is not improbable, they may have been indebted for their plans.

They used a non-condensing, return connecting-rod engine, and carried as high as sixty to eighty pounds of steam.

They built a locomotive-engine in 1804 (Fig. 29), for the railway

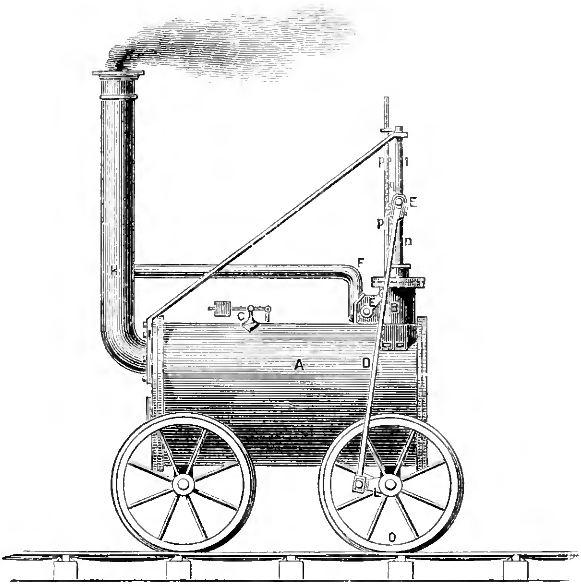


Fig. 29.—Trevithick's Locomotive, 1804.

at Merthyr-Tydvil, in South Wales, which was quite successful, although sometimes giving trouble by slipping its wheels.

This engine had one steam-cylinder $4\frac{3}{4}$ inches diameter, and carried forty pounds steam.

In consequence of a fear of the wheel slipping, Blenkinsop employed, in 1811, a pinion on the locomotive shaft, gearing into a rack on the road-bed.

In 1813 Brunton, of Butterly, tried to introduce a locomotive-engine propelled by levers, like an animal's legs, pushing behind; and just at this time mechanics, all over the world, seem to have become very much interested in this problem.

55. It is at about this period that we find evidence of the intelligent labors of another of our countrymen—one who, in consequence of the unobtrusive manner in which his work was done, has never received the full credit to which he is entitled.

Colonel John Stevens, of Hoboken, as he is generally called, was born in the city of New York, in 1749, but, throughout his business life, he was a resident of New Jersey.

He was undoubtedly the greatest engineer and naval architect living at the beginning of the present century.

JOHN STEVENS.

Without having made any one superlatively great improvement in the mechanism of the steam-engine, like that which gave Watt his fame; without having the honor of being the first to propose navigation by steam, or steam transportation on land, he exhibited a far better knowledge of the science and of the art of engineering than any man of his time, and he entertained and urged more advanced opinions and more statesmanlike views, in relation to the economical importance of the improvement of the steam-engine, both on land and water, than seem to have been attributable to any other leading engineer of that time.

His attention is said to have been first called to the application of steam-power by seeing the experiments of John Fitch with his steamer. He entered upon the work of the introduction of steam in navigation with characteristic energy, and with a success that will be indicated when we come to the consideration of that branch of the subject.

But this far-sighted engineer and statesman saw plainly the importance of applying the steam-engine to land transportation as well as navigation; and not only that, but he saw with equal distinctness the importance of a well-devised and carefully-prosecuted scheme of internal communication by a complete system of railroads.

56. In 1812 he published a pamphlet embodying "Documents tending to prove the Superior Advantages of Railways and Steam-Carriages over Canal Navigation."[1]

At this time, the only working locomotive in the world was that of Trevithick and Vivian, at Merthyr-Tydvil, and the railroad itself had not grown beyond the old wooden tram-roads of the collieries.

Yet, Colonel Stevens says in this paper, "I can see nothing to hinder a steam-carriage moving on its ways with a velocity of one hundred miles an hour," adding in a foot-note: "This astonishing velocity is considered here merely possible. It is probable that it may not, in practice, be convenient to exceed twenty or thirty miles per hour. Actual experiments can only determine this matter, and I should not be surprised at seeing steam-carriages propelled at the rate of forty or fifty miles an hour."

At a yet earlier date he had addressed a memoir to the proper authorities, urging his plans for railroads.

He proposed rails of timber, protected when necessary by iron plates, or to be made wholly of iron. The car-wheels were to be of cast-iron, with inside flanges to keep them on the track. The steam-engine was to be driven by steam of fifty pounds pressure, and to be non-condensing.

Answering the objections of Robert R. Livingston and of the commissioners of New York, he goes further into details.

57. He gives 500 to 1,000 pounds as the maximum weight to be placed on each wheel, shows that the trains or "suites of carriages," as he calls them, will make their journeys "with as much certainty and celerity in the darkest night as in the light of day," shows that the grades of proposed roads would offer but little resistance, and places the whole subject before the public with such accuracy of statement, and such evident appreciation of its true value, that every one who reads this remarkable document will agree fully with the late President Charles King, of Columbia College, who said that "whosoever shall attentively read this pamphlet will perceive that the political, financial, commercial, and military aspects of this great question were all present to Colonel Stevens's mind, and that he felt that he was fulfilling a patriotic duty when he placed at the disposal of his native country these fruits of his genius.

"The offer was not then accepted. The *Thinker* was ahead of his age, but it is grateful to know that he lived to see his projects carried out—though not by the Government—and that before he finally, in 1838, closed his eyes in death, at the great age of eighty-nine, he could justly feel assured that the name of Stevens, in his own person

[1] Printed by T. & J. Swords, 1160 Pearl Street, New York, 1812.

and that of his sons, was imperishably enrolled among those which a grateful country will cherish."

A patent issued to Colonel Stevens by the British Government in 1805, and a section of a "safety-tubular" boiler subsequently built on the same plan, and used on a locomotive, are preserved in the Stevens Institute of Technology, at Hoboken, New Jersey.

GEORGE STEPHENSON.

58. In 1814 George Stephenson, to whom is generally accorded the honor of having first made the locomotive-engine a success, built his first engine at Killingworth, England.

It had been found during the previous year, by Blackett & Headly, whose engine is still preserved at the South Kensington Patent Museum, that the slipping of the wheels could be avoided without recourse to extraordinary contrivances, and Stephenson made his engine a success, using smooth wheels.

At this time, Stephenson was by no means alone in the field, for the idea of applying the steam-engine to driving carriages on common roads and on railroads was beginning to attract considerable attention.

Stephenson, however, combined in a very fortunate degree the advantages of great natural inventive talent and an excellent mechanical training, his characteristics as an engineer reminding one strongly of those of James Watt. Indeed, Stephenson's portrait bears some resemblance to that of the great inventor.

59. George Stephenson was born in Wylam, in the north of England, near Newcastle-upon-Tyne, and was the son of a "north-country

miner." When still a child, he exhibited great mechanical talent and unusual love of study.

When set at work about the mines, his attention to duty and his intelligence obtained for him rapid promotion, until, when about seventeen years of age, he was made engineer, and took charge of the pumping-engine at which his father was fireman.

A little later he was made engine-wright at Killingworth, where he soon inspired those who employed him with such confidence in his skill and reliability as to obtain an opportunity to design his first locomotive-engine, Lord Ravensworth, one of the principal proprietors, furnishing the necessary funds.

60. In 1815 he applied the blast-pipe in the chimney, by which the puff of the exhaust steam is made useful in intensifying the draught, and applied it successfully to his second locomotive, here seen in section (Fig. 30). This is the essential characteristic of the locomotive-engine.

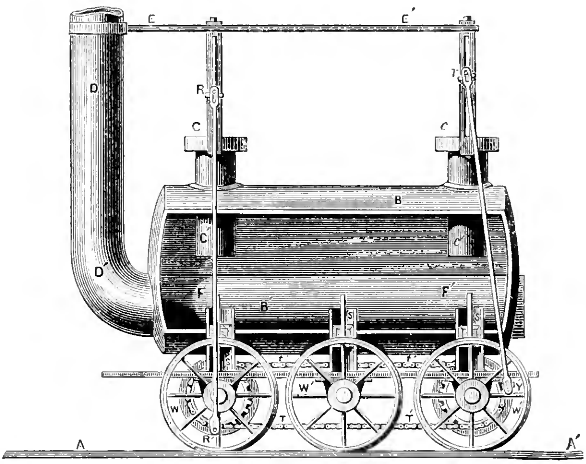


FIG. 30.—STEPHENSON'S LOCOMOTIVE, 1815.

In 1815, therefore, we may say that the modern locomotive steam-engine came into existence, for it is this invention of the blast-pipe that gives it its life, and it is the mechanical adaptation of this and of the other organs of the steam-engine to locomotion that gives George Stephenson his greatest claim to distinction.

61. In 1825 the Stockton & Darlington Railroad was opened, and one of Stephenson's locomotives, in which he employed his "steam-blast," was successfully used, drawing passenger as well as coal trains. Stephenson had at this time become engineer of the road.

The time required to travel the distance of twelve miles was two hours. This "No. 1 Engine" is still preserved at Darlington Station, mounted on a granite pedestal, as shown in the picture (Fig. 32).

62. One of the most important and interesting occasions in the history of the application of the non-condensing steam-engine to railroads, as well as in the life of Stephenson, was the opening of the Liverpool & Manchester Railroad in the year 1829.

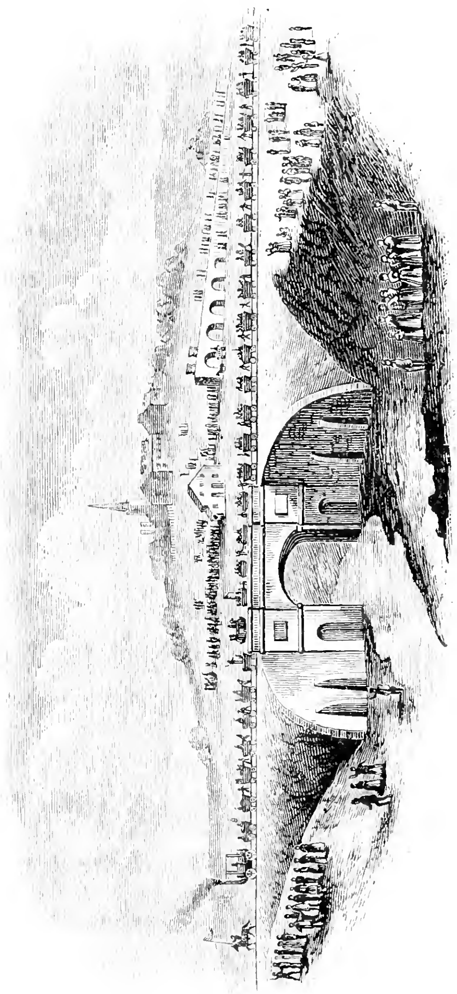


Fig. 31.—Opening of the Stockton & Darlington Railroad, 1825.

When this road was built, it was determined, after long and earnest discussion, to try whether locomotive-engines might not be used to the exclusion of horses, and a prize of £500 was offered for the best that should be presented at a date which was finally settled at the 6th of October, 1829.

Four engines competed, and the "Rocket," built by Stephenson, received the prize.

63. This engine (Fig. 33) weighed four and one-fourth tons, with its supply of water. Its boiler was of the fire-tubular form, a form

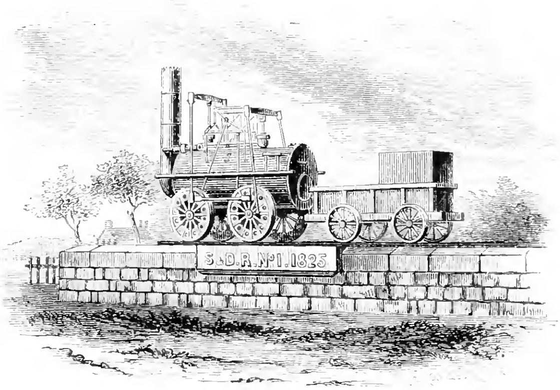


FIG. 32.—STOCKTON & DARLINGTON ENGINE NO. 1, 1825.

that had grown into shape in the hands of several inventors,[1] and was three feet in diameter, six feet long, with twenty-five three-inch tubes, extending from end to end of the boiler. The steam-blast was carefully adjusted by experiment, to give the best effect. Steam-pressure was carried at fifty pounds per square inch.

The average speed of the Rocket on its trial was fifteen miles per hour, and its maximum was nearly double that, twenty-nine miles an hour; and afterward, running alone, it reached a speed of thirty-five miles.

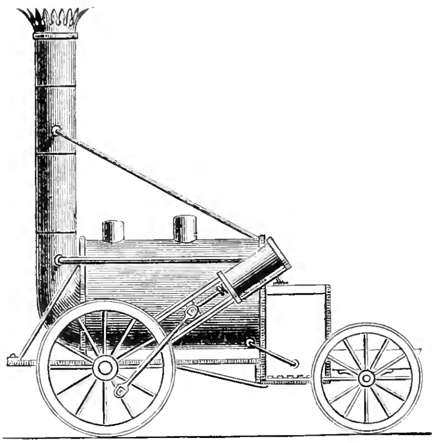


FIG. 33.—THE ROCKET, 1829.

The shares of the company immediately rose ten per cent. in value. Thus the combination of the non-condensing engine with a steam-blast and the multitubular boiler, designed by the clear head and constructed under the watchful eye of an accomplished engineer and mechanic, made steam-locomotion so evident and decided a success that thenceforward its progress has been uninterrupted and wonderfully rapid.

[1] Barlow and Fulton, 1795; Nathan Read, Salem, United States, 1796; Booth, of England, and Séguin, of France, about 1827 or 1828.

64. In America the locomotive was set at regular work on railroads, for the first time, on the 8th of August, 1829.[1]

This first locomotive was built by Foster, Rastrick & Co., at Stourbridge, England, and was purchased by Mr. Horatio Allen for the Delaware & Hudson Canal Company's road from Carbondale to Honesdale, Pennsylvania.

Mr. Peter Cooper, of New York, placed an experimental locomotive on the Baltimore & Ohio Railroad in 1829. It ran about fifteen miles an hour at maximum speed.

The first American locomotive to do real service continuously was the "Best Friend" (Fig. 34), built at the West Point Iron Foundery,

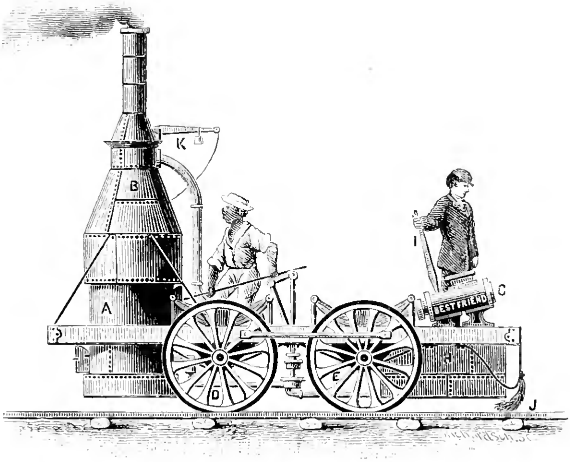


FIG. 34.—THE "BEST FRIEND," 1830.

in the year 1830, for the South Carolina Railroad, on which road it ran from January, 1831, to June 17th of the same year, when it was destroyed by the explosion of its boiler.

A second locomotive (Fig. 35) was built at West Point for the same road in 1831, which resembled somewhat those built at about the same time, and a little later, by Stephenson.

It was at this time (1831), also, that Mr. Horatio Allen introduced the first eight-wheeled locomotives ever built, and gave them a form (Fig. 36) which will be at once recognized by the engineer as the prototype of a recently-built locomotive which has been brought out in Great Britain. In this year, also, an engine, the De Witt Clinton, was built for John B. Jervis of the Mohawk & Hudson Railroad.

65. At about the time of the opening of the early railroads, the

[1] "History of the First Locomotive in America," W. H. Brown. D. Appleton & Co., New York, 1872.

introduction of steam-carriages on the common highway had become a favorite idea with engineers.[1]

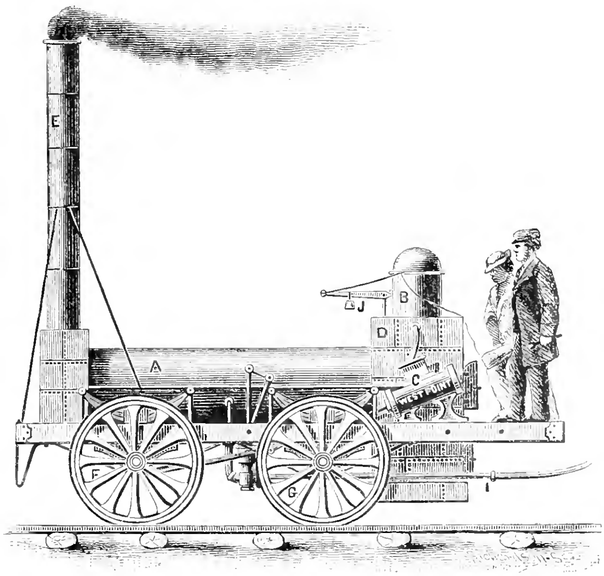


FIG. 35.—THE WEST POINT, 1831.

In December, 1833, about twenty steam-carriages and traction road-engines were running or were in course of construction in and near London.

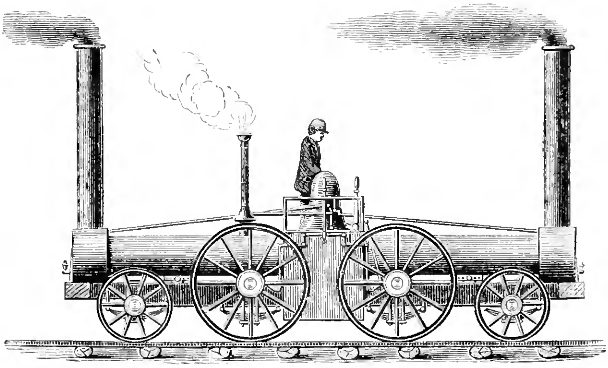


FIG. 36.—THE SOUTH CAROLINA, 1831.

In our own country, the roughness of roads discouraged inventors, and, in Great Britain even, the successful introduction of road-locomotives, which seemed at one time almost an accomplished fact, finally

[1] "Road-Locomotives and Traction-Engines," *Journal of the Franklin Institute*, 1871.

met with so many obstacles that even Hancock and Gurney, the most ingenious, persistent, and successful constructors, gave up in despair. Hostile legislation procured by opposing interests, and possibly also the rapid progress of steam-locomotion on railroads, caused this result.

In consequence of this interruption of experiment, almost nothing was done during the succeeding quarter of a century, and it is only within a few years that anything like a business success has been founded upon the construction of road-locomotives, although the scheme seems to have been at no time entirely given up.

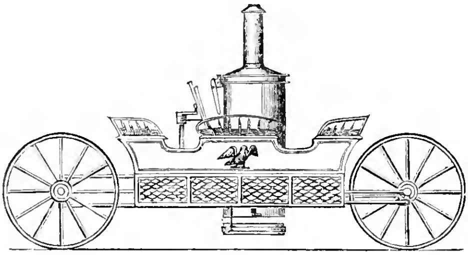


Fig. 37.—Fisher's Steam-Carriage, 1870.

Messrs. Aveling & Porter, J. Scott Russell, Boydell, and a few others in England, and Messrs. Roper, Dudgeon, Fawkes, Latta, and J. K. Fisher, in the United States, have all, at various times, labored in this direction.

The last-named engineer designed his first steam-carriage in 1840, and was still at work at the time of his death, in 1873.

Abroad, a few firms have succeeded, within a few years past, in making a business of considerable extent in constructing road-locomotives for hauling heavy loads, and in building steam road-rollers.

While steam-carriages of high speed, and adapted to the transportation of passengers, have not yet been successfully introduced, a most promising start has been made in the application of steam to the heavier kinds of work on the common road.

The great impediments seem to be the roughness and bad construction of the ordinary highway, the damages arising from the taking fright of horses, the engineering difficulties of construction, and the limited power of the machine as it has usually been built. Hostile legislation might perhaps be placed in the category, but we are probably sufficiently far advanced in civilization to-day to be able to secure liberal legislation when the people shall be satisfied that the introduction of the road-locomotive will be of great public advantage.

66. The capabilities of the road-locomotive are readily determined by experiment, and the following is an abstract of the results of several series of trials.[1] A trial of a road-engine was made by the well-known French engineer, H. Tresca, in presence of Prof. Fleeming Jenkin, and the report was submitted on January 15, 1868. The results were as follows: 1. The coefficient of traction was about 0.25 on a good road with easy grades. 2. The consumption of coal was 4.4 pounds per horse-power per hour. 3. The consumption of water was 132.2 gallons an hour with the ten-horse engine. 4. The coefficient of ad-

[1] Appletons' American Cyclopædia, article "Steam-Carriage."

herence, or of friction between the wheels and the soil, was 0.3. 5. A speed of seven miles an hour caused no special difficulty in managing either the locomotive or its load. At about this time M. Servel con-

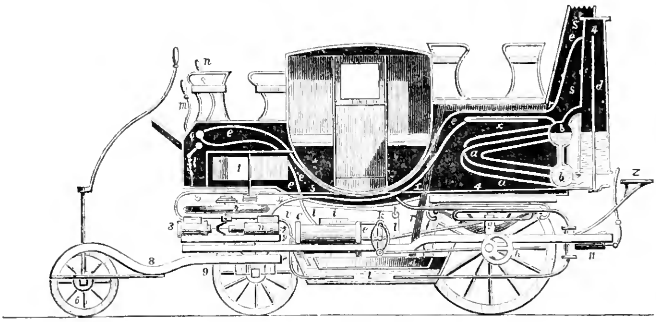


FIG. 38.—GURNEY'S STEAM-CARRIAGE, 1833.

ducted a series of experiments with a similar machine upon paved and upon macadamized roads, during what he described as the most trying of winter weather. He reports the following distribution of weight per cent.:

Weight of locomotive	41.4
" " wagons	18.2
" " paying load	40.4
Total	100

The average total weight of three loaded wagons, which was the usual load, was 22,575 kilogrammes, or about twenty-two tons. The experiment was made in 1867–'68 of applying these engines to the towage of boats on the French canals, with very encouraging results.

In 1871 several traction-engines were exhibited before the Royal Agricultural Society of England at Wolverhampton, and the judges made a series of careful tests, reported in its "Journal" for that year. The coal used on special trial amounted to 3.2 pounds per indicated horse-power per hour, and the evaporation of water was 7.62 pounds per pound of coal consumed, the average temperature of feed being 175° Fahr. The load drawn up the maximum grade of 264 feet to the mile on Tottenham Hill, which is 1,900 feet from top to bottom, was twenty-six tons, and including weight of engine thirty-eight tons, giving a coefficient of traction of 0.35. On a country-road sixteen miles long it drew fifteen tons at an average rate of 3½ miles an hour, using 2.85 pounds of coal and 1.94 gallon of water per ton of useful load per mile.

67. In October, 1871, the writer conducted a public trial of road-engines and steam road-rollers, on a well-macadamized road at South Orange, New Jersey. Two road-steamers (Fig. 39) or traction-en-

gines and a steam road-roller were tried. The following were the principal dimensions: Weight of engine complete, five tons four hundred-weight (11,648 pounds); diameter of steam-cylinder, $7\frac{3}{4}$ inches; stroke of piston, ten inches; revolutions of crank to one of driving-wheel, seventeen; diameter of driving-wheels, sixty inches; length of boiler over all, eight feet; diameter of boiler-shell, thirty inches; load on driving-wheels, four tons ten hundred-weight (10,080 pounds). The boiler was of the ordinary locomotive type, and the engine was mounted upon it, as is usual with portable engines. The engine valve-gear consisted of a three-ported valve and Stephenson-link, with reversing lever, as generally used on locomotives. The connection between the

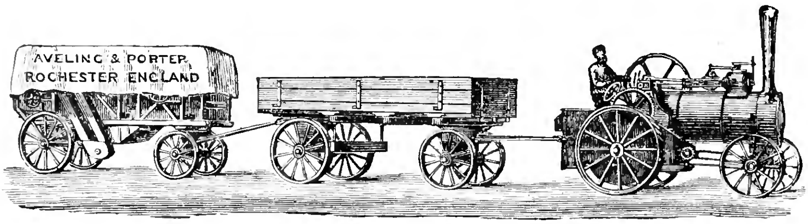


Fig. 39.—Modern Road-Locomotive.

gearing and the driving-wheels was effected by the device called by builders of cotton-machinery a Jack-in-the-box gear, or differential gear. By this combination, the effort exerted by the engine is made equal at both wheels at all times, even when the engine is turning a corner. The following is a summary of the conclusions deduced from the trial, and published in the *Journal of the Franklin Institute:* A traction-engine may be so constructed as to be easily and rapidly manœuvred on the common road; and an engine weighing over five tons may be turned continuously without difficulty on a circle of eighteen feet radius, or even on a road but little wider than the length of the engine. A locomotive of five tons four hundred-weight has been constructed, capable of drawing on a good road 23,000 pounds up a grade of 533 feet to the mile, at the rate of four miles an hour; and one might be constructed to draw more than 63,000 pounds up a grade of 225 feet to the mile, at the rate of two miles an hour. It was further shown that the coefficient of traction with heavily-laden wagons on a good macadamized road is not far from $\frac{4}{100}$; the traction-power of this engine is equal to that of twenty horses; the weight, exclusive of the weight of the engine, that could be drawn on a level road, was 163,452 pounds; and the amount of fuel required is estimated at 500 pounds a day. The advantages claimed for the traction-engine over horse-power are: No necessity for a limitation of working-hours; a difference in first cost in favor of steam; and in heavy work on a common road the expense by steam is less than twenty-five per cent. of the average cost of horse-power, a traction-engine capable of doing the work of twenty-five horses being worked at as little expense as six or eight horses.

68. Now, thirty years after the defeat of the intelligent, courageous and persistent Hancock and his co-workers in the scheme of applying the steam-engine usefully on the common road, we find strong indications that, in a new form, the problem has been again attacked and at least partially solved. It was formerly supposed that success in the transportation of passengers by steam on post-routes would lead to the application of that motor to the movement of heavy loads and to agricultural purposes generally. When, after so long a trial, the experiment finally seemed to have failed of success, it was believed that steam could not be applied to heavier work on common roads. As we have now seen, however, it appears probable that the inventors of that day attacked the problem at the wrong point, and that, on the common road, the transportation of heavy loads by steam being accomplished with economical success, under ordinarily favorable circumstances, it may prove introductory to the use of steam in carrying passengers and light freight at higher velocities.

One of the most important of the prerequisites to ultimate success in the substitution of steam for animal power on the highway is that our roads shall be well made.

As the greatest care and judgment are exercised, and an immense outlay of capital is considered justifiable, in securing easy grades and a smooth track on our railroad routes, we may readily believe that similar precaution and outlay will be found advisable in adopting the common road to the road-locomotive.

It is undeniably the fact that, even when relying upon horse-power, far less attention has been paid to the improvement of our roads than true economy would dictate. With steam-power, the gain by careful grading and excellence of construction of the road-bed becomes still more important. The animal mechanism is less affected in its power of drawing heavy loads than is the machine. With the horse, a bad road impedes transportation principally by resisting the movement of the load rather than of the animal, while with the traction-engine the motor is as seriously retarded as the train which follows it, and frequently much more, on soft ground.

Steam, therefore, cannot be expected to attain its full measure of success on rough and ill-made roads; but where highways are intelligently engineered and thoroughly well built, or where Nature has relieved the engineer and the road-builder of the expensive work of grading, as throughout a very large extent of the Western and Southern portion of our country, we may expect to see the road-locomotive rapidly introduced.

The earliest and most perfect success of the traction-engine, and its probable successor, the steam-carriage, may be expected to occur in such districts. Its great economical advantage over animal power, its freedom from liability to become disabled by epizoötic diseases, its reliability under all circumstances, and the many other advantages which are possessed by the machine, are already securing its introduction, despite the difficulties arising from popular prejudice and unfamiliarity, from hostile municipal laws and other existing obstacles.

We are learning that this motor, when it can be used at all, is comparatively inexpensive; that our roads are improved by it; and that the ancient idea of its conflicting with the interests of owners and workers of horses is only a superstition.

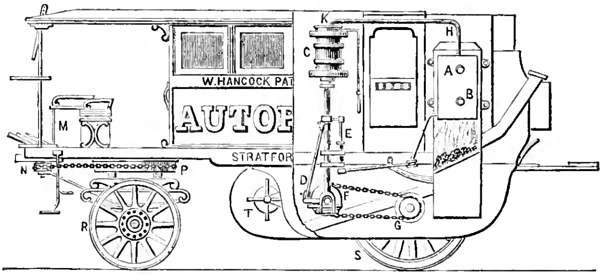


FIG. 40.—HANCOCK'S STEAM-CARRIAGE, 1833.

Such a commencement having been made, it is difficult to conceive how great may not be the future of this branch of industry when the valley of the Mississippi and our Western plains, the natural habitat of this motor, shall have become finally a principal seat of its manufacture as well as of its employment.[1]

69. The steam-blast of Hackworth, the tubular boiler of Séguin, and the link-motion of Stephenson, constitute the essential features of the modern locomotive. Locomotives have gradually and steadily increased in size and power from the date of their introduction. The Rocket, which first proved conclusively, in 1829, the value of steam-locomotion, weighed $4\frac{1}{4}$ tons. In 1835 Robert Stephenson, who had constructed it with his father, writing to Robert L. Stevens, said that he was making his engines heavier and heavier, and that the engine of which he inclosed a sketch weighed nine tons, and could draw "100 tons at the rate of sixteen miles an hour, on a level." Locomotives are now built weighing seventy tons, and powerful enough to draw more than 2,000 tons at a speed of twenty miles an hour. The modern locomotive consists of a boiler, mounted upon a strong light frame of forged iron, by which it is connected with the wheels. The largest engine yet constructed in the United States is said to be one in use on the Philadelphia & Reading Railroad, having a weight of about 100,000 pounds, which is carried on twelve driving-wheels. A locomotive has two steam cylinders, either side

[1] *Vide* paper by the author, *Journal of the Franklin Institute*, 1871.

by side within the frame, and immediately beneath the forward end of the boiler, or on each side and exterior to the frame. The engines are non-condensing and of the simplest possible construction. The whole machine is carried upon strong but flexible steel springs. The steam-pressure is usually more than 100 pounds. The pulling-power is generally about one-fifth the weight under most favorable conditions, and becomes as low as one-tenth on wet rails. The fuel employed is wood in new countries, coke in bituminous coal districts, and anthracite coal in the eastern part of the United States.

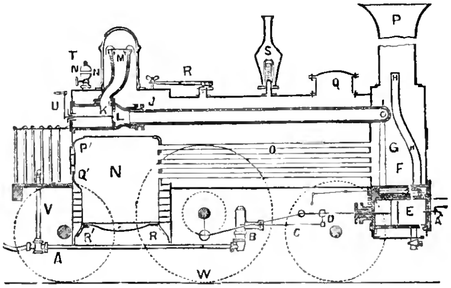


Fig. 41.—British Express-Engine.

The general arrangement and the proportions of locomotives differ somewhat in different localities. In Fig. 41, a British express-engine, *O* is the boiler, *N* the fire-box, *X* the grate, *G* the smoke-box, and *P* the chimney. *S* is a spring, and *R* a lever safety-valve, *T* is the whistle, *L* the throttle or regulator valve, *E* the steam-cylinder, and *W* the driving-wheel. The force-pump, *B C*, is driven from the cross-head, *D*. The frame is the base of the whole system, and all other parts are firmly secured to it. The boiler is made fast at one end, and provision is made for its expansion when heated. Adhesion is secured by throwing a proper proportion of the weight upon the driving-wheel *W*. This is from about 6,000 pounds on standard freight-engines, having several pairs of drivers, to 10,000 pounds on passenger-engines, per axle. The peculiarities of the American type (Figs. 42, 43) are the truck or bogie supporting the forward part of the engine, the system of equalizers, or beams which distribute the weight of the machine equally over the several axles, and minor differences of detail. The cab or house protecting the engine-driver and fireman is an American device, which is gradually coming into use abroad also. The American locomotive (Fig. 43) is distinguished by its flexibility and ease of action even upon roughly-laid roads. The cost of passenger-locomotives of ordinary size is about $12,000; heavier engines sometimes cost $20,000. The locomotive is usually furnished with a tender, which carries its fuel and water. The standard passenger-engine on the Pennsylvania Railroad is quite similar in form to the Baldwin engine (Fig. 42), and has four driving-wheels (*G*, *H*), $5\frac{1}{2}$ feet diameter; steam-cylinders (*C*, *D*), seventeen inches diameter and two feet stroke; grate-surface (*N*) $15\frac{1}{2}$ square feet, and heating-surface 1,058 square feet. It weighs 63,100 pounds, of which 39,000 pounds are on the drivers and 24,100 on the truck, *L K*. The shell of the boiler is $49\frac{1}{4}$ inches diameter and 20 feet $2\frac{1}{2}$ inches long.

The fire-box, *N N*, is of steel, six feet two inches long outside, $3\frac{1}{2}$ feet wide, and five feet four inches high. The tubes, *O O*, are of iron, 142 in number, $2\frac{1}{4}$ inches diameter, and eleven feet seven inches long. The steam-dome, *R*, is thirty inches outside diameter, the smoke-

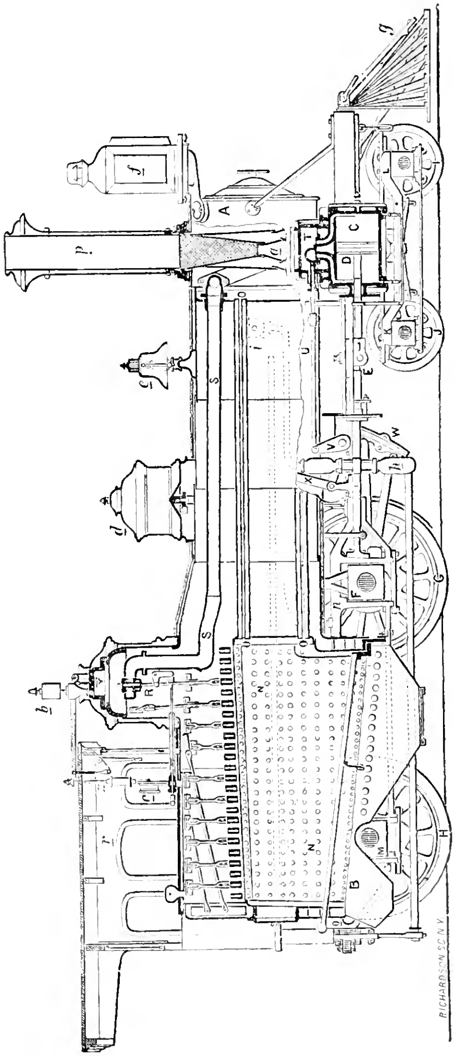


Fig. 42.—The Baldwin Locomotive, 1878.

stack, *p*, $14\frac{1}{2}$ inches. The feed-water is supplied by one pump, *h*, of $2\frac{1}{2}$ inches diameter and two feet stroke, and by a No. 8 Giffard injector. The valves, *T*, are $16\frac{1}{2}$ inches wide by $8\frac{1}{2}$ inches long, and have five inches travel. The steam-ports are $15\frac{15}{16}$ inches wide and $1\frac{1}{4}$ inch long, and the exhaust-port $15\frac{15}{16}$ by $2\frac{1}{2}$ inches. The lap of the valve is, outside $\frac{3}{4}$ inch, inside $\frac{1}{64}$ inch. The eccentrics have a throw of $4\frac{1}{8}$ inches. The standard freight-engine has six driving-wheels, $54\frac{5}{8}$ inches in diameter. The steam-cylinders are eighteen inches in diameter, stroke twenty-two inches, grate-surface 14.8 square feet, heating-surface 1,096 feet. It weighs 68,500 pounds, of which 48,000 are on the drivers and 20,500 on the truck. The boiler is nearly of the same dimensions as that of the passenger-engine, but the tubes are $2\frac{1}{2}$ inches in diameter, twelve feet $9\frac{9}{16}$ inches long, and 119 in number. The stack is eighteen inches in diameter. The pump is $2\frac{1}{4}$ inches in diameter, and has a stroke of twenty-two inches. The valve has $\frac{3}{4}$ inch inside lap, $\frac{1}{16}$ inch outside. The former takes a train of five cars up an average grade of ninety feet to the mile. The latter is attached to a train of eleven cars. On a grade of fifty feet to the mile, the former takes seven and the latter seventeen cars. Tank-engines for very heavy work, such as on grades of 320 feet to the mile, which are found on some of the railroads where gradients are very steep, have five pairs of coupled driving-wheels, and are not fitted with trucks. Such engines have, usually, steam-cylinders about twenty inches in diameter and two feet stroke of piston. Their grates have an area of fifteen or sixteen square feet, and the heating-surface has an area of 1,400 to 1,500 square feet. Engines of this class, weighing fifty tons, have hauled 110 tons up the heaviest grades of the Pennsylvania Railroad at the rate of five miles an hour. Steam-pressure is carried at from 125 to 150 pounds on the square inch.

70. A train weighing 150 tons is drawn by an express-engine (Fig.

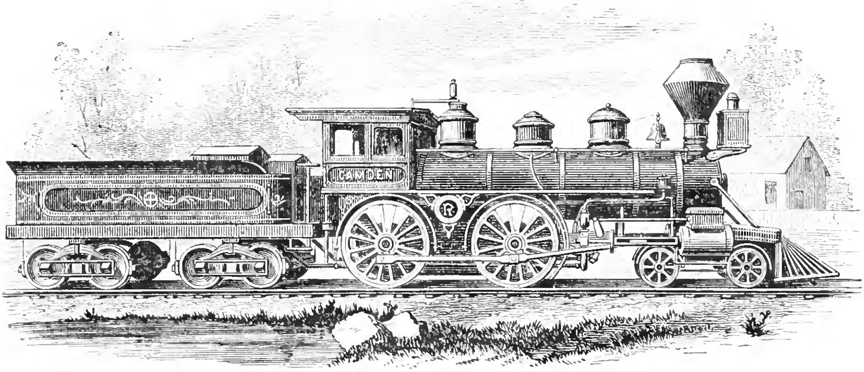


Fig. 43.—Standard Passenger and Express Engine, 1878.

43) at the speed of sixty miles an hour, the engine developing about 800 horse-power.[1] An engine drawing a light train has been known to make about one hundred miles in one hundred minutes, which speed may be taken as representing the maximum for the best modern engines on the best existing roads.

[1] Nearly equivalent to the actual power of 1,200 horses.

The life of the locomotive, when well cared for, cannot be exactly stated, but may be taken as not far from thirty years. Repairs cost, annually, ten or fifteen per cent. of the first cost. While running, each engine requires about four pints of oil and two tons of coal for each one hundred miles.

71. After their introduction, the growth of railroads and the use of locomotives extended in the United States and in Europe with great rapidity.

The first railroad in the United States was built near Quincy, Massachusetts, in 1826.

In 1850 there were about 700 miles in operation; in 1860 there were over 30,000; and there are to-day about 76,000 miles of completed road in the United States, and the rate of increase had risen in 1873 to above 7,000 miles per year, as a maximum, and the consumption of rails for renewal alone amounts to nearly a half-million tons per year.

HEALTH-MATTERS IN JAPAN.

By EDWARD S. MORSE.

THE problem which excites more interest than any other in the larger cities of our country is that in regard to the best disposition of sewage. People have slowly come to realize that in some way a series of disorders arises from the presence of waste matter in cities. So well ascertained is this fact that diseases which are attributed to the presence of filth are aptly called *filth-diseases*, and it is well that they are at last branded by their right name. One has only to consult the valuable reports of the State boards of health for infomation on these matters. In these reports he will find an overwhelming mass of evidence tracing typhoid fever, cholera infantum, and other diseases, to the presence of filth, and to its infectious character when communicating with water-supplies, or through its malarial gases affecting the air of houses. At present the causes of high death-rates are as certainly known as the course of storms. Indeed, the intelligent physician will predict the necessary consequences which must ensue from the presence in a crowded city of matter which should be removed. Interested as I have been in these subjects, I looked forward with considerable eagerness to an opportunity for studying the conditions which obtain among the Japanese concerning these matters. Their manner of living, their food, their domestic habits, are all so different from ours, that it naturally occurred to me, if these filth-diseases are as common here, with their cleanly habits, and the universal custom of removing offal from their dwellings, as with us where the same matter lies in a frightful state for months to pollute the neighborhood, then the points urged in regard to the relations between filth-diseases and offal must be modified or abandoned.

What do the facts show?

At home, the following conditions are rightly looked upon as grave sources of danger: the presence of privies in the vicinity of wells, cellars filled with decaying vegetable matter, a water-closet or privy connected immediately with a house, or the ingress of sewage-gas to a house. It is at present difficult to get any vital statistics regarding the Japanese. While the Government and people have made the most surprising strides toward the civilization of Western nations (for they have a civilization of their own which in many respects is far ahead of ours [1]), and have established normal schools and universities, medical and naval colleges, hydrographic and other surveys, they have not yet seen the importance of organizing a board of health.[2]

One would be justified in assuming that if these sources of danger existed, the foreigner, unacclimated as he is, would be more susceptible to their influence than the native. Dr. Stuart Eldridge, of Yokohama, a distinguished physician, who has had a long and varied experience in this country in hospital-work and as an active practitioner, has kindly furnished me with the following data at my request: "Scarlet fever *almost unknown*, never epidemic. Diphtheria almost unknown, never epidemic. Severer forms of bowel-disease, such as dysentery and chronic diarrhœa, very rare. Mala-

[1] If some of the indications of civilization are to treat each other kindly, to treat their children with unvarying kindness, to treat the animals below them with tenderness, to honor their father and mother, to be scrupulously clean in their persons, to be frugal and temperate in their habits—if these features be recognized as civilized, then this pagan nation in these respects is as far ahead of us as we are ahead of the Tierra del Fuegans.

[2] We ought not to expect this of Japan, perhaps, since the representatives sent by Maine to her Legislature were, with few exceptions, too ignorant to appreciate the necessity of a State board of health, and were incredulous that the physicians who urged the measure so strongly were unselfishly working for its establishment!

rial diseases of severe nature uncommon; even the milder forms in most localities not common. Typhoid and typhus rarely epidemic, the latter uncommon." With these facts before us, let us examine the conditions of living among these people. It is well known that their houses are so arranged that the winds blow through them from one end to the other. In summer they are entirely open. The privies are never connected immediately with the houses except among the lower classes in the larger cities, where, as in Tokio for example, among the poorer houses the privy is in the back part of the house, but even in these cases a close sliding-door always separates this apartment from the living-room, and a grated window without glass permits thorough ventilation. In the public inns, too, the privy is sometimes connected with the building, to the great discomfort of foreigners. In the country villages it stands alongside the road, separate from the house. Their sewage system, so far as I am aware, is superficial, and there is no sewage-gas to contaminate the air. The houses have no cellars, and consequently the air in them is not polluted from this source. On the other hand, their wells are not always properly situated, and the water is liable to pollution from gutters. The important point to be noted, however, is in regard to the disposition of their offal, and it is well known that every day or two this is removed and scattered on their rice-fields and other cultivated areas. The vaults consist of water-tight vessels of limited capacity. In Tokio they use for this purpose oil-barrels, which they coat with a kind of varnish inside and out. From the small size of this vessel accumulation never occurs, and from its nature the soil never becomes saturated by its contents. Men, instead of being paid to remove it, actually pay for it!

The Japanese having no cattle or sheep, but few horses, no pigs, and but few fowls at the most, depend entirely upon the sewage of towns for the fertilizing material of their farms. No one at home can form any idea of the perfect manner of this work. Even in as large a city as Tokio, with its million inhabitants, this service is performed with a neatness and thoroughness which surpasses belief. The foreigner finds one of his senses rudely assailed at times, though, as to that matter, he may go into one of the most refined cities of America, and, with the exception of a few summer months, encounter the same discomforts. Dr. David Murray has called my attention to the very important service performed by the crows and a kind of hawk which act as scavengers. We are so accustomed at home to find these birds especially wild and wary, that it is a somewhat startling sight to see them perching on the buildings in a crowded city like Tokio, and swooping down in front of you in quest of food, which might otherwise decay and vitiate the atmosphere. The destructiveness and brutality, generally speaking, of the children of Christian nations lead to the stoning of dogs, cats, and birds of all kinds. In Japan such a thing is unknown, and a stone thrown at a dog (I speak from experience) is generally answered by an inquiring look, hens hop out of the way, and even cats do not take the hint! In other words, the crows and hawks are never molested, and the result is that all carrion and other stuff left in the streets are pounced upon and carried off immediately.

As far as climatic conditions are concerned everything is most favorable for the development of filth-diseases, provided the sources of danger were present. In the summer months the heat is oftentimes oppressive, the moisture excessive, meat decays rapidly, and the decomposition of fruit and vegetables quickly ensues. With fruit especially ripeness is almost coincident with decay.

In regard to the personal habits of the people, it is interesting to remark that they drink very little cold water. The water is drunk as hot tea—in other words, it is boiled. Of extreme importance, too, in regard to children's disorders, is the fact that, until they are two or three years old, they draw their nourishment from the maternal fount. *No child is fed artificially.*

On the other hand, it is interesting to note that the Japanese eat unripe fruit to an inordinate extent. The moment fruit shows the slightest signs of being soft as an evidence of ripeness, it is considered by them as unfit to eat. It is astonishing to see them eat hard, green peaches—clinching them in the fist, as a country boy does a hard apple, and biting off each mouthful with a loud snap. They eat their pears in the same way; cucumbers are eaten in a more unripe condition than with us even; and water-melons, which are so much inveighed against at home, are here eaten by all classes and at all times.

In fact, they seem to revel in those things which at home are considered so productive of summer-complaints; who does not recall the astonishment he has felt at the sight of country children of tender age eating green apples, green corn uncooked, and similar things, and yet suffering no ill-effects therefrom? These facts may not prove, perhaps, that unripe fruit is harmless; but, in connection with the other statements, they do show that the removal of sewage-matter from houses is the important point to consider, and that its removal insures an absence, or a less number, of cases of those diseases which enhance our death-rate at home, and lends an additional reason for the necessity of vigilance on the part of communities regarding these matters.

Concerning sunstroke, it is believed at home that one of its inciting causes is the exposure of the body or head to the overpowering heat of the sun; and the subjection of the uncovered head to the direct rays of the sun is looked upon as dangerous. On the other hand, it is admitted that intemperance in food or drink, and particularly the latter, may be inducing causes. Be that as it may, it is suggestive to note the rare occurrence of sunstroke among the Japanese, and to remark that two out of three go bareheaded. The women never have their heads covered, and the men do not always protect theirs with the sun-shade. Among the lower classes, few have their heads covered except in the hottest weather—the Jinrikisha men and the Bettoes[1] running for miles bareheaded. In most cases the head is shaved on top. If exposure of the head to the direct rays of the sun is the inducing cause of sunstroke, then here, in latitude 35°, we should expect numerous cases, while, if over-eating and over-drinking—in other words, intemperate habits—are the inducing causes, then we can understand the immunity of the Japanese from this malady: for a more temperate and frugal people do not exist on the face of the globe.

One observes in traveling through the country the almost entire absence of deformities arising from accidents—no broken backs or broken noses, no unequal legs, or other mutilations or deformities of any sort. A fruitful source of these misfortunes at home may be traced to accidents which befall children, such as falling out of windows, tumbling down-stairs, being knocked down in the street by runaway horses, and, in later years, the deformities of the face, oftentimes the result of drunken rows and fights; the common occurrence of building-accidents, from insecure and dishonest staging, and the hundreds of other ways in which mutilations are met with in large factories. In Japan the houses are one story high; generally speaking, there are no windows to tumble out of, or flights of stairs to tumble down. Horses, except as pack-horses, are rare.[2] The people do not have drunken brawls. Their stagings are always built to hold together, and thus pagan temples are reared, and pagan temples are repainted, without those appalling accidents which occur in a service of like nature at home. There are no big factories; and so, with these sources of danger eliminated, we find a reason, perhaps, for the absence of deformities.

In regard to the prevalence of certain other diseases which may be of interest in a paper of this nature, it is gratifying to know that small-pox, which was formerly endemic, is now coming under control by the Government taking active measures to insure vaccination. A vaccine farm is maintained, and it is compulsory on every one to be vaccinated. The frightful scourges of this disease in past times are seen in the sadly-scarred faces of so many of the people, and in the number of blind persons one encounters.

Eye-diseases of various kinds are prevalent, and near-sightedness seems very common, judging from the number of people who wear glasses. Weakness of vision must in some measure be attributed to

[1] Bettoes are servants who run beside the horses or before them when one is driving.

[2] Only within a few years have horses been used in the streets of Tokio, and a police regulation requires a man to run in front of each one in every crowded thoroughfare.

the poor light the people provide themselves with. A dim candle, or, at most, a tiny wick resting on the edge of a vessel of vegetable oil of feeble illuminating power, and this inclosed in a paper lantern, is the almost universal lamp of the Japanese; and with this dim light the student studies his Chinese classics, the characters of which are so confusedly wrought together, and the woman performs her sewing on the customary dark-blue cloth. The gradual introduction of kerosene-oil, which is now going on, must in some way modify these troubles.

Measles is occasionally epidemic, and, owing to the exposed life of the people, often very severe. Phthisis is not more common in Japan than in our Middle States. Articular rheumatism is not common, but muscular rheumatism is very common. Skin-diseases are common, especially the contagious forms. The universal use of the razor in shaving, and the custom of itinerant barbers, who travel from one village to another shaving indiscriminately, indicate too plainly the reason for the prevalence of contagious diseases of the skin. In Japan everybody shaves. The men shave the tops of their heads, the beard and mustache, and, curiously enough, every portion of the face, even to the eyelids (not the eyelashes), the lobes of the ears, and the nose to its very tip. Married women shave their eyebrows; widows and priests shave the entire scalp; babies even have their heads shaved in such a manner as to leave the most grotesque bunches of hair symmetrically disposed, like a fancy garden-plot, the remaining portions of the scalp being entirely denuded. It is rather the exception than the rule to find a child's head free from an eruption of some kind, and for this reason, as a general thing, the Japanese babies are unattractive.

My observations on the facts kindly furnished me by Dr. Eldridge apply only to the region about Tokio. The experience upon which these are made is based on a tour of a hundred miles to the northwest of Tokio, a good part of the inland journey being made on foot, many rambles through the streets of Tokio, and a six weeks' sojourn in a little village seventeen miles south of Yokohama. During all these trips and sojourns I have had my note and sketch book constantly with me, and have given the strictest attention to the sanitary condition of the houses and their surroundings.

In conclusion, it is gratifying to know that more solid progress has been made in medicine and surgery than in any other branch of Western science, and that the old Chinese system, with its grotesque absurdities, is doomed.

P. S.—Just as I am mailing this, the alarming news comes that the Asiatic cholera has made its appearance in Yokohama in the most emphatic manner. It will, of course, extend to Tokio; and, curiously enough, the very customs of the people which tend to thwart the ravages of certain other diseases will in this case be the very conditions to promote the ravages of cholera. A parallel case would be that of carefully removing the coals of fire from a building every night, as a safeguard to the structure; but let a sudden gale spring up, and the embers thus removed would be scattered far and wide.

ILLUSTRATIONS OF THE LOGIC OF SCIENCE.

By C. S. PEIRCE,

ASSISTANT IN THE UNITED STATES COAST SURVEY.

SECOND PAPER.—HOW TO MAKE OUR IDEAS CLEAR.

I.

WHOEVER has looked into a modern treatise on logic of the common sort, will doubtless remember the two distinctions between *clear* and *obscure* conceptions, and between *distinct* and *confused* conceptions. They have lain in the books now for nigh two centuries, unimproved and unmodified, and are generally reckoned by logicians as among the gems of their doctrine.

A clear idea is defined as one which is so apprehended that it will be recognized wherever it is met with, and so that no other will be mistaken for it. If it fails of this clearness, it is said to be obscure.

This is rather a neat bit of philosophical terminology; yet, since it is clearness that they were defining, I wish the logicians had made their definition a little more plain. Never to fail to recognize an idea, and under no circumstances to mistake another for it, let it come in how recondite a form it may, would indeed imply such prodigious force and clearness of intellect as is seldom met with in this world. On the other hand, merely to have such an acquaintance with the idea as to have become familiar with it, and to have lost all hesitancy in recognizing it in ordinary cases, hardly seems to deserve the name of clearness of apprehension, since after all it only amounts to a subjective feeling of mastery which may be entirely mistaken. I take it, however, that when the logicians speak of "clearness," they mean nothing more than such a familiarity with an idea, since they regard the quality as but a small merit, which needs to be supplemented by another, which they call *distinctness*.

A distinct idea is defined as one which contains nothing which is not clear. This is technical language; by the *contents* of an idea logicians understand whatever is contained in its definition. So that an idea is *distinctly* apprehended, according to them, when we can give a precise definition of it, in abstract terms. Here the professional logicians leave the subject; and I would not have troubled the reader with what they have to say, if it were not such a striking example of how they have been slumbering through ages of intellectual activity, listlessly disregarding the enginery of modern thought, and never dreaming of applying its lessons to the improvement of logic. It is easy to show that the doctrine that familiar use and abstract distinctness make the perfection of apprehension has its only true place in philosophies which have long been extinct; and it is now time to formulate the method of attaining to a more perfect clearness of thought, such as we see and admire in the thinkers of our own time.

When Descartes set about the reconstruction of philosophy, his first step was to (theoretically) permit skepticism and to discard the practice of the schoolmen of looking to authority as the ultimate source of truth. That done, he sought a more natural fountain of true principles, and professed to find it in the human mind; thus passing, in the directest way, from the method of authority to that of apriority, as described in my first paper. Self-consciousness was to furnish us with our fundamental truths, and to decide what was agreeable to reason. But since, evidently, not all ideas are true, he was led to note, as the first condition of infallibility, that they must be clear. The distinction between an idea *seeming* clear and really being so, never occurred to him. Trusting to introspection, as he did, even for a knowledge of external things, why should he question its testimony in respect to the contents of our own minds? But then, I suppose, seeing men, who seemed to be quite clear and positive, holding opposite opinions upon fundamental principles, he was further led to say that clearness of ideas is not sufficient, but that they need also to be distinct, i. e., to have nothing unclear about them. What he probably meant by this (for he did not explain himself with precision) was, that they must sustain the test of dialectical examination; that they must not only seem clear at the outset, but that discussion must never be able to bring to light points of obscurity connected with them.

Such was the distinction of Descartes, and one sees that it was precisely on the level of his philosophy. It was somewhat developed by Leibnitz. This great and singular genius was as remarkable for what he failed to see as for what he saw. That a piece of mechanism could not do work perpetually without being fed with power in some form, was a thing perfectly apparent to him; yet he did not understand that the machinery of the mind can only transform knowledge, but never originate it, unless it be fed with facts of observation. He thus missed the most essential point of the Cartesian philosophy, which is, that to accept propositions which seem perfectly evident to us is a thing which, whether it be logical or illogical, we cannot help doing. Instead of regarding the matter in this way, he sought to reduce the first principles of science to formulas which cannot be denied without self-contradiction, and was apparently unaware of the great difference between his position and that of Descartes. So he reverted to the old formalities of logic, and, above all, abstract definitions played a great part in his philosophy. It was quite natural, therefore, that on observing that the method of Descartes labored under the difficulty that we may seem to ourselves to have clear apprehensions of ideas which in truth are very hazy, no better remedy occurred to him than to require an abstract definition of every important term. Accordingly, in adopting the distinction of *clear* and *distinct* notions, he described the latter quality as the clear apprehension of everything contained in the definition; and the books have ever since copied his words. There is no danger that his chimerical scheme will ever again be overvalued. Nothing new can ever be learned by analyzing definitions. Nevertheless, our existing beliefs can be set in order by this process, and order is an essential element of intellectual economy, as of every other. It may be acknowledged, therefore, that the books are right in making familiarity with a notion the first step toward clearness of apprehension, and the defining of it the second. But in omitting all mention of any higher perspicuity of thought, they simply mirror a philosophy which was exploded a hundred years ago. That much-admired "ornament of logic"—the doctrine of clearness and distinctness—may be pretty enough, but it is high time to relegate to our cabinet of curiosities the antique *bijou*, and to wear about us something better adapted to modern uses.

The very first lesson that we have a right to demand that logic shall teach us is, how to make our ideas clear; and a most important one it is, depreciated only by minds who stand in need of it. To know what we think, to be masters of our own meaning, will make a solid foundation for great and weighty thought. It is most easily learned by those whose ideas are meagre and restricted; and far happier they than such as wallow helplessly in a rich mud of conceptions. A nation, it is true, may, in the course of generations, overcome the disadvantage of an excessive wealth of language and its natural concomitant, a vast, unfathomable deep of ideas. We may see it in history, slowly perfecting its literary forms, sloughing at length its metaphysics, and, by virtue of the untirable patience which is often a compensation, attaining great excellence in every branch ef mental acquirement. The page of history is not yet unrolled which is to tell us whether such a people will or will not in the long-run prevail over one whose ideas (like the words of their language) are few, but which possesses a wonderful mastery over those which it has. For an individual, however, there can be no question that a few clear ideas are worth more than many confused ones. A young man would hardly be persuaded to sacrifice the greater part of his thoughts to save the rest; and the muddled head is the least apt to see the necessity of such a sacrifice. Him we can usually only commiserate, as a person with a congenital defect. Time will help him, but intellectual maturity with regard to clearness comes rather late, an unfortunate arrangement of Nature, inasmuch as clearness is of less use to a man settled in life, whose errors have in great measure had their effect, than it would be to one whose path lies before him. It is terrible to see how a single unclear idea, a single formula without meaning, lurking in a young man's head, will sometimes act like an obstruction of inert matter in an artery, hindering the nutrition of the brain, and condemning its victim to pine away in the fullness of his intellectual vigor and in the midst of intellectual plenty. Many a man has cherished for years as his hobby some vague shadow of an idea, too meaningless to be positively false; he has, nevertheless, passionately loved it, has made it his companion by day and by night, and has given to it his strength and his life, leaving all other occupations for its sake, and in short has lived with it and for it, until it has become, as it were, flesh of his flesh and bone of his bone; and then he has waked up some bright morning to find it gone, clean vanished away like the beautiful Melusina of the fable, and the essence of his life gone with it. I have myself known such a man; and who can tell how many histories of circle-squarers, metaphysicians, astrologers, and what not, may not be told in the old German story?

II.

The principles set forth in the first of these papers lead, at once, to a method of reaching a clearness of thought of a far higher grade than the "distinctness" of the logicians. We have there found that the action of thought is excited by the irritation of doubt, and ceases when belief is attained; so that the production of belief is the sole function of thought. All these words, however, are too strong for my purpose. It is as if I had described the phenomena as they appear under a mental microscope. Doubt and Belief, as the words are commonly employed, relate to religious or other grave discussions. But here I use them to designate the starting of any question, no matter how small or how great, and the resolution of it. If, for instance, in a horse-car, I pull out my purse and find a five-cent nickel and five coppers, I decide, while my hand is going to the purse, in which way I will pay my fare. To call such a question Doubt, and my decision Belief, is certainly to use words very disproportionate to the occasion. To speak of such a doubt as causing an irritation which needs to be appeased, suggests a temper which is uncomfortable to the verge of insanity. Yet, looking at the matter minutely, it must be admitted that, if there is the least hesitation as to whether I shall pay the five coppers or the nickel (as there will be sure to be, unless I act from some previously contracted habit in the matter), though irritation is too strong a word, yet I am excited to such small mental activity as may be necessary to deciding how I shall act. Most frequently doubts arise from some indecision, however momentary, in our action. Sometimes it is not so. I have, for example, to wait in a railway-station, and to pass the time I read the advertisements on the walls, I compare the advantages of different trains and different routes which I never expect to take, merely fancying myself to be in a state of hesitancy, because I am bored with having nothing to trouble me. Feigned hesitancy, whether feigned for mere amusement or with a lofty purpose, plays a great part in the production of scientific inquiry. However the doubt may originate, it stimulates the mind to an activity which may be slight or energetic, calm or turbulent. Images pass rapidly through consciousness, one incessantly melting into another, until at last, when all is over—it may be in a fraction of a second, in an hour, or after long years—we find ourselves decided as to how we should act under such circumstances as those which occasioned our hesitation. In other words, we have attained belief.

In this process we observe two sorts of elements of consciousness, the distinction between which may best be made clear by means of an illustration. In a piece of music there are the separate notes, and there is the air. A single tone may be prolonged for an hour or a day, and it exists as perfectly in each second of that time as in the whole taken together; so that, as long as it is sounding, it might be present to a sense from which everything in the past was as completely absent as the future itself. But it is different with the air, the performance of which occupies a certain time, during the portions of which only portions of it are played. It consists in an orderliness in the succession of sounds which strike the ear at different times; and to perceive it there must be some continuity of consciousness which makes the events of a lapse of time present to us. We certainly only perceive the air by hearing the separate notes; yet we cannot be said to directly hear it, for we hear only what is present at the instant, and an orderliness of succession cannot exist in an instant. These two sorts of objects, what we are *immediately* conscious of and what we are *mediately* conscious of, are found in all consciousness. Some elements (the sensations) are completely present at every instant so long as they last, while others (like thought) are actions having beginning, middle, and end, and consist in a congruence in the succession of sensations which flow through the mind. They cannot be immediately present to us, but must cover some portion of the past or future. Thought is a thread of melody running through the succession of our sensations.

We may add that just as a piece of music may be written in parts, each part having its own air, so various systems of relationship of succession subsist together between the same sensations. These different systems are distinguished by having different motives, ideas, or functions. Thought is only one such system, for its sole motive, idea, and function, is to produce belief, and whatever does not concern that purpose belongs to some other system of relations. The action of thinking may incidentally have other results; it may serve to amuse us, for example, and among *dilettanti* it is not rare to find those who have so perverted thought to the purposes of pleasure that it seems to vex them to think that the questions upon which they delight to exercise it may ever get finally settled; and a positive discovery which takes a favorite subject out of the arena of literary debate is met with ill-concealed dislike. This disposition is the very debauchery of thought. But the soul and meaning of thought, abstracted from the other elements which accompany it, though it may be voluntarily thwarted, can never be made to direct itself toward anything but the production of belief. Thought in action has for its only possible motive the attainment of thought at rest; and whatever does not refer to belief is no part of the thought itself.

And what, then, is belief? It is the demi-cadence which closes a musical phrase in the symphony of our intellectual life. We have seen that it has just three properties: First, it is something that we are aware of; second, it appeases the irritation of doubt; and, third, it involves the establishment in our nature of a rule of action, or, say for short, a *habit*. As it appeases the irritation of doubt, which is the motive for thinking, thought relaxes, and comes to rest for a moment when belief is reached. But, since belief is a rule for action, the application of which involves further doubt and further thought, at the same time that it is a stopping-place, it is also a new starting-place for thought. That is why I have permitted myself to call it thought at rest, although thought is essentially an action. The *final* upshot of thinking is the exercise of volition, and of this thought no longer forms a part; but belief is only a stadium of mental action, an effect upon our nature due to thought, which will influence future thinking.

The essence of belief is the establishment of a habit, and different beliefs are distinguished by the different modes of action to which they give rise. If beliefs do not differ in this respect, if they appease the same doubt by producing the same rule of action, then no mere differences in the manner of consciousness of them can make them different beliefs, any more than playing a tune in different keys is playing different tunes. Imaginary distinctions are often drawn between beliefs which differ only in their mode of expression;—the wrangling which ensues is real enough, however. To believe that any objects are arranged as in Fig. 1, and to believe that they are arranged in Fig. 2, are one and the same belief; yet it is conceivable that a man should assert one proposition and deny the other. Such false distinctions do as much harm as the confusion of beliefs really different, and are among the pitfalls of which we ought constantly to beware, especially when we are upon metaphysical ground. One singular deception of this sort, which often occurs, is to mistake the sensation produced by our own unclearness of thought for a character of the object we are thinking. Instead of perceiving that the obscurity is purely subjective, we fancy that we contemplate a quality of the object which is essentially mysterious; and if our conception be afterward presented to us in a clear form we do not recognize it as the same, owing to the absence of the feeling of unintelligibility. So

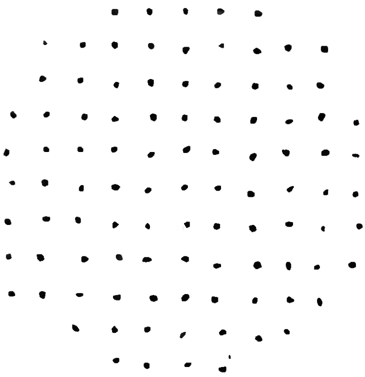


Fig. 1.

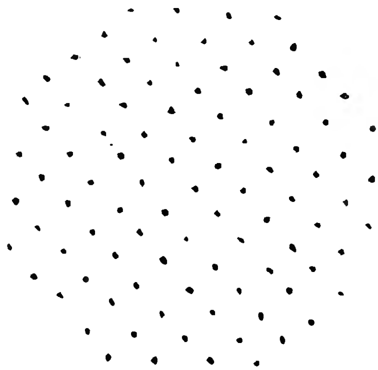


Fig. 2.

long as this deception lasts, it obviously puts an impassable barrier in the way of perspicuous thinking; so that it equally interests the opponents of rational thought to perpetuate it, and its adherents to guard against it.

Another such deception is to mistake a mere difference in the grammatical construction of two words for a distinction between the ideas they express. In this pedantic age, when the general mob of writers attend so much more to words than to things, this error is common enough. When I just said that thought is an *action*, and that it consists in a *relation*, although a person performs an action but not a relation, which can only be the result of an action, yet there was no inconsistency in what I said, but only a grammatical vagueness.

From all these sophisms we shall be perfectly safe so long as we reflect that the whole function of thought is to produce habits of action; and that whatever there is connected with a thought, but irrelevant to its purpose, is an accretion to it, but no part of it. If there be a unity among our sensations which has no reference to how we shall act on a given occasion, as when we listen to a piece of music, why we do not call that thinking. To develop its meaning, we have, therefore, simply to determine what habits it produces, for what a thing means is simply what habits it involves. Now, the identity of a habit depends on how it might lead us to act, not merely under such circumstances as are likely to arise, but under such as might possibly occur, no matter how improbable they may be. What the habit is depends on *when* and *how* it causes us to act. As for the *when*, every stimulus to action is derived from perception; as for the *how*, every purpose of action is to produce some sensible result. Thus, we come down to what is tangible and practical, as the root of every real distinction of thought, no matter how subtile it may be; and there is no distinction of meaning so fine as to consist in anything but a possible difference of practice.

To see what this principle leads to, consider in the light of it such a doctrine as that of transubstantiation. The Protestant churches generally hold that the elements of the sacrament are flesh and blood only in a tropical sense; they nourish our souls as meat and the juice of it would our bodies. But the Catholics maintain that they are literally just that; although they possess all the sensible qualities of wafer-cakes and diluted wine. But we can have no conception of wine except what may enter into a belief, either—

1. That this, that, or the other, is wine; or,
2. That wine possesses certain properties.

Such beliefs are nothing but self-notifications that we should, upon occasion, act in regard to such things as we believe to be wine according to the qualities which we believe wine to possess. The occasion of such action would be some sensible perception, the motive of it to produce some sensible result. Thus our action has exclusive reference to what affects the senses, our habit has the same bearing as our action, our belief the same as our habit, our conception the same as our belief; and we can consequently mean nothing by wine but what has certain effects, direct or indirect, upon our senses; and to talk of something as having all the sensible characters of wine, yet being in reality blood, is senseless jargon. Now, it is not my object to pursue the theological question; and having used it as a logical example I drop it, without caring to anticipate the theologian's reply. I only desire to point out how impossible it is that we should have an idea in our minds which relates to anything but conceived sensible effects of things. Our idea of anything *is* our idea of its sensible effects; and if we fancy that we have any other we deceive ourselves, and mistake a mere sensation accompanying the thought for a part of the thought itself. It is absurd to say that thought has any meaning unrelated to its only function. It is foolish for Catholics and Protestants to fancy themselves in disagreement about the elements of the sacrament, if they agree in regard to all their sensible effects, here or hereafter.

It appears, then, that the rule for attaining the third grade of clearness of apprehension is as follows: Consider what effects, which might conceivably have practical bearings, we conceive the object of our conception to have. Then, our conception of these effects is the whole of our conception of the object.

III.

Let us illustrate this rule by some examples; and, to begin with the simplest one possible, let us ask what we mean by calling a thing *hard*. Evidently that it will not be scratched by many other substances. The whole conception of this quality, as of every other, lies in its conceived effects. There is absolutely no difference between a hard thing and a soft thing so long as they are not brought to the test. Suppose, then, that a diamond could be crystallized in the midst of a cushion of soft cotton, and should remain there until it was finally burned up. Would it be false to say that that diamond was soft? This seems a foolish question, and would be so, in fact, except in the realm of logic. There such questions are often of the greatest utility as serving to bring logical principles into sharper relief than real discussions ever could. In studying logic we must not put them aside with hasty answers, but must consider them with attentive care, in order to make out the principles involved. We may, in the present case, modify our question, and ask what prevents us from saying that all hard bodies remain perfectly soft until they are touched, when their hardness increases with the pressure until they are scratched. Reflection will show that the reply is this: there would be no *falsity* in such modes of speech. They would involve a modification of our present usage of speech with regard to the words hard and soft, but not of their meanings. For they represent no fact to be different from what it is; only they involve arrangements of facts which would be exceedingly maladroit. This leads us to remark that the question of what would occur under circumstances which do not actually arise is not a question of fact, but only of the most perspicuous arrangement of them. For example, the question of free-will and fate in its simplest form, stripped of verbiage, is something like this: I have done something of which I am ashamed; could I, by an effort of the will, have resisted the temptation, and done otherwise? The philosophical reply is, that this is not a question of fact, but only of the arrangement of facts. Arranging them so as to exhibit what is particularly pertinent to my question—namely, that I ought to blame myself for having done wrong—it is perfectly true to say that, if I had willed to do otherwise than I did, I should have done otherwise. On the other hand, arranging the facts so as to exhibit another important consideration, it is equally true that, when a temptation has once been allowed to work, it will, if it has a certain force, produce its effect, let me struggle how I may. There is no objection to a contradiction in what would result from a false supposition. The *reductio ad absurdum* consists in showing that contradictory results would follow from a hypothesis which is consequently judged to be false. Many questions are involved in the free-will discussion, and I am far from desiring to say that both sides are equally right. On the contrary, I am of opinion that one side denies important facts, and that the other does not. But what I do say is, that the above single question was the origin of the whole doubt; that, had it not been for this question, the controversy would never have arisen; and that this question is perfectly solved in the manner which I have indicated.

Let us next seek a clear idea of Weight. This is another very easy case. To say that a body is heavy means simply that, in the absence of opposing force, it will fall. This (neglecting certain specifications of how it will fall, etc., which exist in the mind of the physicist who uses the word) is evidently the whole conception of weight. It is a fair question whether some particular facts may not *account* for gravity; but what we mean by the force itself is completely involved in its effects.

This leads us to undertake an account of the idea of Force in general. This is the great conception which, developed in the early part of the seventeenth century from the rude idea of a cause, and constantly improved upon since, has shown us how to explain all the changes of motion which bodies experience, and how to think about all physical phenomena; which has given birth to modern science, and changed the face of the globe; and which, aside from its more special uses, has played a principal part in directing the course of modern thought, and in furthering modern social development. It is, therefore, worth some pains to comprehend it. According to our rule, we must begin by asking what is the immediate use of thinking about force; and the answer is, that we thus account for changes of motion. If bodies were left to themselves, without the intervention of forces, every motion would continue unchanged both in velocity and in direction. Furthermore, change of motion never takes place abruptly; if its direction is changed, it is always through a curve without angles; if its velocity alters, it is by degrees. The gradual changes which are constantly taking place are conceived by geometers to be compounded together according to the rules of the parallelogram of forces. If the reader does not already know what this is, he will find it, I hope, to his advantage to endeavor to follow the following explanation; but if mathematics are insupportable to him, pray let him skip three paragraphs rather than that we should part company here.

A *path* is a line whose beginning and end are distinguished. Two paths are considered to be equivalent, which, beginning at the same point, lead to the same point. Thus the two paths, $A\ B\ C\ D\ E$ and $A\ F\ G\ H\ E$, are equivalent. Paths which do *not* begin at the same point are considered to be equivalent, provided that, on moving either of them without turning it, but keeping it always parallel to its original position, when its beginning coincides with that of the other path, the ends also coincide. Paths are considered as geometrically added together, when one begins where the other ends; thus the path $A\ E$ is conceived to be a sum of $A\ B$, $B\ C$, $C\ D$, and $D\ E$. In the parallelogram of Fig. 4 the diagonal *A C* is the sum of *A B* and *B C*; or, since *A D* is geometrically equivalent to *B C*, *A C* is the geometrical sum of *A B* and *A D*.

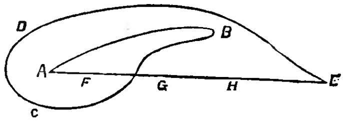


Fig. 3.

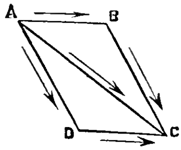


Fig. 4.

All this is purely conventional. It simply amounts to this: that we choose to call paths having the relations I have described equal or added. But, though it is a convention, it is a convention with a good reason. The rule for geometrical addition may be applied not only to paths, but to any other things which can be represented by paths. Now, as a path is determined by the varying direction and distance of the point which moves over it from the starting-point, it follows that anything which from its beginning to its end is determined by a varying direction and a varying magnitude is capable of being represented by a line. Accordingly, *velocities* may be represented by lines, for they have only directions and rates. The same thing is true of *accelerations*, or changes of velocities. This is evident enough in the case of velocities; and it becomes evident for accelerations if we consider that precisely what velocities are to positions—namely, states of change of them—that accelerations are to velocities.

The so-called "parallelogram of forces" is simply a rule for compounding accelerations. The rule is, to represent the accelerations by paths, and then to geometrically add the paths. The geometers, however, not only use the "parallelogram of forces" to compound different accelerations, but also to resolve one acceleration into a sum of several. Let *A B* (Fig. 5) be the path which represents a certain acceleration—say, such a change in the motion of a body that at the end of one second the body will, under the influence of that change, be in a position different from what it would have had if its motion had continued unchanged such that a path equivalent to *A B* would lead from the latter position to the former. This acceleration may be considered as the sum of the accelerations represented by *A C* and *C B*. It may also be considered as the sum of the very different accelerations represented by *A D* and *D B*, where *A D* is almost the opposite of *A C*. And it is clear that there is an immense variety of

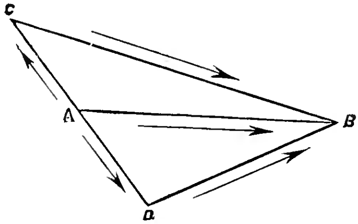


Fig. 5.

ways in which $A\ B$ might be resolved into the sum of two accelerations.

After this tedious explanation, which I hope, in view of the extraordinary interest of the conception of force, may not have exhausted the reader's patience, we are prepared at last to state the grand fact which this conception embodies. This fact is that if the actual changes of motion which the different particles of bodies experience are each resolved in its appropriate way, each component acceleration is precisely such as is prescribed by a certain law of Nature, according to which bodies in the relative positions which the bodies in question actually have at the moment,[1] always receive certain accelerations, which, being compounded by geometrical addition, give the acceleration which the body actually experiences.

This is the only fact which the idea of force represents, and whoever will take the trouble clearly to apprehend what this fact is, perfectly comprehends what force is. Whether we ought to say that a force *is* an acceleration, or that it *causes* an acceleration, is a mere question of propriety of language, which has no more to do with our real meaning than the difference between the French idiom "*Il fait froid*" and its English equivalent "*It is cold.*" Yet it is surprising to see how this simple affair has muddled men's minds. In how many profound treatises is not force spoken of as a "mysterious entity," which seems to be only a way of confessing that the author despairs of ever getting a clear notion of what the word means! In a recent admired work on "Analytic Mechanics" it is stated that we understand precisely the effect of force, but what force itself is we do not understand! This is simply a self-contradiction. The idea which the word force excites in our minds has no other function than to affect our actions, and these actions can have no reference to force otherwise than through its effects. Consequently, if we know what the effects of force are, we are acquainted with every fact which is implied in saying that a force exists, and there is nothing more to know. The truth is, there is some vague notion afloat that a question may mean something which the mind cannot conceive; and when some hair-splitting philosophers have been confronted with the absurdity of such a view, they have invented an empty distinction between positive and negative conceptions, in the attempt to give their non-idea a form not obviously nonsensical. The nullity of it is sufficiently plain from the considerations given a few pages back; and, apart from those considerations, the quibbling character of the distinction must have struck every mind accustomed to real thinking.

IV.

Let us now approach the subject of logic, and consider a conception which particularly concerns it, that of *reality*. Taking clearness

[1] Possibly the velocities also have to be taken into account.

in the sense of familiarity, no idea could be clearer than this. Every child uses it with perfect confidence, never dreaming that he does not understand it. As for clearness in its second grade, however, it would probably puzzle most men, even among those of a reflective turn of mind, to give an abstract definition of the real. Yet such a definition may perhaps be reached by considering the points of difference between reality and its opposite, fiction. A figment is a product of somebody's imagination; it has such characters as his thought impresses upon it. That whose characters are independent of how you or I think is an external reality. There are, however, phenomena within our own minds, dependent upon our thought, which are at the same time real in the sense that we really think them. But though their characters depend on how we think, they do not depend on what we think those characters to be. Thus, a dream has a real existence as a mental phenomenon, if somebody has really dreamt it; that he dreamt so and so, does not depend on what anybody thinks was dreamt, but is completely independent of all opinion on the subject. On the other hand, considering, not the fact of dreaming, but the thing dreamt, it retains its peculiarities by virtue of no other fact than that it was dreamt to possess them. Thus we may define the real as that whose characters are independent of what anybody may think them to be.

But, however satisfactory such a definition may be found, it would be a great mistake to suppose that it makes the idea of reality perfectly clear. Here, then, let us apply our rules. According to them, reality, like every other quality, consists in the peculiar sensible effects which things partaking of it produce. The only effect which real things have is to cause belief, for all the sensations which they excite emerge into consciousness in the form of beliefs. The question therefore is, how is true belief (or belief in the real) distinguished from false belief (or belief in fiction). Now, as we have seen in the former paper, the ideas of truth and falsehood, in their full development, appertain exclusively to the scientific method of settling opinion. A person who arbitrarily chooses the propositions which he will adopt can use the word truth only to emphasize the expression of his determination to hold on to his choice. Of course, the method of tenacity never prevailed exclusively; reason is too natural to men for that. But in the literature of the dark ages we find some fine examples of it. When Scotus Erigena is commenting upon a poetical passage in which hellebore is spoken of as having caused the death of Socrates, he does not hesitate to inform the inquiring reader that Helleborus and Socrates were two eminent Greek philosophers, and that the latter having been overcome in argument by the former took the matter to heart and died of it! What sort of an idea of truth could a man have who could adopt and teach, without the qualification of a perhaps, an opinion taken so entirely at random? The real spirit of Socrates, who I hope would have been delighted to have been "overcome in argument," because he would have learned something by it, is in curious contrast with the naïve idea of the glossist, for whom discussion would seem to have been simply a struggle. When philosophy began to awake from its long slumber, and before theology completely dominated it, the practice seems to have been for each professor to seize upon any philosophical position he found unoccupied and which seemed a strong one, to intrench himself in it, and to sally forth from time to time to give battle to the others. Thus, even the scanty records we possess of those disputes enable us to make out a dozen or more opinions held by different teachers at one time concerning the question of nominalism and realism. Read the opening part of the "Historia Calamitatum" of Abelard, who was certainly as philosophical as any of his contemporaries, and see the spirit of combat which it breathes. For him, the truth is simply his particular stronghold. When the method of authority prevailed, the truth meant little more than the Catholic faith. All the efforts of the scholastic doctors are directed toward harmonizing their faith in Aristotle and their faith in the Church, and one may search their ponderous folios through without finding an argument which goes any further. It is noticeable that where different faiths flourish side by side, renegades are looked upon with contempt even by the party whose belief they adopt; so completely has the idea of loyalty replaced that of truth-seeking. Since the time of Descartes, the defect in the conception of truth has been less apparent. Still, it will sometimes strike a scientific man that the philosophers have been less intent on finding out what the facts are, than on inquiring what belief is most in harmony with their system. It is hard to convince a follower of the *a priori* method by adducing facts; but show him that an opinion he is defending is inconsistent with what he has laid down elsewhere, and he will be very apt to retract it. These minds do not seem to believe that disputation is ever to cease; they seem to think that the opinion which is natural for one man is not so for another, and that belief will, consequently, never be settled. In contenting themselves with fixing their own opinions by a method which would lead another man to a different result, they betray their feeble hold of the conception of what truth is.

On the other hand, all the followers of science are fully persuaded that the processes of investigation, if only pushed far enough, will give one certain solution to every question to which they can be applied. One man may investigate the velocity of light by studying the transits of Venus and the aberration of the stars; another by the oppositions of Mars and the eclipses of Jupiter's satellites; a third by the method of Fizeau; a fourth by that of Foucault; a fifth by the motions of the curves of Lissajoux; a sixth, a seventh, an eighth, and a ninth, may follow the different methods of comparing the measures of statical and dynamical electricity. They may at first obtain different results, but, as each perfects his method and his processes, the results will move steadily together toward a destined centre. So with all scientific research. Different minds may set out with the most antagonistic views, but the progress of investigation carries them by a force outside of themselves to one and the same conclusion. This activity of thought by which we are carried, not where we wish, but to a foreordained goal, is like the operation of destiny. No modification of the point of view taken, no selection of other facts for study, no natural bent of mind even, can enable a man to escape the predestinate opinion. This great law is embodied in the conception of truth and reality. The opinion which is fated[1] to be ultimately agreed to by all who investigate, is what we mean by the truth, and the object represented in this opinion is the real. That is the way I would explain reality.

But it may be said that this view is directly opposed to the abstract definition which we have given of reality, inasmuch as it makes the characters of the real to depend on what is ultimately thought about them. But the answer to this is that, on the one hand, reality is independent, not necessarily of thought in general, but only of what you or I or any finite number of men may think about it; and that, on the other hand, though the object of the final opinion depends on what that opinion is, yet what that opinion is does not depend on what you or I or any man thinks. Our perversity and that of others may indefinitely postpone the settlement of opinion; it might even conceivably cause an arbitrary proposition to be universally accepted as long as the human race should last. Yet even that would not change the nature of the belief, which alone could be the result of investigation carried sufficiently far; and if, after the extinction of our race, another should arise with faculties and disposition for investigation, that true opinion must be the one which they would ultimately come to. "Truth crushed to earth shall rise again," and the opinion which would finally result from investigation does not depend on how anybody may actually think. But the reality of that which is real does depend on the real fact that investigation is destined to lead, at last, if continued long enough, to a belief in it.

But I may be asked what I have to say to all the minute facts of history, forgotten never to be recovered, to the lost books of the ancients, to the buried secrets.

> "Full many a gem of purest ray serene
> The dark, unfathomed caves of ocean bear;
> Full many a flower is born to blush unseen,
> And waste its sweetness on the desert air."

Do these things not really exist because they are hopelessly beyond

[1] Fate means merely that which is sure to come true, and can nohow be avoided. It is a superstition to suppose that a certain sort of events are ever fated, and it is another to suppose that the word fate can never be freed from its superstitious taint. We are all fated to die.

the reach of our knowledge? And then, after the universe is dead (according to the prediction of some scientists), and all life has ceased forever, will not the shock of atoms continue though there will be no mind to know it? To this I reply that, though in no possible state of knowledge can any number be great enough to express the relation between the amount of what rests unknown to the amount of the known, yet it is unphilosophical to suppose that, with regard to any given question (which has any clear meaning), investigation would not bring forth a solution of it, if it were carried far enough. Who would have said, a few years ago, that we could ever know of what substances stars are made whose light may have been longer in reaching us than the human race has existed? Who can be sure of what we shall not know in a few hundred years? Who can guess what would be the result of continuing the pursuit of science for ten thousand years, with the activity of the last hundred? And if it were to go on for a million, or a billion, or any number of years you please, how is it possible to say that there is any question which might not ultimately be solved?

But it may be objected, "Why make so much of these remote considerations, especially when it is your principle that only practical distinctions have a meaning?" Well, I must confess that it makes very little difference whether we say that a stone on the bottom of the ocean, in complete darkness, is brilliant or not—that is to say, that it *probably* makes no difference, remembering always that that stone *may* be fished up to-morrow. But that there are gems at the bottom of the sea, flowers in the untraveled desert, etc., are propositions which, like that about a diamond being hard when it is not pressed, concern much more the arrangement of our language than they do the meaning of our ideas.

It seems to me, however, that we have, by the application of our rule, reached so clear an apprehension of what we mean by reality, and of the fact which the idea rests on, that we should not, perhaps, be making a pretension so presumptuous as it would be singular, if we were to offer a metaphysical theory of existence for universal acceptance among those who employ the scientific method of fixing belief. However, as metaphysics is a subject much more curious than useful, the knowledge of which, like that of a sunken reef, serves chiefly to enable us to keep clear of it, I will not trouble the reader with any more Ontology at this moment. I have already been led much further into that path than I should have desired; and I have given the reader such a dose of mathematics, psychology, and all that is most abstruse, that I fear he may already have left me, and that what I am now writing is for the compositor and proof-reader exclusively. I trusted to the importance of the subject. There is no royal road to logic, and really valuable ideas can only be had at the price of close attention. But I know that in the matter of ideas the public prefer the cheap and nasty; and in my next paper I am going to return to the easily intelligible, and not wander from it again. The reader who has been at the pains of wading through this month's paper, shall be rewarded in the next one by seeing how beautifully what has been developed in this tedious way can be applied to the ascertainment of the rules of scientific reasoning.

We have, hitherto, not crossed the threshold of scientific logic. It is certainly important to know how to make our ideas clear, but they may be ever so clear without being true. How to make them so, we have next to study. How to give birth to those vital and procreative ideas which multiply into a thousand forms and diffuse themselves everywhere, advancing civilization and making the dignity of man, is an art not yet reduced to rules, but of the secret of which the history of science affords some hints.

THE ARCHER-FISHES.[1]

By E. SAUVAGE.

IN the elegance and variety of their colors, in the splendor and brilliancy of the tints with which they have been adorned by Nature, marine animals have no reason to envy the inhabitants of air; and if in the tropical regions of Africa and America the forests are embellished by the presence of innumerable birds of gorgeous plumage, the Indian Ocean and the Antilles Sea possess countless legions of fishes that are more beautiful still, whose scales flash with all the colors of the metals and precious stones, while a thousand varied ornamentations are traced in vivid colors on the general tone.

The animals known to our colonists on the Antilles Islands under the names of *Demoiselles*, *Portugais*, *Bandoulières*, are, in this respect, not inferior to the most richly-adorned of fishes. Accustomed to keep near the shore, amid the rocks and in shallow waters, swimming swiftly and ever moving, they are constantly reflecting the splendid colors with which they are decorated. Rose-color, purple, azure, velvety-black, milk-white, are gorgeously displayed on their surface, in the form of bands, streaks, curved lines running in various directions, rings, ocellated spots. These colors stand out boldly on the surface of the body, which furnishes a background of the richest nacreous tints of gold and silver, or of polished steel.

In all of these fishes the body is compressed, and the vertical fins are covered with scales, whence the name *Squamipinnes*, by which they are known to naturalists. The shape of the body is sometimes peculiar, and the buffalo or cow fish of the Malays is one of the most

[1] Translated from the French, by J. Fitzgerald, A. M.

curious of the class, as well by reason of the protuberance and the sharp, recurved horns of the head, and the compressed and unequal spines of the back, as on account of the broad, yellow, green, and brown *zebraizations* which adorn the body. The jaws sometimes are armed with minute teeth like the nap of velvet, as in the archer-fish; sometimes these teeth are superseded by fine, compact, silky filaments, performing the same functions as the barbs of the whale—they serve to strain the water and to retain the little animals on which the fish preys. The fishes of this class are the *Chætodon*, with its rich colors; the *Holacanthus*, which is perhaps the most beautiful member of the family; the *Pomacanthus*, known to our French colonists as *Le Portugais* (the Portuguese); and sundry others.

Of the *Chætodons*, some have the muzzle long and slender, formed by the bones of the jaw, which are united along nearly their entire length by a membrane, so that the mouth is simply an horizontal slit at the extremity of this cylinder, or elongated cone. The vertical diameter of the body is very great, and the upright fin of the back is high and scaly; the tail is cut square; the profile, which is concave in front of the eyes, rises almost vertically, so that the snout is about one-fourth the depth of the head. These fishes, known under the name of *Chelmons*, inhabit the Indian Ocean; naturalists distinguish two species, the beaked *Chelmon* and the long-beaked *Chelmon* (*see* the latter in Fig. 1). These species differ from each other not only in length of beak, but also in the arrangement of the colors which adorn them.

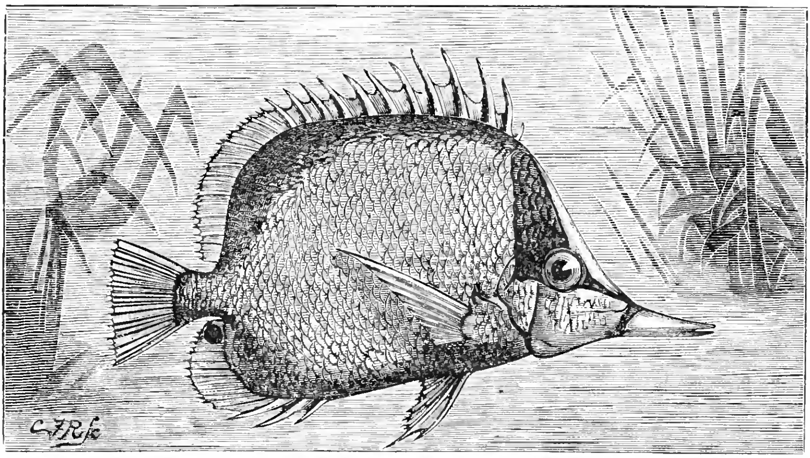


FIG. 1.

In the beaked *Chelmon* the body is greenish and iridescent; the fins are green, with reflection of azure; a black spot, surrounded by a pearl-white circle, is seen on the dorsal fin, in length about one-third that of the soft rays; five vertical stripes of azure-color, and bordered with a nacreous white line, adorn the body; one of these stripes crosses the eye obliquely; a second one, bisecting the nape of the neck, extends to the ventral fins; the next two mark the flanks, and the posterior stripe bisects the root of the caudal fin.

The long-beaked *Chelmon's* body is yellow. Instead of the stripe crossing the eye, seen in the other species, we find on the anterior portion of the body a broad, blackish spot, triangular in shape, and terminating in a point on the snout. This spot is bordered by a nacreous white stripe; the forehead is of azure tint, with a shade of sea-green; the eye is of a pure rose-color; a narrow stripe of black adorns the margin of the fins, which themselves are of mauve-color; on the posterior part of the anal fin, near its edge, is seen a deep-black spot, encircled by a line of pearly white.

The *Chelmon*, particularly the beaked *Chelmon*, has been described by Schlosser, under the title of Archer-fish, in the "Philosophical Transactions." The animal is said to obtain its food in a peculiar way, and hence the names given to it by Schlosser (*Jaculator*) and by the Dutch colonists of the East Indies (*Spuytvisch*, pump-fish or spitting-fish).

Lacépède, following the narratives of travelers, tells us that the long-beaked *Chætodon* "usually keeps near to the mouths of rivers, and especially frequents places where the water is not deep. It feeds on insects, especially such as live on the marine plants which rise above the surface of the sea. In taking them it resorts to a noteworthy manœuvre, which it is enabled to perform by the very elongated form of the snout; and a similar sort of manœuvre is performed by the *Sparus insidator*, the bellows-chætodon, and other fishes, with very long, very narrow, and nearly cylindrical beak, like that of the animal we are now describing. When the archer espies an insect which it wishes to seize, but which is flying too high above the surface to be captured by leaping out of the water, it approaches as near as possible to its prey, then it fills its mouth-cavity with water, shuts its gill-openings, suddenly compresses its little slit of a mouth, and, ejecting rapidly the water through the very narrow tube which forms its snout, squirts it often to the distance of two metres, and that with such force that the insect is stunned and falls into the sea. The performance is so amusing that rich people throughout the greater part of the East Indies keep long-beaked *Chætodons* in large vessels."

Bloch, in his "History of Fishes," which was published at the close of the last century, tells us, on the authority of Mynheer Hommel, inspector of the Batavia Hospital, that the bandoulière or beaked *Chætodon* has a very singular way of procuring food. "Observe," says Bloch, "how this fish ensnares the flies it discovers on the marine plants which project above the water. It approaches within four to six feet of the insect, and then squirts water upon it with such force that it never fails to bring it down and make it its prey." Mynheer

Hommel himself made the following experiment: He had a few of these fishes placed in a large vessel containing sea-water. When they had become accustomed to this prison, he ran a pin through a fly, and made it fast to one side of the vessel. He then was so fortunate as to see "these fishes vying with one another in their efforts to seize the fly, and continually squirting little drops of water, without ever missing their aim."

We owe it to truth to add that Bleeker, who resided so long in the Dutch Indies, and who is perfectly familiar with the ichthyological fauna of that region, not only finds in the habits of the bandoulière no confirmation of this singular method of catching insects, but he never even heard it mentioned during his sojourn at Batavia. "Certain it is," adds he, "that at Batavia this species inhabits only the waters of the reefs of the little islands in the bay, and never visits the swampy and sandy beach in the vicinity of the capital, or the mouths of the rivers."

A fish belonging to the same family—*Squamipinnes*—but classed in another group, has likewise received from Schlosser and Pallas the name of Archer.

Four species, inhabiting the waters of Polynesia and the Indian Archipelago, constitute this group of the Archers, or *Toxotæ*. Instead of being more or less oval in shape, as is the case with the *Chætodons*, the body is here elongated, the line of the back being nearly straight, while that of the belly is curved, so that the fish assumes a triangu-

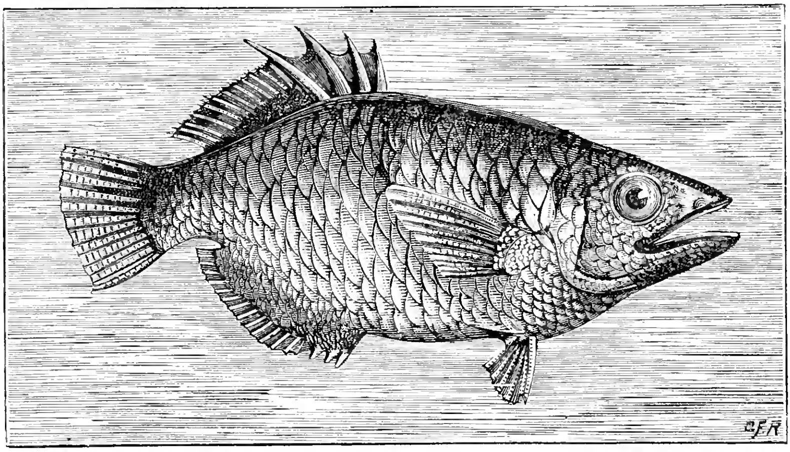


FIG. 2.

lar shape. The distinguishing feature of these fishes is the backward position of the dorsal fin, which, relegated to the posterior part of the body, is armed with only three or four spines (Fig. 2). The head, lying in the same plane with the line of the back, is pointed; the eye is large, and the mouth opens wide. The brilliant colors of the *Chætodons*, properly so called, are here wanting; the body is olive-brown or yellow, and bears broad, round, or oblong spots, or vertical stripes of black color; the eye is rose-color and brilliant; the belly, silvery-white.

According to Cuvier and Valenciennne, "though the mouth of this fish differs immensely in its organization from that of *Chelmon*, it, too, can shoot drops of water to a great height, and can hit, with almost unerring aim, insects and other little animals on aquatic plants, or even on the herbage at the water's edge. The inhabitants of sundry regions in India," add these authors, "and particularly the Chinese in Java, keep these fish in their houses for the sake of the amusement afforded by witnessing their performances, offering it ants and flies on a string, or on the end of a stick, brought within range. . . . The species is known in the Indian Archipelago under the Malay name of *ikansumpit*."

Bleeker, in a recent work on the *Toxotæ*, tells us that at Batavia this fish is no longer kept, as it appears to have been a century ago, either by Europeans or by the Chinese. He further says that neither from Chinese nor from natives, whether at Batavia or elsewhere, has he been able to obtain any confirmation of the accounts which have been given concerning its skill in seizing its prey. According to him, the celebrity enjoyed by the archer-fish is undeserved, and rests upon a misapprehension; in short, he shows from the very texts of Pallas and Schlosser that Hommel's observation applies to the long-beaked *Chelmon*, of which we have spoken above, and that like habits have been gratuitously attributed to the two species, they having been regarded as generically identical.—*La Nature.*

TEMPERAMENTS.

By ELY VAN DE WARKER, M. D.

EVERY adult human being carries about with him an atmosphere of individuality. By this means is the gregarious animal called man enabled to preserve in himself such an isolation from the mass of his fellows that he can gain and hold whatever may be his share of prosperity and remembrance. In this individuality lie his powers of offense and defense—the buckler and spear of his *ego;* and in it also is expressed the sum of his mental and physical traits in such a manner that, once having known, we may remember him. There are two elements that enter into the formation of this distinctive and memorable quality, mental and physical. These factors enter unequally into the formation of this individual total. The element that has really the least to do with that subtile force called character is the one by which we chiefly recognize the man. This is the *ensembled physique*, the mental picture we have formed of the bodily man; it is only by long association that we come to speak of one by his mental traits, and can recall him to our minds, not by accidents of size, shape, complexion, but by the tone, manner, and quality, of the mental man. It is curious, however, to reflect that our chief means of mutual identity are the same as those by which we distinguish horse from horse, and dog from dog; and that such is the infinite variety in the merely physical development of men, that this is sufficient for the practical affairs of life. In fact, it is not within experience that two human beings ever existed who were so nearly alike that side by side they could not be distinguished.[1] But human individuality is separated from that of the brute by the refinement of a physical quality. This is called temperament. Although temperaments are purely of physical origin, yet their outlet is mainly found in the actions or the mental habits of the individual, and thus it is that temperaments, like charity, cover a multitude of sins. Even those who believe in the immateriality and separate entity of mind, do not hesitate to ascribe the fretfulness, fickleness, temper, and other mental shortcomings of their friends, to faults of temperament. This may in a measure be the result of habit, but I believe that there is about it the force of a truth that even the most spiritual of psychologists cannot escape. It exists as a physical medium, through which the mental life shines forth, tinged and refracted by its passage. The old word expresses it, *humors* of the body, a mythical, potent, and subtile fluid, mingling with the bodily substance, and rising, exhalation-like, into the brain, obscuring, revealing, exalting, and depressing the operations of the mind according as it is acting well or ill; as hypothetical as the interplanetary ether, yet as real as a fit of the blue devils. This was somewhat the old notion, and a well-fought battle-ground it was, over which the solidists and humoralists contended right gallantly. A standpoint upon a solid basis of fact is to this day wanting from which we may say they were wrong.

Many of these old fathers in medicine fairly reveled in the idea of temperaments. It contained just enough of the mysterious to spur on their wonder-loving minds. All there was of fact about it, however, they brought out, and all that we know about it they knew. We are to this day using their terms and classification, and have added nothing to them. It stands as a fact in physiology which we have inherited from the remotest boundary of historical medicine.

The four qualities of Hippocrates were believed to be the origin of the temperaments. In moisture and dryness, in heat and cold, not as conditions of existence but as entities in life, were found the mate-

[1] There are several remarkable cases of wonderfully close resemblance and mistaken identity on record, but none that stood the test indicated in the text.

rials that either singly or together formed the temperaments. They were combined thus: hot and moist produced blood, hence the sanguine temperaments; cold and moist caused phlegm or pituita, and from this the phlegmatic or lymphatic; hot and dry produced yellow bile, and gave us the sanguine or choleric; and cold and dry caused black bile, which predominating in the body resulted in the melancholic or bilious temperament.[1] In order to understand the profound reason involved in this it must be remembered that these four primary principles of living bodies were believed to be compounded of the simple elements of Nature. Here is shadowed, dimly it is true, but from the very depths of Nature, the theory of the correlation of forces, and even evolution itself. Boerhaave was among the first who attempted to improve the classification of Hippocrates, and then followed Hoffmann, Cullen, and Haller, who, however much reason they may have had, failed to refine the rugged simplicity of the old Greek. Absurd as we may deem the incarnation of the four elements in the form of temperaments by Hippocrates to be, yet from the length of time this idea has prevailed, and the profound influence it has exerted upon science for centuries, we may believe that it possessed the soul of truth that exists in things erroneous, as Herbert Spencer says. Not until 1757 was anything like a scientific explanation given. The learned Haller was the first to give the four elements their final overthrow, and place the phenomena upon a physiological basis;[2] and even he failed to suggest any improvement in the old nomenclature. It is strong evidence of the force that exists latently in old ideas that all modern attempts to extend the scope of the Hippocratic terms have never gained credit. Dr. Gregory renamed the temperaments, and added a fifth, which he called the nervous, and which has been accepted and rejected a score of times; while it is a convenient term to use, it is true that it describes no temperament that may not be included under the old terms. Then came Dr. Pritchord, who rejected the reforms of Dr. Gregory, restored the original terms, and barely escaped calling his predecessor hard names. But the temperaments, simple as they may seem, have afforded groundwork for a separate science—not formulated deductions from dry facts, but drawn warm from the mass of living, suffering humanity. Dr. W. B. Powell spent forty years of his life in the study, and at last evolved a "human science" with ten compounds of temperaments with binary, ternary, and quaternary subdivisions.[3] If human science, as taught by Dr. Powell, be true, it ought to be the ceaseless study of every man and woman, taught along with the creed and catechism—which are the spiritual to this its earthly and carnate part—to the youngest child. Lurking in this science are more than Dantesque horrors,

[1] "De Natura Hominis," tom. ii., ed. Kühn.

[2] "Elementa Physiologiæ Corporis Humani," 1757.

[3] *Journal of Human Science*, Cincinnati, 1860.

which are liable to spring upon the most circumspect of us in the shape of physiological incest; as if in the decalogue and through the ingenuity of man there were not already more crimes than human nature can withstand, that we should be exposed to others we know not of. This physiological crime consists in the marital union of like temperaments. Human science has revealed another latent offense, called sexual incompatibility, which, so far as I know, has not yet, in its sexual guise, obtruded itself in the divorce courts. It is a standing rebuke to those who build imaginary sciences, without a foothold in the solid world of facts, that, in giving their shadowy creations to the people, they are inviting the cold scrutiny of an aggregate common-sense that never fails in time to separate the true from the false.

But temperaments have been made to play a more agreeable *rôle* in human affairs than in defining physiological crimes. In the history of this physical attribute it is interesting to cite its literary aspects. Ben Jonson devoted whole plays to the idealizations of individual temperaments, in which a peculiarity was made to play its part as a *dramatis persona.* The keen and careful analysis of the poet in character is immortalized in his play of "Every Man in his Humor." Shakespeare proved himself a good physiologist as well as a good judge of a conspirator in contrasting Cassius, "lean and hungry," with men "that are fat; sleek-headed men, and such as sleep o' nights." In the earlier English novels, temperament was given a more careful study than in the modern school of light literature. Goldsmith proved himself an enemy of the humoral pathologists in saying of Olivia, in "The Vicar of Wakefield," that the temper of woman is generally formed from the cast of her features. Fielding, in his creative novel of "Tom Jones," speaks of temperaments in such a happy vein of his inimitable philosophy, that it is worth quoting and remembering: "I make no manner of doubt," he says, "but that, in this light, we may see the imaginary future chancellor just called to the bar, the archbishop in crape, and the prime-minister at the tail of an opposition, more truly happy than those who are invested with all the power and profit of these respective offices." A more perfect description of a sanguine man was never written. Novelists, as a rule, analyze temperaments the opposite of their own in their ideal characters. Scott generally describes the bilious in his heroes and heroines, and is never purely realistic in describing the sanguine type to which he belonged. Dickens is always happier in his female characters, and they are good specimens of the sanguine. Dolly, the locksmith's daughter, is a very truthful portrait of this type; while Mark Tapley, famous as the character may be, is an atrabilious, who is continually violating his physiology by being happy under the very circumstances that bring out the unmixed misery of his class. Dickens himself was decidedly of the lymphatic—a type he rarely attempted in his creations. Richter, in "Hesperus," gives some very perfect studies of temperament; but the court physician in that novel is represented of his own type. George Eliot never violates Nature in her female characters, who are generally described as bilious or sanguine; but the least said about her heroes the better. Deronda is surely a mistake. He is first described as a good specimen of the sturdy, bilious man, and is transformed toward the close of the book into the extreme of the sanguine.

To the scientific mind there is always something assuring when we can leave the field of speculation and enter that of fact. Here chemical analysis brings to our aid positive reasons for a classification of men and women according to temperaments. Mr. Rees,[1] quoting from the researches of M. Lecanu, gives us the material for constructing the following table. The figures are ratios to 1,000 parts of blood:

TABLE I.—Ratio of Water, Albumen, and Red Blood-Globules in the Blood of Different Temperaments.

	Sanguine.	Lymphatic.	Difference.
	Water.	Water.	
Females	793.007	803.710	10.703
Males	786.584	800.566	13.982
	Albumen.	Albumen.	
Females	71.264	68.660	2.604
Males	65.85	71.701	5.851
	Red Globules.	Red Globules.	
Females	126.990	117.300	8.874
Males	136.497	110.667	19.830

This proves conclusively that temperaments have their origin deep and unchangeably fixed in the organic life. Can we, in view of this, look doubtingly upon their potent influence on the current of thought and emotions? Water, plasmic material, and the red blood-globules—the oxygen-carriers of living bodies—rush to the brain in proportions fixed by the law of temperaments; to one brain more, to another less, but with differences sufficient to give vigor, vivacity, tenacity, and mental breadth to the action of one; while the other moves more slowly, its mental life obscured by the smaller proportion of mind-food.

There is one point about which the reader needs to have a clear understanding. This is the difference between temperament and idiosyncrasy. "Temperament is built in a man, as bricks compose a well," says Dr. Southey; "his idiosyncrasy is developed according to the soil in which he is planted, the conditions under which he grows, and the tendency in him to vary."[2] A man has his temperament as a birth-

[1] "On the Analysis of the Blood and Urine in Health and Disease," London, 1836.

[2] *London Lancet*, American edition, May, 1876.

right, his idiosyncrasy he acquires, changes, makes it subject to his will, or is ruled by it. The distinction is broader than this, however. Temperament is a race-attribute. It is distributed like plants according to latitude and altitude. The bilious is tropic; it thrives best near the equator. The lymphatic belongs to the races of the North. Between these polar types are distributed races that monopolize temperaments as they do their language. The Celt is sanguine, the Saxon lymphatic, the Gaul nervous, the Latin bilious. Thus, temperament is pandemic, while idiosyncrasy belongs to the individual. M. Begin calls the first "la variété organique la plus générale," and the latter "celle qui est plus restreinte."

The tendency among recent writers upon physiology is to exclude the bilious, classing it with the nervous, and making three in place of four. This is the classification of M. Michel Lévy.[1] I shall retain the bilious, as being a term too commonly used by learned and unlearned to be omitted from a popular description.

The sanguine temperament presents marked physical traits. The mean height of the male is five feet eight and a half inches, and of the female two and a half inches less. The head is small comparatively, the face is made square by a firm and angular lower jaw, the forehead is slightly sloping, the nose prominent; it has a determined, resolute, exacting look. Under thirty-five the figures of both sexes are sparely covered with fat, but withal muscular. The chest is large, measuring thirty-five inches in average girth, and the abdomen flat. The complexion is light, and is florid only by exception to the rule; the hair light, light brown, or auburn, and often curly. The mouth is usually large, the lower lip full, and the teeth are regular, with a slightly-yellow tinge, which indicates firm and lasting dentine. The sanguine are generally good eaters and drinkers. All of the vital functions are active; the large chest-room, the vigorous heart, the firm muscles, insure a bodily activity that keeps the operations of organic life in unconscious and easy motion. Digestion, assimilation, excretion, and elimination, work in harmony and with vigor.

Mentally, this type is the reflection of its physical traits. The rich blood, by its active circulation through the brain, causes vivid and active mental action. The general cast of the mind is never gloomy. The mental vision is outward rather than inward, and sees things near or remote tinted by glowing, joyous colors, as through a prism. This mental outlook never implies profound insight, or deep thought, or conscious indwelling. It is the surface of things that is studied with quick and transient glances of all that is pleasant, revolting from the difficult or painful. The sanguine man, therefore, learns quickly and knows a little of everything, and by his ready tongue and quick wit is good company—a thorough good fellow. He is brave from a sense of perfect muscular strength, loving sport and athletic games.

[1] "Traité d'Hygiène."

He is quick to anger, but soon forgets wrong; a word and a blow, and oftentimes the blow first, are the features of his wrath.

It is in medicine only that the temperaments have practical importance, if we reject Dr. Powell's new science. Sanguine people are prone to acute diseases of the inflammatory type. Apoplexy, diseases of the heart and blood-vessels, hæmorrhages, acute fevers, pneumonia, pleurisy, and closely-allied disorders, are the forms of disease generally met with. Dr. Southey assigns to this class the old idea of crises; that is, in febrile diseases, at certain times, there will be sudden losses of the fluids of the body spontaneously, by which the diseased action secures a new outlet, and this is followed by a rapid convalescence. These evacuations, if the temperament of the patient be understood, are never interfered with by the physician, as they are Nature's own efforts to throw off the disease. Rapid recovery, or a speedy fatal result, may generally be looked for among sanguine people. In this temperament the physical part of man reaches its most perfect expression; the body is here in even balance with the brain. Such a combination as that of persistent intellectual effort with a typical sanguine temperament is rare. Prof. John Wilson (Christopher North) is an example of this, and of which there is scarce another illustration in literature. This temperament, finding its purer expression in a near approach to human animalism, with soul and body adjusted and evenly poised, a happy mingling of mind and matter, must surely have been the type of the Miltonic man. The fancy cannot paint him other than this, and believe him capable of contending with the dangers, obstacles, and unrelenting hardships, of his life. Of this type have the sailors, colonists, soldiers, and explorers, generally been—all men who lead in the battle with Nature's obstacles.

In the lymphatic temperament we have a direct antithesis of the sanguine. Typically, the lymphatics are heavily framed, the limbs are clumsy and large-jointed, awkward and slow in movement. This is due to the thickness of the articular surfaces of the long bones, and this also explains the large wrists and ankles; the head is large, the face unanimated, thick-lipped, pale, and with large features, the expression listless and apathetic; the eyes are blue or gray, the hair white, blond, or light auburn, and abundant. The male figure is between five feet eight inches and six feet two inches in height, the female five feet six or nine inches high (Southey), and such are the proportions that a person of this temperament rarely meets the artistic ideal of human beauty. The texture of the flesh is soft and flabby, and generally abundant, the muscles small and slow in their development. Puberty is late in its advent; this is but a characteristic, however, of the slow and deliberate manner of the general development. Functions are slowly performed and not evenly balanced; the fluid secretions too abundant, the absorbents inactive in comparison: thus, the figure has the deceptive appearance of a superabundant nutrition. This is a one-sided nutrition, the appropriation of fatty material to the neglect of the solid, motor machinery of brawn and muscles.

The mental traits seem to take direction and tone from the bodily characteristics. The passions move slowly and are easily kept under control, in marked contrast to those of the sanguine man who has no more control than is sufficient to keep him within the not too narrow limits of the social barriers. From the moderate emotional development there is little need of energetic will-power. Where the moral qualities have any chance of growth and exercise they are always "good people," orthodox, and conservative. The mind acts slowly, but is very retentive, logical and sound in its conclusions. They are persistent in their undertakings, honorable in their affairs with other men; commonplace and common-sense govern them in their daily life. They are apt to be dull companions, but constant and steadfast friends.

This temperament is found in its most perfect form among men; women rarely show it uncrossed, especially as it easily blends with other temperaments. There is no doubt but in this type there are inherent defects of histological structure. Dr. Southey says it is due to a too exuberant vegetative cell-life. Whatever may be the radical cause, persons of this type are weak in vital energy, and short-lived. They are the usual subjects of structural changes, such as scrofula, phthisis, and articular rheumatism, and in whom these morbid processes show the largest ratio of mortality. It will be noticed that these are diseases with a marked hereditary force. It would be interesting to study how much of this heredity exists in the morbid processes, or in the temperament itself, which offers a fair field for their onset.

Nature exerts herself in a more eccentric manner in the nervous temperament. Here we find greater variety in the physical signs, and diversity in the mental traits. Typical instances of the nervous temperament are not good specimens anatomically. In stature they are below the average, the bones small and lightly covered with flesh in both sexes up to middle life. The head is large and covered with not over-abundant dark-brown or black hair; the eyes are dark, the skin dark, sallow, and pale; pigmentation of the skin is more abundant than in any other temperament, while the cuticle is hot, dry, and firm. The muscles are small and compact. Persons of this temperament are capable of sudden outlays of great strength, but the muscles do not work in harmony, the movements being oftentimes irregular. The want of nervous coördination is a marked trait, and tells upon their efficiency in any occupation requiring trained and accurate touch. Dr. Southey explains this by what he calls cerebro-central preoccupation, which means that the brain and spinal cord are slow in receiving and responding to the wants of different and remote parts of the body. This is further shown in the unequal distribution of the circulation, the head being often hot while the feet are cold, or the extremities are cold while the body maintains a nearly febrile temperature. The heart beats more rapidly than in other temperaments, or is attended with nervous irregularity in its action. Functionally the nervous temperament is liable to serious complications; the liver is one of the organs more liable to acute derangement—not, however, in the direction of over but rather that of under action. Digestion is a delicate function, the merest trifles interfering with its proper performance. A leading trait of the nervous temperament is the mutual reaction between it and the vital glandular functions; thus sudden mental or nervous impressions will upset the whole glandular machinery, or serious mental or nervous disturbances result from causes acting in the opposite direction.

If we were to select any one quality as the leading trait of the mental constitution of this type, it would be the great emotional tension. The emotions often usurp the place of higher faculties, and reason, judgment, and the sense of right or wrong, are biased or replaced by emotional qualities. They have an acute sense of right or wrong, but they are disposed to give it a personal rather than a vicarious application. They have an extraordinary capacity for both pleasure and misery, and the nervous man may be said to be undergoing one or the other through life, never knowing what it is to be in the happy mean of negation. They are never contented with their surroundings for any great length of time, but chafe and fret against their fate, no matter how happy it may seem. They have great fixity of opinion, and but little respect for that of others; and are prone to find a particular antagonism in persons of their own temperament. The sexual emotions are unduly developed, oftentimes giving tone to the character, or acting with explosive violence. Persons of this type are not among those who form the grand aggregate of the conservative opinion of society, the inflexible and implacable character of which we all know, and which upon the emotional tension of the nervous man often reacts harmfully rather than well. Typical instances of this temperament are confined to the male sex, the other sex usually showing a cross with the sanguine or bilious.

This temperament does not show a liability to any class of disease, but gives its own characteristic reaction upon the disease itself. From the ascendency of the nervous system in the physical and mental composition, diseases of the nerves are very liable to appear, but not as a primary derangement any more than as a complication grafted upon some previously-existing disease. Nervous headache, neuralgia, epilepsy, insomnia, and hysteria, are among the nervous affections most liable to appear, either as primary or secondary derangements. With this class it is difficult to give an opinion as to the result in any serious disease (prognosis), as they often die of diseases that in other temperaments are deemed trifling; and then again, on the contrary, make most surprising recoveries. With them the will-power is oftentimes an element in the recovery, throwing off disease by the determination not to yield to its influence. There is no doubt but that this temperament is more liable to mental derangement than any other; the great emotional intensity and the difficulty of moral control laying the mind open to causes that tend to produce insanity. Many of the nervous constituents of this type belong to the bilious temperament. We have but to tone down the nervous excitability of the first by an addition of the phlegm of the lymphatic, and add flesh to the spare, nervous figure, and we have the bilious temperament. In its typical phase, the subject is apt to be grave, taciturn, even morose; mind and body move slowly but surely, not eccentrically, but by determination and conviction. Persons of this temperament are remarkable for inflexibility of will, sound judgment, strong convictions, abiding affections, and great love for those dependent upon them.

The study of the relations of temperaments to development and vitality is one of great interest. While we know tolerably well their reaction with disease, and the groups of diseases that are liable to cluster round them, we have but few facts bearing upon the normal relations of the temperaments to vital capacity. There are many difficulties in the way of this study. In the first place, we have no unit of measure or comparison, and, in the next, it is difficult to collect the facts. In a very remarkable work consisting mainly of tabulations of a vast number of data relating to anthropometry, or the measurement of men, I discovered facts that throw considerable light upon this subject. During the late war of the rebellion the provost-marshal-general had to pass upon the fitness for military service of a vast number of conscripts. The results of over a million examinations are embodied in two massive quartos, by Dr. J. H. Baxter, late chief medical officer of that bureau of the War Department.[1] From the elaborate statistical table of Dr. Baxter, I am able to construct a few tables that throw light upon some of the more obscure relations of temperaments. The facts embodied in the tables are picked out here and there from this mass of tabulation; while the figures have suffered no manipulation, except such as may be necessary to arrive at mean values.

A word as to the value of complexion as indicating temperament. A light color of the hair and skin, and blue or gray eyes, instead of indicating any one temperament, define broadly a group of two—the sanguine and lymphatic. A sallow or dark complexion, with black eyes and hair, indicates the bilious and nervous, and in this country, among natives, probably an excess of the latter. If, for the sake of narrowing the dark-haired group, we adopt the more modern classifi-

[1] "Statistics, Medical and Anthropological, of the Provost-Marshal-General's Bureau." By J. H. Baxter, A. M., M. D. Washington, D. C., 1875. Two vols., 4to.

cation, and ignore the bilious temperament, we have in this class only the nervous, while in the first group we have both the sanguine and lymphatic, with no means of separating them, except that the national characteristic shows an excess of the sanguine over the lymphatic, probably about the ratio of three to one.

TABLE II.—Vital Capacity as indicated by Ratio of Chest-Expansion of over Three Inches for all Heights to Complexion. Based upon the examination of 190,621 American-born white men accepted; expressed in ratios of 1,000.

GIRTH OF CHEST AT EXPIRATION.	LIGHT.[1]	DARK.[2]
Under 29 inches	3.588	1.141
29 and under 31 inches	37.654	15.285
31 " " 33 "	98.387	46.906
33 " " 35 "	103.015	56.605
35 " " 37 "	46.255	26.793
37 inches and over	12.676	7.151
Total number of men accepted	126,445	64,176

Table II. shows the relation of chest-expansion to complexion. The range of chest-movement, while it cannot be deemed an absolute measure of vitality, which must be regarded rather as the sum of organic and functional action than the degree of perfection in any one set of organs, yet may be fairly assumed to bear a close relation to the general vigor of the system that defines the quality of vital activity. A free chest-expansion implies a large consumption of oxygen, a corresponding degree of force and activity in the circulation of the blood, and this, in its turn, calls for a large demand for food, with a proportional muscular vigor. In the table, a chest-expansion of over three inches is taken as the basis of comparison, for the reason that, at an expansion less than this, men of impaired strength may be included. It is but necessary to glance at the table in order to understand all that is implied by it—that size and muscular vigor of the sanguine and lymphatic greatly exceed these conditions in the nervous.

TABLE III.—Ratio of Diseases to Complexion.

DISEASES IN GENERAL DIVISIONS.	Number examined, 117,029.	Number examined, 217,292.
	DARK.	LIGHT.
	Ratio per 1,000.	Ratio per 1,000.
General diseases	26.857	31.552
Diseases of the nervous system	11.322	12.366
Diseases of the circulatory system	30.881	36.614
Diseases of the respiratory system	9.271	10.902
Diseases of the digestive system	87.978	95.894
Diseases of the urinary system	1.871	2.467
Diseases of the generative system	6.392	7.713
Diseases of the organs of locomotion	30.334	37.180
Diseases of the cellular tissues[3]	0.752	1.063
Diseases of the cutaneous system	11.638	11.860

[1] Blue or gray eyes; light hair. [2] Black or hazel eyes; dark hair.

[3] This division includes abscess and obesity only.

In Table III. we have the ratio of disease to complexion. In this, the light complexions show their marked predisposition to skin-diseases; and, notwithstanding their free lung-expansion, show a nearly equal liability to diseases of the respiratory organs with those of dark skins. The light men prove their greater glandular and muscular activity by their excess over dark in diseases of the digestive, circulatory, and locomotor systems; while the dark group, although composed largely of men of nervous temperament, nearly equal the light in frequency of nervous disease. It is interesting to note that, in the same table from which Table III. is compiled, Dr. Baxter gives the total of dark men rejected for all diseases at 38,916, and of the light, 83,700, a difference rather less than that indicated by the mean difference as exhibited in our table. In general diseases, which include fevers, infectious diseases, and all others not confined locally, we find the light men leading the dark by a difference only equaled by their excess over the latter in diseases of the digestive system. This is due, I think, in a great measure to the predisposition of the sanguine to diseases of the febrile or inflammatory type, as has been already mentioned.

TABLE IV.—Ratio of Deformities to Complexion.

DEFORMITIES.	Number examined, 117,129. DARK. Ratio per 1,000.	Number examined, 217,321. LIGHT. Ratio per 1,000.
Curvature of spine	4.110	4.874
Atrophy of limb	3.640	4.303
Club-foot	1.128	1.579
Wry-neck	0.103	0.143
Deficient size of chest	11.100	17.405
Deformity of chest	2.128	2.996
Loss of limb	0.598	0.686
Defects or deformities of hand	7.032	7.699
Defects or deformities of foot	8.605	9.899

Table IV. gives an idea of the ratios of deformities in the two groups, and, while not proving much either way, presents a few facts of great interest. It will be observed that the physical defect which shows the greatest difference, and that in favor of the dark class, is deficient size of the chest. In view of the fact that light men exhibit a larger range of chest-expansion, this excess in the defective size of the chest is unlooked for. The other chest-defect is deformity, in which the difference in ratio in the two groups is only about .18. The fact that two classes are made in the chest-deformities leads me to suppose that the deformities are congenital, or the result of defective development in childhood; while the deficiency in size is the result of disease or injury later in life. This supposition opens the way to an explanation of the phenomenon. Owing to the greater liability of the light, or partly sanguine group, to active inflammations, a potent factor in causing this deficient size of the chest is inflammation, mainly pleurisy and pneumonia, and, as a not uncommon result, a collapse of one, or both, of the chest-walls. This theory is the only one that offers a reasonable explanation of a very remarkable statistical result. The increased ratio in both groups, but notably in the light, of defects or deformities of the feet rather than of the hands, while having no relation to the difference of temperament, shows the careful way in which Nature protects the natural weapons of human beings—the hands. It confirms, in a broad way, what has probably been noticed by the observant reader, that deformities of the lower are more frequent than those of the upper extremities.

These few figures, taken from Dr. Baxter's vast collection of statistics, if not demonstrating anything positively, have at least the merit of not proving too much—a common fault of figures, if we are to believe the anti-statisticians. They are important, however, in showing the direction in which the study of temperaments may be pushed in order to give practical results. Social reformers, so called, human-science men, and less respectable students under various names, have used temperaments as their physiological basis for widely different theories. To one who is content with marriage as established by law, society, and religion, it is a suspicious circumstance that this is the social relation that has sustained the most determined assaults. The physiological attacks have been made in the interests of marriage-reform, "natural marriage," and of no marriage at all. While there is very strong evidence showing that intermarriage between relations tends to the deterioration of the offspring, there are hardly any facts showing that the matrimonial union of healthy persons of like temperaments has the same effect. It is true that social theorists assert the contrary, but they do so without considering that the intermarriage of kin, from which they draw their chief arguments, is surrounded by conditions that cannot exist in the intermarriage of like temperaments. That there are deep-lying physiological reasons against the union of relations, we need go no further than the oft-quoted fact of the sure impairment of the stock of domestic animals from inbreeding, to establish. Whatever the source of this gradual impairment may be, it is wanting in the marriage of those who are allied only by similarity of temperament. In the absence of conditions that are necessary to render the arguments drawn from analogy valid, the advocates of the theory of physiological incompatibility are obliged to fall back upon facts having a direct bearing, and they have in this field, as yet, reaped no harvest. There is, however, in the human family a sort of natural selection existing, that renders a marriage between parties of like temperament not an ordinary occurrence. Both Dr. Ryan and Mr. Walker, in their works on marriage, refer to the common tendency of one sex to seek the opposite temperament in the other. But, upon the subject of matrimony, even in its physiological relations, society unwittingly does very well.

THE ICE AGE.

By L. P. GRATACAP, Ph. B.

AT the end of that long course of geological ages, from the Archæan to the Tertiary, which built up the solid portions of the earth in their present configuration, geologists now universally recognize, in the evidence before them, the presence of a remarkable and stupendous period—a period so startling that it might justly be accepted with hesitation, were not the conception unavoidable before a series of facts as extraordinary as itself, and which, partaking of its astonishing character, are explained upon no simpler hypothesis. This era is known as the Glacial. It was an era which has left its traces in unmistakable monuments over the surface of either hemisphere, and written its history in no less explicit characters upon their rocks. It was an epoch of arctic rigidity, when the temperature of the earth had become so lowered that the cold regions of either pole *alternately* were permitted to extend their previously contracted circles over the temperate latitudes, and to envelop with a universal and prodigious mantle of ice the lands which once, beneath milder suns, had been the home of an abundant and tropical vegetation. The skirts of that glacial sea which perennially spreads its icy and resplendent surface over polar lands had then, by a favorable conjunction of solar and terrestrial influences, been expanded so widely, that to within the latitude of 39° north its frigid folds hid the surface of the earth, while below the equator a similar period seems to have left scarcely less visible traces amid the forests and pampas of South America. The evidence which has established the actual presence of these arctic conditions over a great portion of our earth is complete and irrefragable, and, aided by the contemporaneous study of Alpine glaciers and the Greenland icebergs, we can draw conclusions as to the nature and the succession of events which these conditions occasioned.

It was Agassiz who first insisted, perhaps almost with trepidation, that Central Europe, England, Scotland, and Ireland, had been buried beneath thousands of feet of solid ice; that from the mountain-tops of Scandinavia, the Grampians of Scotland, the Lake Hills of England, and the summits of the Alps, had proceeded vast rivers of ice whose confluent seas had swept over Europe, and beneath their resistless, ceaseless, and perpetual advance, grooved it with valleys, channeled the courses of its rivers, engraved its rocks, scooped out its lakes, and scattered their burden of *débris* far and wide over its plains. The conception was a bold, almost a terrifying one; and, because the actual history and nature of glaciers was so little known, it was regarded with aversion and spoken of with contempt. Agassiz had laboriously studied the glaciers of the Alps, he had conned the lesson they taught with eager apprehension of its great significance, and he knew so well every characteristic of their work that he instantly recognized abroad the same indelible evidence of their past presence.

Venetz, Rendu, and Charpentier, had preceded him in glacial study, and had insisted upon an extension of the Alpine glaciers far beyond their present beds in past ages, but had not realized the immense utility of these views in explaining the glaciated surfaces of Europe. Forbes, Hopkins, and Tyndall, succeeded him in the investigation of glacial physics, and by their close scrutiny into the constitution of ice, and the laws of ice-making and glacial motion, fairly established a new department of physical science, and added confirmation to the views of Agassiz.

Now, let us examine some of these singular and hitherto inexplicable records, which elicited Agassiz's theory, and which, long before they were harmonized by that assumption, had been attentively examined by geologists and explained upon other grounds. Furthermore, we will review them without reference to the theory of glacial action, and only subsequently compare them with the effects now being produced wherever glaciers and icebergs are at work.

The rocks as they lie in place, the flanks and summits of mountains to heights of 5,000 and 10,000 feet, and the surfaces of outcropping masses over immense areas of the world, are all gauged in long, straight channels, sometimes a foot deep, sometimes eight feet deep, with widths from two to three feet. These grooves, of all dimensions, pass over the rock in groups like mouldings, and the rocks they occur upon are polished and oftentimes lustrous. The channels diminish in size to the faintest striæ, which, like sharp scratches, cover the surface, running along at times in parallel series, or diverging in different directions, as though the great primitive plane had varied its course over them, scouring with exquisite fineness.

These lines and runnels score the rocks over the Northern United States and Canada, throughout Europe, in Asia, and over the shores of South America. We discover almost instantly that in the same region they have the same direction; that they seem, as it were, to stream with us from the north; and that, wherever other scores contravene this, these secondary markings are themselves harmonious, indicating some subsequent action upon the rock, in character similar to the first, though varying in its motion, and probably restricted in its extent and importance. Thus the scores upon the rocks of New England point northwest and southeast, and only local derangements disturb this prevalent direction. The easting increases as we progress to the ocean, reaching its maximum in Maine and the borders of Canada; while, as we retire from the margin of the States, we observe that the scratches and grooves acquire a north-and-south direction, becoming nearly meridional over New York, and then slowly swing round to the west, until in Ohio, Indiana, Illinois, Missouri, and the western limits of the continent, they lie pointing northeast and southwest. Thus they assume a rudely-outlined radiation from the highlands of Canada, and stretch out from an hypothetical centre there like the multiplied spokes of a great wheel. In Switzerland they sweep down and out from the central ranges of the Alps in all directions, and, while locally uniform, they converge from the south, and east, and north, and west, toward the lofty slopes and pinnacles of this congeries of mountains. Over West Russia and Northern Europe, where the markings are discovered, they indicate the Scandinavian mountains to have been the seat of whatever disturbance or agency has, at a distant period, fluted and engraved the continent; similarly, as the rocks lie related to the Highlands of Scotland, the Lake Hills of England, or the mountains of Wales, the striæ impressed upon them extend toward every point of the compass. They stream north and south from the summits of the Pyrenees, from the peaks of the Caucasus, and down the valleys of the Himalayas. It must be understood, however, that these conclusions are based upon an average of the bearings of the grooves in each instance, and that these are infinitely varied by the construction and irregularity of the land.

Thus over greater portions of the world we find the rocks furrowed, polished, and striated, in long, frequently deep and rectilinear grooves, which lie in groups and series identical in direction, and pointing to associated highlands, or distant continental mountain-ranges, as the source of whatever strange and inexorable instrumentalities have produced them. Over New York Island the gneissoid and granitic rocks, where they raise their tilted strata and broken shoulders above the ground, are scored frequently with deep and sinuous channels. In Central Park, along Fifty-ninth Street, up the west side, the contorted and twisted humps of gneiss are moulded in this way. Sometimes, where a rupture exists, and one part of an outcrop has fallen below the other, the grooves are continued on the lower half; frequently the lines are crowded together like rulings on a page, and again the groove is of irregular depth, its floor rising and falling as though hitches had occurred when it was first planed, the great chisel meeting resistance, or being thrown up at points along its path. In the White Mountains the sides of the mountains, the valleys, the top of Mount Washington, at 5,000 feet above the sea, are all cut with these strange furrows, the rocks polished, and the whole country bearing these evidences of past erosion wherever the naked rock meets the eye. Over Maine the same phenomena present themselves in endless succession, the grooves striping the country, and losing themselves in the sea along the coast, while they corrugate the borders of the innumerable bays, and the walls of the deep fiords that indent the shores. These furrows can be traced for miles across the country, cutting the three ranges that lie between Bangor and the sea almost at right angles, traversing these highlands as though they were level surfaces, dipping beneath the sea, and reappearing upon the sides of Mount Desert, to be again lost in the waters of the Atlantic. Unquestionably, over that sea-floor, could we follow their tracks, the same furrows continue to the verge of the continent which lies miles out to seaward, when the steep edge of the land falls precipitately to the true bottom of the ocean. Over the West, throughout Canada, and upon the ancient rocks of the Great Lakes, these evidences of past erosion exist upon an enormous scale. As a rule, these striæ indicate a planing surface advancing from the north, and, though a second series may occur, as upon the islands of Lake Erie, from east to west, whose furrows obliterate the first inscription, such phenomena are local merely, and infrequent. Again, upon the Sierras, the tops and declivities of the ranges are scored and engraved with the indelible signatures of past erosions, and the rocks of the barren wastes of British America are signalized in the same manner. So much for striæ: we perceive their universal presence, and their marked reference to the north, or elevated regions which dominate over level plains.

The second feature of this epoch, designated by common consent the Drift, is a series of surprising facts, evincing, throughout all this deeply-scored and paneled country, the past presence of extraordinary transporting agencies. We find rocks of enormous size, in some instances weighing 3,000 tons, planted in fields and lowlands, or strewed over hills and moors, where no rocks lie in place, sunken in the soil where the lithology of the district is entirely distinct, while that of the monoliths themselves is identical with rock many miles northward. These gigantic bowlders, Titanic mementos of the past, are scattered over Central Europe, over Germany, Holland, and Russia, are identical in character, and can have no nearer origin than in the mountains of Scandinavia. Some of these blocks of stone are of incredible dimensions, and are accompanied by innumerable smaller ones that lie over these districts as if flung in sport by some pre-Adamite Antæus. They have served the most useful purposes in the flat countries through which they are found, being used for buildings of every description, and their smallest associates have helped to pave the highways between Hamburg, Magdeburg, and Breslau. Accredited in ruder times to the malevolent agency of man's spiritual foes, they were called *devil-stones*; but Science, recognizing their distant origin, has named them *erratics*, and the Germans, more picturesquely, *wanderers*. Not only are they found upon level and loamy lands, utterly unaccountable except by the assumptions of transportation, but they are also discovered capping the cliffs of mountain-chains, hanging by the side of depths, over which they must have been carried, and into which, by the Nemesis of destiny, they are now doomed to fall. The Jura Mountains, north of the great valley of Switzerland, and opposite the western or Bernese Alps, along the frontier of France, are thus studded with these bowlders, some of them containing 50,000 to 60,000 cubic feet of stone. These have come from the Alps; they are crystalline rocks, gneiss, and granite, and they lie upon ridges of limestone. They are virtually nothing less than dislocated fragments of those abraded and decreasing hills perched upon the Jura cliffs. Prof. Guyot has placed, beyond all doubt, their home upon the summits and sides of the Swiss Alps, and shown that they have attained their present eminence by a positive carriage from these original localities. This position has indeed been made impregnable by a protracted and laborious survey of innumerable "wanderers" found upon the Juras, whose lithological character identified them with the Alpine formation, while it served to trace the probable path of their transmission. These blocks have been found at elevations ranging from 2,000 to 3,500 feet above the sea, and in Carinthia similar erratics have been described at great elevations, proceeding from an opposite quarter of the Alps.

In North America, and especially throughout the Northern States, the bowlders are numerous, often of great size, and indicating transits of many miles. Over the Eastern, Middle, and Northwestern States, bowlders, that have emigrated from distant points to the northward, occur in such abundance that they may almost anywhere be found if the inquirer will only examine the country he passes over. Upon Mount Katahdin, in the Moosehead region of Maine, stones can be seen, lying over 4,000 feet above the sea, fossiliferous in their nature and coming from northern sites; while toward Mount Desert, masses, some forty to fifty feet in height, are sprinkled everywhere, and, as in the case of the Dedham granite distributed to the south, invariably show northern origin. In Berkshire County, Massachusetts, these traveled rocks lie in long alignments, passing over the Lenox Hills, and extending in a generally southeasterly direction for fifteen or twenty miles, and have been filched from the Canaan and Richmond Hills across the line in New York, being of chloritic slate, with angular specimens of limestone intermixed. Some granites from Vermont, on the west of the Green Mountains, have been lifted over these barriers and transferred to the southern margins of Massachusetts; while in Vermont a bowlder weighing over 3,400 tons, and known as the Green Mountain Giant, has been drifted from the Green Mountains easterly across the valley of the Deerfield River, and planted 500 feet above that stream. In Michigan, near the Menomonee River, a field upon the northern slope of a mountain is densely covered with bowlders, so that a mile can be traversed without once touching the ground. Again, huge nuggets of copper, torn from the immense deposits of native copper at Keweenaw Point, Portage Lake, and the Ontonagon district, on the southern shore of Lake Superior, are found widely disseminated to the south of these localities in Michigan, Wisconsin, Ohio, and Minnesota, a few of which have weighed 300, 800, and one 3,000 pounds. From the sides of the White Mountains fragments of rock have been carried away, and not only conveyed southward, but, as Agassiz first pointed out, distributed northward, though only at comparatively slight distances. Long Island, that narrow fork of land running eastward and separated from the southern shore of Connecticut by the Long Island Sound, a shallow and turbulent trough, is lined, alike on its southern and northern edges, with bowlders, while its backbone of low hills is also strewed with their *débris*. They occur gathered together in groups forming topographical features in the landscape, and single ones have a weight of 2,000 tons. As regards their origin, they seem to have drifted from three localities, from the Helderberg Mountains in Central New York, from Manhattan Island, and from various points in Rhode Island, Connecticut, and Massachusetts. Those about the west end of the island may be traced to the Eastern States lying to the north, while many of the western visitors appear to have approached along the valley of the Hudson from the Highlands of New York. On Staten Island we may trace still farther the current of traveled rocks, and find both centres of emigration represented: the bowlders, now gray with lichens, half emerging from the soil, or deeply buried beneath gravel, clay, and sand, or else dispersed in colonies over the surface like pebbles on a board. Manhattan Island, along its southern shore, has been dotted with bowlders of serpentine, dragged from Hoboken, while gneiss and anthophyllite from the bed-rock of the island, limestone from Kingsbridge, and jasper from the Palisades, have likewise been sown across it, though before the restless advance of population they are fast disappearing. In Westchester, Putnam, and Orange Counties, along the banks of the Hudson, these bowlders, all indicating northern extraction, are repeatedly found, frequently at heights of 1,000 feet. These erratics have come from the Shawangunk Mountains, from Whitehall, Essex County, and from Potsdam; in short, they are witnesses of an invasion of northern material prevalent over the State. That these rocks belong northward is not difficult to prove. The reasoning is simply this: When anthophyllite, for instance, a rock unknown *in situ* to Long Island, appears there in broken and detached masses, we must conclude it belongs to the nearest deposits of the same rock, where it occurs in place, as upon Manhattan Island, and the hornblendic rock, the gneiss, trap, and iron-ore, similarly found on Long Island, we refer to those conspicuous and well-known localities in Connecticut and Rhode Island where exactly these rocks, identical in chemical composition, are quarried.

In the West the same tale is repeated. Throughout Ohio, bowlders are found which are composed of rock utterly foreign to their present surroundings; indeed, of material not known within the limits of the State. These are found perched over declivities, buried in the soil with their exposed edges showing above the surface, or else lying unencumbered in slight depressions of the ground. In Indiana, Michigan, Illinois, Wisconsin, etc., they are omnipresent, and the streets of Cincinnati are paved with the smaller specimens that crowd in exhaustless trains upon the footsteps of their larger companions. In short, we gather the irrefragable testimony, wherever we look for it, through our Northern States, through Europe and Asia, and even along the western coast of South America, that some immense force has been exerted in times past, not only to dislocate and shatter the rocky barriers which opposed it, but also to carry away the evidences of its ravages, and scatter them in its southward movement far removed from their place of origin. Further, let it be remarked that, though one class of these erratics is composed of angular and unworn stones, another yields bowlders that have undergone severe attrition, and along their larger axes are striated and polished; bearing in mind, moreover, that the direction of their transit coincides with that of the furrows and flutings in the same region, we may strictly conclude that they are a feature also of the same excessive and gigantic system of erosion.

But there is another appearance which we believe vitally connected with these, and one of a yet broader and more significant character in its general relations than they are. Over Scotland, England, Ireland, Scandinavia, Denmark, Central Europe, Switzerland, Russia, France, Spain, and in North and South America, in short, wherever we discover bowlders and grooved surfaces, we find a deep and characteristic deposit, not the work of alluvial formations or recent detritus, for it underlies these, but the record of a vast disintegration which, having planed and corroded the continents, has covered the land with sheets of gravel, clay, silt, and sand, all intermixed with stones and bowlders, variously combined in their order of succession, and ranging in depth to over 300 feet. These immense beds furnish gravel for roads and ballast, sand for glass-making and mortars, and clay for pottery; their included stones and fragments are scored and embroidered with fine and interlacing striæ, and they cover the furrowed surfaces of either hemisphere for miles.

They represent the accumulated wear and tear of continents, under some extraordinary agent of erosion and denudation, whose teeth have resistlessly ground upon the solid rocks of the hills and highlands, hiding disfigured surfaces beneath a covering of ruin. Long Island is itself but one long dirt-heap: an accumulated pile of continental *débris*, sand, clay, gravel, intermixed and overlaid by bowlders, is here gathered together into a more or less stratified state, as if, in an enormous denudation of New England, the aggregated material, scoured from its hills and valleys, had been dropped just upon their outskirts in this long detrital barrow or mound. Yet over New England this same deposit is wide-spread; it lies up and down the valleys, it forms the terraces of its rivers, the shores of its lakes, and, spread over the face of the land, is frequently the immediate soil beneath the feet. This member of the geological series, exhibiting various phases in its deposition, from the bowlder-clay to the lake-ridges, is widely distributed, indeed is universal over the Northern States, and as far south as 40° north latitude extends its sheets and centres of pebbly and sandy deposit in mounds and ridges, themselves capped with accidental bowlders, and resting upon the furrowed and seamed surfaces of the rock beneath. Sometimes they may be found collected in heaps and walls at the foot of the polished rocks, as if silent and incontrovertible witnesses of their severe and prolonged erosion.

In Scotland it is the *till*, a stiff clay interspersed with polished stones, crowding down the valleys and prevalent over the lower slopes, varying in its lithological character with the character of the surrounding rocks. Gravel and sand beds are intercalated with it and superimposed upon it. In England, Ireland, Scandinavia, Switzerland, we discover identical strata—strata which, while yielding different subdivisions, in their entire extent are the same thing, and only varied according to the local force and extent of the wearing agent, the local peculiarities of the country over which it operated, and the effect which submergence beneath the sea had in redistributing and rearranging the beds of detritus already laid down. In the sequel we shall more particularly revert to this drift-material, and indicate the part it has played in the economy of our landscape-changes; how it constitutes the terraces of our rivers and the successive beaches of our Great Lakes, and how it has choked up the former courses of rivers, forcing them to find new ones by larger and circuitous deflections. Associated with this phenomenon are the appearances known as crushed ledges and *roches moutonnées*, both of which testify to the exertion of enormous pressure—the one of pressure continuous and progressive, the other, perhaps, of percussive and intermittent attacks.

Crushed ledges designate those plicated, overthrown, or curved exposures where parallel laminæ of rocks, as talcose schist, usually vertical, are bent and fractured as if by a maul-like force battering on them from above. The strata are oftentimes tumbled over upon a cliff-side like a row of books, and rest upon heaps of fragments broken away by the strain upon the bottom layers, or crushed off from their exposed surfaces. *Roches moutonnées* are those rounded and swelling prominences, often seen in a landscape, which, when examined more closely, show themselves to be truncated masses of rock whose asperities have been smoothed away by the same agency which has planed the rocks everywhere. Only the *roches moutonnées* have been left furrowed and scratched upon one side, whence the abrading and engraving tool advanced, but upon the other unscored, and hidden beneath a tail of fragments ground from their opposite slopes. The significance of this we shall see later.

Thus, imperfectly described, we have reviewed the most prominent features of a comparatively modern period, viz., the widely-grooved and polished condition of northern rocks, especially hard-grained rocks, which retain these impressions; the occurrence of wandering bowlders, transported longer or shorter distances from their primitive sites, and the detrital matter from continental abrasion deeply burying the rocky face of the country, and in ridges, mounds, and sheets, extending east and west, and along the greater water-courses, stretching itself down into the Southern States in irregular tails and projections. We will now venture to examine the theories advanced to explain these singular phenomena, and describe that one which best accounts for these facts, with many correlated ones, offering an hypothesis which rationally secures their complete and harmonious agreement.

TEACHINGS OF A DAY.

By LOUISA S. BEVINGTON.

MORNING.

WHAT'S the text to-day for reading
  Nature and its being by?
There is effort all the morning
  Through the windy sea and sky.

All, intent in earnest grapple,
  That the All may let it be:
Force, in unity, at variance
  With its own diversity.

Force, prevailing unto action:
  Force, persistent to restrain:
In a twofold, one-souled wrestle,
  Forging Being's freedom-chain.

Frolic! say you—when the billow
  Tosses back a mane of spray?
No; but haste of earnest effort;
  Nature works in guise of play.

Till the balance shall be even
Swings the to and fro of strife;
Till an awful equilibrium
Stills it, beats the Heart of Life.

What's the text to-day for reading
Nature and its being by?
Effort, effort all the morning,
Through the sea and windy sky.

AFTERNOON.

Purple headland over yonder,
Fleecy, sun-extinguished moon,
I am here alone, and ponder
On the theme of Afternoon.

Past has made a groove for Present,
And what fits it *is*: no more.
Waves before the wind are weighty;
Strongest sea-beats shape the shore.

Just what is is just what can be,
And the Possible is free;
'Tis by being, not by effort,
That the firm cliff juts to sea.

With an uncontentious calmness
Drifts the Fact before the "Law;"
So we name the ordered sequence
We, remembering, foresaw.

And a law is mere procession
Of the forcible and fit;
Calm of uncontested Being,
And our thought that comes of it.

In the mellow shining daylight
Lies the Afternoon at ease,
Little willing ripples answer
To a drift of casual breeze.

Purple headland to the westward!
Ebbing tide and fleecy moon!
In the "line of least resistance"
Flows the life of Afternoon.

TWILIGHT.

Gray the sky, and growing dimmer,
  And the twilight lulls the sea;
Half in vagueness, half in glimmer,
  Nature shrouds her mystery.

What have all the hours been spent for?
  Why the on and on of things?
Why eternity's procession
  Of the days and evenings?

Hours of sunshine, hours of gloaming,
  Wing their unexplaining flight,
With a measured punctuation
  Of unconsciousness, at night.

Just at sunset was translucence,
  When the west was all aflame;
So I asked the sea a question,
  And an answer nearly came.

Is there nothing but Occurrence?
  Though each detail seem an Act,
Is that whole we deem so pregnant,
  But unemphasizèd Fact?

Or, when dusk is in the hollows
  Of the hill-side and the wave,
Are things just so much in earnest
  That they cannot but be grave?

Nay, the lesson of the Twilight
  Is as simple as 'tis deep;
Acquiescence, acquiescence,
  And the coming on of sleep.

MIDNIGHT.

There are sea and sky about me,
  And yet nothing sense can mark;
For a mist fills all the midnight,
  Adding blindness to its dark.

There is not the faintest echo
  From the life of yesterday:
Not the vaguest stir foretelling
  Of a morrow on the way.

'Tis negation's hour of triumph,
In the absence of the sun;
'Tis the hour of endings, finished,
Of beginnings unbegun.

Yet the voice of awful silence
Bids my waiting spirit hark;
There is action in the stillness,
There is progress in the dark.

In the drift of things and forces,
Comes the better from the worse,
Swings the whole of Nature upward,
Wakes, and thinks—a universe.

There will be *more* life to-morrow,
And of life, more life that *knows;*
Though the sum of Force be constant,
Yet the Living ever grows.

So we sing of Evolution,
And step strongly on our ways,
And we live through nights in patience,
And we learn the worth of days.

In the silence of murk midnight
Is revealed to me this thing:
Nothing hinders, all enables
Nature's vast awakening.

HISTORY OF THE DYNAMICAL THEORY OF HEAT.[1]

By PORTER POINIER.

II.

ABOUT one year after the reading of the famous paper of Rumford, in the early part of 1799, Sir Humphry Davy, then but twenty years of age, published his first scientific memoir, entitled "An Essay on Heat, Light, and the Combinations of Light." Clearly ennunciating the two systems of hypothesis previously held, he chose to follow Newton in rejecting the materiality of heat, while still clinging to the corpuscular or emission theory of light.

His position with respect to the existence of caloric he asserted in this thesis:

"The Phenomena of Repulsion are not dependent on a peculiar Elastic Fluid for their Existence, or Caloric does not exist;"

[1] Introduction to an unpublished work on Thermo-Dynamics.

proceeding to maintain it by a series of experimental *reductio ad absurdum.*

Premising that the temperature of a body could not be increased unless either its "capacity" were diminished from some cause, or heat were added to it from still other bodies *in contact*, and observing a production of heat to be consequent on friction or percussion, he enumerated the following as including all possible explanations of the phenomenon consistent with the assumption of caloric:

First, the production by the friction of a specific diminution in the "capacity" of the body, whereby caloric would be disengaged, and thus made sensible. This was the supposition which Count Rumford showed to be quite incompatible with the inexhaustibility of the supply.

Second, the liberation of caloric during some slow process of combustion accompanying the friction, the source in this case being the oxygen of the surrounding medium. This contingency was likewise anticipated by Rumford, who failed to detect any indications of such an action.

And, third, the production of some occult change in the bodies rubbed, whereby they might acquire the property of abstracting an unusual quantity of heat-substance from surrounding matter.

His argument against the existence of caloric depended, therefore, upon showing that these different suppositions were all contrary to the indications of experiment, whence the inference as to the untenability of the hypothesis itself. But, although this method of reasoning has been characterized as "somewhat confused," the following experiments upon which it was based are now considered classical.

Two parallelopipedons of ice, initially at a temperature of 29° Fahr., were fastened in an apparatus by which they might be rubbed together, and kept in a continued and violent friction with each other. They thus were almost wholly melted, the temperature of the resulting water being "ascertained to be 35°, after remaining in an atmosphere of a lower temperature for some minutes." The fusion also was observed to take place only at the rubbing surface.

From this experiment it was therefore to be inferred that the "capacity" of a body was not necessarily diminished by friction; for, according to the discoveries of Black, the melting of a quantity of ice could only take place with the absorption of a definite quantity of heat—its latent heat of fusion.

Upon the second supposition, Davy remarked:

"From this experiment it is likewise evident that the increase of temperature consequent on friction cannot arise from the decomposition of the oxygen gas in contact, for ice has no attraction for oxygen. Since the increase of temperature consequent on friction cannot arise from the diminution of capacity or oxidation of the acting bodies, the only remaining supposition is, that it arises from an absolute quantity of heat added to them, which heat must be attracted from the bodies in contact. Then friction must induce some change in bodies enabling them to attract heat from the bodies in contact."

To determine, therefore, upon this last alternative, he performed the following experiment:

A block of ice, having a small channel cut around its upper edge, was placed under the receiver of an air-pump. The channel was filled with water, and upon the block, though not in contact with the water, was also placed a clock-work so contrived that one of the external wheels of its machinery came in contact with a thin metal plate. By the friction between these surfaces a considerable amount of heat could be produced, which might be made to melt wax, tallow, or any similar substance fusible at the temperature which could be thus produced.

The receiver, previously filled with carbonic-acid gas, was next exhausted as completely as possible by the air-pump and absorption by caustic potash; upon then setting the machine to work the wax was melted rapidly, and the temperature of the whole apparatus increased by more than 1° Fahr., thus proving the excitation of heat under the conditions imposed.

Consistently with the remaining supposition—the third—it was then only to be inferred that caloric had been collected from the bodies in contact. Neglecting, however, the vapor of water which formed the rarefied atmosphere within the receiver, the only other body in contact with the apparatus was the ice. But against the assumption of this latter having furnished any heat, Davy here drew attention to the water still remaining liquid in the canal, and which presumably would have been frozen had the ice parted with any heat.

It is easy to perceive that such a course of reasoning was neither exhaustive with respect to the non-existence of caloric, nor conclusive as to the dynamic character of heat. For, had he even been successful in demolishing the doctrine of caloric, the simple refutation of one physical hypothesis could never have been construed into more than an increase in probability of all those opposed to it; and in this instance, perhaps no considerations would have been accepted as conclusive by the materialists, which, failing to experimentally establish the true nature of heat, should still have left their favorite notion open to any modification, however artificial, which might reconcile it in the least degree with facts which would be doubted and distorted in the interest of these preconceived opinions.

Heat being only a particular phase of energy, it was necessary and sufficient to show, as done by Rumford, with respect to its frictional excitation, that its production depended only on the expenditure of energy—implied in its inexhaustibility—and always in the same degree, as he proved by special determinations.[1] It was the subsequent

[1] Professors Tait and Balfour Stewart are authority for the statement that "Rumford pointed out other methods to be employed in determining the amount of heat produced by the expenditure of mechanical power, instancing particularly the agitation of water or other liquids, as in churning."—(Tait's "Historical Sketch," p. 7; Stewart's "Elementary Treatise on Heat," p. 307.)

extension of this experimental process to all modes of heat-production that constituted the great work of Joule, to be described hereafter.

But if Davy thus failed to render his experiments truly conclusive against the materiality of heat, his subsequent observations showed that individually his perceptions were most clear and definite.

Heat, ultimately, he conceived to depend upon molecular motion —calling this the repulsive motion—and to produce an effect exactly opposite to that of cohesion. The action of this motion in altering the state of aggregation, he interpreted essentially as is the custom now, and spoke of temperatures as indicating the relative quantities of repulsive motion in the same substance. He also mentioned three modes in which this motion might be increased:

"1. By the transmutation of mechanical into repulsive motion, that is, by friction or percussion. In this case the mechanical motion lost by the masses of matter in friction is the repulsive motion gained by their corpuscles.

"2. By the motion of chemical combinations of decomposition.

"3. From the communicated repulsive motion of bodies in apparent contact, that is, by conduction simply. And subsequently he generalized this statement in the dictum:[1]

"The immediate cause of the phenomena of heat, then, as Lavoisier long ago stated, is motion, and the laws of its communication are precisely the same as the laws of the communication of motion."

These essays of Rumford and Davy failed to produce, with a few rare exceptions, any perceptible effect upon the scientific opinions of their contemporaries. There would seem to have prevailed at this time a remarkable incapacity to appreciate the importance of experiments whose indications were opposed to preconceived ideas, and an antipathy to engage in unfamiliar issues; and the same distrust and indifference which so deadened the brilliance of Fresnel's immortal work in France proved quite effectual in deferring for the time the discoveries which might otherwise have followed the immediate development and experimental prosecution of this theory. Whatever interest was awakened seems to have been, for the most part, displayed in the petty, irrelevant objections, and misstatements even, brought against their methods of experiment and observed results; and the injustice of which, when not apparent, might have been easily exposed by a careful repetition or extension of these same determinations.

Dr. Thomas Young, however, in his "Lectures on Natural Philosophy," delivered at the Royal Institution, and published in 1807,[2]

[1] "Elements of Chemical Philosophy," 1812. Complete Works, vol. iv., p. 66. The laws of motion here referred to were those of Newton, especially the third, application to molecular magnitudes being included, and the modifications introduced by the new facts as to the effect of friction understood; for, "in Newton's day, and long afterward, it was supposed that work was *absolutely lost* by friction."—(Thomson and Tait, "Natural Philosophy," p. 108.)

[2] "Lectures on Natural Philosophy," vol. i., p. 653, *et seq.*

assigned to them their true significance, and, reviewing much after Bacon the existing state of experience upon the question, drew forcibly attention to the superficiality of the views of those who still adopted the hypothesis of caloric.

In 1810 Haldat performed an extended series of experiments upon the heat produced by friction between various metallic surfaces.[1] The results which he obtained were not, however, decidedly confirmatory of either supposition, but especially serve to increase our admiration for the acumen of Rumford in perceiving and stating the true law of its excitation.

The rubbing surfaces employed by him were similar in size and shape; the pressure between them was maintained nearly constant in several different experiments; but the power or energy was received in measured quantities, and from an indefinite source, namely, the pulley of a turning-lathe.

The quantities of heat developed for the same number of revolutions, or in proportionate times, were naturally, therefore, different for different metals; but as to the cause of this diversity he hazarded no positive opinion, and indeed his recorded observations do not seem susceptible of reduction to any particular theory. Had he measured the energy absorbed, or the coefficient of friction between the rubbing surfaces, he might possibly have been able to trace some relation between them and the heat produced in the operation. As it was, his observations as to difference of capacity, the influence of density, etc., were equally confused with the results, which he obtained on varying the pressure and substituting different metals; and although upon the whole his conclusions were adverse to the calorists, they were not definite enough to attract any notable attention.

In tracing thus far the inception of mechanical-heat theory, we have seen two important generalizations made: The one, fully attested by experiment, referring to the transformation of work into heat in a peculiar class of operations, and entirely independent of hypothesis, namely, that "the heat generated by friction is exactly proportional to the force with which the two surfaces are pressed together, and to the rapidity of the friction." The other, more comprehensive, including in the spirit of its enunciation thermal phenomena of every variety, and to a greater or less extent dependent on molecular and other hypothesis. These early statements are quite characteristic of, and may be used to illustrate, a subsequent division of our subject necessitated by experimental difficulties of investigation and verification.

The proposition that the entire energy existing in the universe is a magnitude as definite and unchangeable as the quantity of matter which it contains, is now considered one of the most fundamental and far-reaching in natural philosophy. The experimental evidence pos-

[1] *Journal de Physique*, vol. lxv., p. 213; *Nicholson's Journal*, vol. xxvi., p. 30.

sessed as to the fact appears for the most part in the invariability of the ratio of any dynamic magnitude of a definite kind which disappears to that of another kind which is thereby produced, and the numerical value of which, for a particular transformation, depends only on the relative magnitude of the characteristic units as compared by the same standard system of dynamic units. That is, that the conversion of one manifestation of energy into another takes place with as great certainty and absence of waste, and with the same integrity of the elementary magnitude, as the more formal conversion of foot-pounds into kilogrammetres, or British thermal units into calories. To the experimental establishment of this principle as involved in transformations between heat and work, and which is called the First Fundamental Law of Thermo-Dynamics, we shall return hereafter.

But in the transformation of heat into mechanical effect or work, an additional principle has been found to hold, respecting the transformable quantities of these two magnitudes as influenced by temperature, and which is known in like manner as the Second Fundamental Law of Thermo-Dynamics.

Experience has not as yet encountered any phenomena at variance with these fundamental laws; which furthermore agree with the strictest requirements of intuitive science, and illustrate, respectively, the axioms that nothing is by natural means creatable from nothing, and that things are equal to the same thing only which are equal to each other. In the development of these two principles, and the application to them of empirical laws with reference to the behavior of bodies under the action of heat or mechanical effect, consists the first principal division of the subject in which the results obtained are generally reliable.

But in assuming a complete analogy between molecular and mass energy, and in tracing the consequence of this assumption through the different forms of material aggregation, the conclusions reached are generally much beyond the present power of experimental science to explicitly confirm, and, although many of the results obtained in these investigations are of great probability, they yet are of inferior certainty to those properly included in the first division.

In short, although the laws which govern the relations of molar energy to heat are in the abstract positively known, yet in endeavoring to trace the distribution and precise condition of energy when it becomes absorbed within a body, or *vice versa*, the mode and minutest detail of its transformation into gross mechanical effect, the most consistent theories have heretofore depended on the hypothesis that actual or real heat is a condition of molecular kinetic energy, and that the various latent heats are due to potentialities of molecular arrangement.

The full extent to which this principle of the indestructibility of energy had previously been recognized, or involved in the dispute as to the intimate constitution of heat, may be inferred from what has been already given of the history of heat theory. But in 1822, M. A. Seguin, in a letter to Sir J. F. W. Herschel,[1] explicitly asserted it in support of the dynamical existence of heat, and in explanation of the work obtained from caloric in the steam-engine. The view of the subject he claimed to have derived, some years before, from his uncle, the celebrated Montgolfier.

Soon after he restated these considerations in a letter to Sir David Brewster,[2] wherein, by a perfectly legitimate course of reasoning, and in a very lucid manner, he showed that the accepted teachings of the calorists led to a violation of this principle of the conservation of energy. For, quoting his own language:

> "If we suppose, indeed, that at each stroke of the piston of a high-pressure steam-engine the quantity of caloric employed is represented exactly by the elevation of temperature of the water of condensation, abstracting all loss, it follows that we have lost nothing in obtaining a very great effect, and that, if it were possible (which is supposable)[3] to condense the caloric contained in a mass M into another represented by $\frac{M}{x}$, in such a manner that it may be reduced into vapor at the primitive pressure, we may, by means of a small quantity of caloric, produce an indefinite number of oscillations."

He expressly stated, therefore, that after a mechanical effect had been produced through any given thermal agency, as in a steam-engine, only that quantity of molecular motion or heat which had not been thus appropriated would remain as heat.

To him, therefore, most undeniably belongs the credit of having first publicly urged the principle of the conservation of energy against the materiality of heat, and of having considered in this connection the reverse phenomenon of the performance of work by thermal agencies.

The only indefinite or erroneous particular in his statement was that arising from the rather incautious introduction of molecular hypothesis. His leading argument was thoroughly scientific, but the oversight or neglect to refer explicitly to the disturbing effect which latent as distinguished from sensible heat might exert upon the experimental verification of his principles, served afterward as a point of attack upon the accuracy of his reasoning in general, and an opportunity, abundantly improved, to detract from his true merit as an early supporter of the mechanical theory of heat.

This criticism depends upon and applies with still greater justice

[1] Published in the *Edinburgh Philosophical Journal*, x., p. 280.

[2] Published in the *Edinburgh Journal of Science*, iii., p. 276, 1825.

[3] A particular instance of this supposition will be seen in our account of Carnot's engine.

to a principle which he subsequently enunciated in a work on railways,[1] in treating of the motive-power of heat, namely:

"La force mécanique qu'apparait pendent l'abaissement de température d'un gas, comme de tout autre corps qui se dilate, est la mesure et la représentation de cette diminution de chaleur."

If in the single term "chaleur" Seguin intended to include both sensible and latent heat, his principle was undoubtedly correct; but it is to be inferred from an indicated method of determining the relative dynamical value of heat and mechanical units,[2] that he had quite neglected to take into account any change of molecular energy other than that of sensible heat.

Nearly identical with these, though much more celebrated, were the subsequent speculations of Dr. J. R. Mayer upon this subject. In a memoir published in Liebig's *Annalen*, for May, 1842, entitled "Bemerkungen über die Kräfte der neubelebten Natur," he undertook to answer the questions: "What are we to understand by force? and how are different forces related to each other?" Toward the latter part of the disquisition he entered upon the subject of the mutual convertibility of heat and mechanical energy, considering the generation of heat by the shock or gradual stopping of a falling body, by friction, and by compression; and illustrating by the heat excited in the bearings and rubbing surfaces of water-mills and railway-trains; and by the diminution of the earth's bulk in the falling of a body to the ground.

In this he first expressly used the term equivalent, in speaking of the relation of heat, to mechanical effect; and by the same method as that employed in the deduction of Seguin's value, though with more accurate data, found the distance through which any mass of water would have to fall, in order that its temperature, by the shock of sudden stoppage, might be raised from 0° to 1° Cent., to be 365 metres.

The physical reasoning upon which he founded this determination was manifestly incomplete, if not erroneous; and, on this account, his claims as an original promoter of correct theory have been made of late the subject of considerable dispute. In view of the historical importance attaching to this point, and because an allowable explanation of the phenomenon referred to will illustrate very fully the received distinction between sensible and latent heat, we here make a slight digression to consider more particularly the thermal effect attending the compression of elastic fluids.

The term *specific heat* is ordinarily employed to designate that quantity which it is necessary to impart to unity of weight of any

[1] Entitled "Études sur l'Influence des Chemins de Fer," p. 378, *et seq.* Paris, 1838.

[2] The method indicated, with the data then at his command, for steam, gave 650 kilogrammetres as the mechanical value of an increase of temperature of 1° Cent. in one kilogramme of water.

specified substance, in order that its temperature may be raised by one degree; no discontinuous change of physical state occurring. A part of this heat, it is thought, is used in raising the temperature of the substance, and thus increasing the *real heat* or thermal contrast of the body; while the remainder is expended in producing, as it were, some change in the potentiality of intermolecular distance, or molecular motions, not indicated by the thermometer, but in general attended by the expansion or contraction of the body heated. The energy existing in this latter form, and measured in heat-units, has been called by Clausius the ergonal content of the body.

If we were, therefore, to suppose the following effects produced, in a specified manner, during the reception of a quantity of heat by any portion of an elastic fluid, namely, an increase of temperature, a change in the mean distance or motions of the molecules not causing any variation of temperature and a performance of external work by the consequent increase of volume against exterior resistance, it is evident that we could not consider any one of these effects to be the dynamical equivalent of the whole acquisition of heat. Much criticism upon the original reasoning of Mayer has therefore been called forth by this fact, that, without proving the absence of the second effect above mentioned, or in any way referring to the possibility of its disturbing influence upon the calculation, he arbitrarily assumed that the mechanical energy expended in compressing atmospheric air should be regarded as the mechanical equivalent of the heat thus rendered sensible.[1]

But though erroneous in principle, this method of determining the mechanical equivalent of heat was afterward shown by Joule to involve no sensible inaccuracy of result in the case of air and other permanent gases.[2]

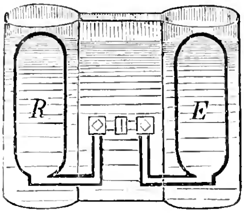
The experiment by which this conclusion was attained consisted in the repetition, with a slight but very important modification, of one originally designed by Gay-Lussac to investigate the effect upon the temperature of a gas of its free expansion into a vacuum.

The apparatus consisted of two reservoirs, *R* and *E*, which might be joined by connecting-tubes and a coupling-nut, and each closed independently by a very perfect stopcock. Into one of these

[1] Besides, the analogy which he drew between the heat produced upon the sudden stoppage of a falling body, constituting a diminution of the earth's bulk, and the forcible compression of an elastic body, is by no means an admissible one, and in seeking to justify this view by the following statement: "Yet just as little as it may be inferred from the relations of falling force to motion, that falling force is motion, so little is the conclusion admissible in the case of heat" (that heat is motion). "We much prefer to adopt the opposite conclusion, that in order to become heat, the motion—either simple or vibratory, as light, radiant heat, etc.—must cease to exist as motion"—he succeeded only in rendering the subject more indefinite and confused.

[2] "On the Changes of Temperature produced by the Rarefaction and Condensation of Air."—(*Philosophical Magazine*, 1845, (3) xxxi., p. 376.)

dry atmospheric air was forced until a tension of about twenty-two atmospheres at the ordinary temperature of the room was attained. The other was exhausted by an air-pump.



Being then coupled together, they were immersed in a tank containing about sixteen and a half pounds of water, which was stirred, and its temperature taken on a very sensible thermometer, indicating approximately thousandths of a degree. The stopcocks were next opened and the air allowed to rush from one reservoir to the other until the tensions were more nearly or quite equal in both. Lastly, the water was again stirred and its temperature carefully noted. A correction was obtained after each experiment, by noting the increase of temperature caused by an equal amount of stirring, uninfluenced by any possible effects of the expansion.

Five experiments upon the thermal effect thus attending the expansion of atmospheric air showed a mean increase in the temperature of the water of 0.0074°, while the correction to be applied amounted to 0.0068, leaving a difference quite within the limits of observation by this method. Joule, therefore, concluded that "*no change of temperature occurs when air is allowed to expand in such a manner as not to develop mechanical power.*"

If this result or property of atmospheric air had been known to Mayer, and construed by him to imply the total absence of a transformable, internal store of potential energy in gaseous substance, so that the energy embodying the condition variously styled its pure, real, actual, or sensible heat could only be affected by some external agency, mechanical or thermal, and if the effect upon a thermometer, produced by this condition, had been also known to vary directly with the whole quantity of energy comprising it, the method which he indicated would have led to an admissible result.

But, in reality, Gay-Lussac, from his original experiments, had not come to any very definite conclusions on this point. The temperature of each receiver had been found by him to change; but not using an equivalent device to that of the submerging tank of water, he had not been able to determine, on the whole, whether heat had been lost, or gained, in the expansion. When, therefore, Mayer, in 1849, defended his claims by a reference to these first experiments on this point, the answer was available to Joule that, prior to his own researches, the all-important principle assumed had not been recognized in science; and that the results obtained by Gay-Lussac tended only to render the question still more doubtful.

STYLE.

By T. H. WRIGHT.

A RECENT historian of Rome, toward the close of his famous attempt to undeceive the world at large with respect to the genius of Cicero, sums up his argument in the following words: "Ciceronianism is a problem which, in fact, cannot be properly solved, but can only be resolved into that greater mystery of human nature—language, and the effect of language on the mind."

These words are suggestive—suggestive, too, of a wider question than at first sight appears. That men are influenced by language at least as much as by ideas; that power of expression is intimately associated with mental grasp generally; even that a fascination is exercised by style to which nothing equivalent is found in the accompanying thought—these are acknowledged truths, readily granted. But it is a most singular thing that they are so readily granted; it is singular that the question is not oftener asked, "Why is this so?"

How is it that language, which is but the vehicle of thought, comes to have a force which is not the mere weight of that which it carries? Even where this is not the case, where there is an equivalence of value in both style and ideas, great conceptions being nobly expressed, how is it that the matter and the form seem to have independent claims upon the attention? In a word, what is that in language which is not mere *expressiveness* of the obvious intentions of the writer, but is yet a merit?

At first sight there appears to be a simple answer to the question. Any of the numerous treatises on style or rhetoric abound with rules for the embellishment of discourse: the reader learns the importance of a choice of fitting words, of the judicious use of figures of speech, of the effect of melodious sentences and suitable cadences; he is instructed in the manipulation of complex constructions, and discovers the force of the gradation, the antithesis and the climax; in short, he is easily led to the conclusion that, besides *expressiveness*, language may have the merit of *beauty*.

That this distinction is a superficial one has been shown with great ability in an article by Mr. Herbert Spencer, on the "Philosophy of Style."[1] He there traces all excellence of composition to two principles—Economy of the Attention, and Economy of the Sensibility of the recipient. Assuming that a reader can have at his command only a definite amount of power of attention, it is clear that whatever part of this is employed on the form of a composition must be subtracted, and leave so much the less to be occupied in the matter. In its popular aspect this is a truth familiar to all. If any author is said

[1] Published in separate form, with flexible covers, by D. Appleton & Co.

to have an obscure style, it is meant that his form obstructs his matter; that it absorbs an inordinate amount of the reader's attention. If he is tedious, it is because his language, by its monotony or redundancy, exhausts our energies, and leaves us correspondingly deficient in the mental vigor to be devoted to what he has to say.

But Mr. Spencer pushes his theory yet further. He shows, with great ingenuity, how various ornaments of style, at first sight most remote from mere utility, are in reality but devices of language which subserve the same purpose of economizing attention. Thus the canon which prefers words of Saxon to words of Latin origin, is justified by the greater familiarity of the former, recalling the associations of childhood, and their comparative brevity, which adds to their force what it diminishes from the effort required to recognize them. On the other hand, the occasional effect of polysyllabic words is attributed to their associated significance; for the effort involved in deciphering or using them, by hinting at a corresponding weightiness in the things implied, gives a force to an epithet which may do for a sentence. The same principle which explains the rules for choice of words is also found adequate to the solution of the reasons why some one order of words is more effective than another; why certain sequences of sentences are better than others; what are the respective merits of the direct and indirect style, and so forth. Then follows an analysis of the various figures of speech—metaphor, simile, and the like—in which their amenableness to the same law is established; and, finally, the applicability of the theory, even to the complex imagery of the poet, is exhibited in a passage which it would be an injustice to the writer not to quote at length:

"Passing on to a more complex application of the doctrine with which we set out, it must now be remarked that not only in the structure of sentences, and the use of figures of speech, may economy of the recipient's mental energy be assigned as the cause of force; but that in the choice and arrangement of the minor images, out of which some large thought is to be built up, we may trace the same condition to effect. To select from the sentiment, scene, or event described, those typical elements which carry many others along with them; and so, by saying a few things, but suggesting many, to abridge the description, is the secret of producing a vivid impression. An extract from Tennyson's 'Mariana' will well illustrate this:

'All day within the dreamy house
The door upon the hinges creaked,
The blue-fly sung i' the pane, the mouse
Behind the mouldering wainscot shrieked,
Or from the crevice peered about.'

The several circumstances here specified bring with them many appropriate associations. Our attention is rarely drawn by the buzzing of a fly in the window, save when everything is still. While the inmates are moving about the house, mice usually keep silence; and it is only when extreme quietness reigns that they peep from their retreats. Hence, each of the facts mentioned, presupposing numerous others, calls up these with more or less distinctness, and revives the feeling of dull solitude with which they are connected in our experience. Were all these facts detailed, instead of suggested, the attention would be so frittered away that little impression of dreariness would be produced. Similarly in other cases. Whatever the nature of the thought to be conveyed, this skillful selection of a few particulars which imply the rest is the key to success. In the choice of competent ideas, as in the choice of expressions, the aim must be to convey the greatest quantity of thoughts with the smallest quantity of words." [1]

But Mr. Spencer does not rest content with deducing what may be called the adventitious charms of poetry from this principle; he even thinks that its distinctive characteristic—the restrictions of metre—may be explained by the same law. "The pleasure," he says, "which its measured movement gives us is ascribable to the comparative ease with which words metrically arranged can be recognized." [2] Most people will be startled at the first sight of this bold dictum, but Mr. Spencer is not the man to shrink from the logical consequences of his principles, and they lead to more than this.

Any one who has attentively read the article, or even the brief *résumé* of it just given, will have seen that the theory furnishes a canon for determining, with some degree of certainty, which of two styles is the better. To quote again: "The relative goodness of any two modes of expressing an idea may be determined by observing which requires the shortest process of thought for its comprehension." [3]

Clearly, then, there must, in every case, be some form of expression which is absolutely the best; in other words, there is such a thing as an ideal style. Mr. Spencer accepts the conclusion, but at the same time reminds us that style must vary with its subject-matter.

"The perfect writer will express himself as Junius, when in the Junius frame of mind; when he feels as Lamb felt, will use a like familiar speech; and will fall into the ruggedness of Carlyle when in a Carlylean mood." [4]

The reservation is a proper one, and with it the argument seems unimpeachable. Yet when Mr. Spencer throws the conclusion into the form of an epigram, and tells us that "to have a specific style is to be poor in speech," [5] he makes the utmost possible demand upon our loyalty to exact reasoning. Like Adeimantus in "The Republic," we are "confounded by this novel kind of draughtsplaying, played with words for counters."

But if the foregoing theory be carefully reviewed, it will be seen that throughout it the treatment is what may be described as objective rather than subjective. Or, to avoid words in which there is a degree of ambiguity, the definite product language is more or less isolated

[1] "Philosophy of Style," p. 34. [2] Ibid., p. 39. [3] Ibid., p. 33.
[4] Ibid., p. 48. [5] Ibid., p. 47.

from the agency using it, and viewed more in relation to the reader's than the writer's mind. But there is another aspect of the relation, which cannot be left out without producing a result which must be one-sided, and may be inaccurate. The following pages will be an attempt to supply this omission by a consideration of the nature of the various devices of language, regarded as the outcome of the mind that employs them.

That "to have a specific style is to be poor in speech" has not been implied in the judgments which the world has from time to time passed upon its greatest writers. Perhaps it would be nearer the truth to say that much in proportion as an author has reached a high eminence in his art, there has been found in his productions a corresponding tendency to an individuality of expression. Is it not a common complaint against inferior artists, whether in prose or verse, in painting or music, that their compositions lack character and originality? Uniformity is the distinguishing feature of mediocrity, while the work of genius is at once recognized and attributed to the origin whose impress it bears. And a little reflection will show that this is exactly what is meant by "style." Various tricks of voice, gesture, and dress, are associated by every one with his friends, glimpses of the hidden self being granted in such half-unnoticed revelations. The chief value, indeed, of such peculiarities rests in the fact that they are commonly unknown to the man himself. For all of us, even the most sincere, are to a certain extent actors in our intercourse with others, and play a part that has been self-assigned, often without due pondering of the player's power. Nature, however, peeps out in countless little traits of character, which find their expression in language, habit, and even in movements. By what subtile union such tricks of manner are linked with what Dr. Johnson has called "the anfractuosities of the human mind," is a curious and intricate question, but no one will doubt the fact of the connection. "That's father!" cries the child as she hears the well-known foot-fall in the hall; "How like the man!" we exclaim, when some characteristic remark is reported to us. Spite of the progress in complexity from a sound to a sentiment, each obeys the same law; and the connection between the foot-fall and the foot, between the speech and the mind that conceived it, is one and the same.

Let us follow out the thought a little further. Not only, to put the fact in its popular aspect, has every one his peculiarities; but there are degrees of peculiarity accompanying degrees of individuality; as a man deviates in *character* from the type ordinarily met with, so are his *habits* singular to himself, till a point is reached where the personality is remarkable, and the behavior eccentric. Where such manners are perfectly unaffected they are a reflection of a self that stands alone among many, so that the common dictum, that genius is eccentric, has a philosophical foundation. There is no need to linger on the numerous and tolerably obvious reservations which make it impossible to convert the proposition—in other words, to infer unusual power from singularity; the broad fact remains that where there is that marked originality called genius, it is an originality not of thought, emotion, or pursuits, but of the man.

The application of this to literary style is easy, and will be found to lead to some interesting results.

In its powers of direct expression, language is tolerably efficient, and were there nothing but facts, considered objectively, to be conveyed, even a simpler vehicle would suffice. Swift, in one of the most humorous passages of "Gulliver's Travels," describes a set of philosophers, who, disdaining language as the ordinary means of expressing their thoughts, preferred to carry with them a pack of the things most commonly referred to in every-day parlance, by the dexterous manipulation of which they contrived to carry on long conversations. Now this represents, with the necessary freedom of caricature, a real truth with regard to a certain class of discourse. In any written composition, the less the author's personality is involved in the matter treated, the simpler the language which suffices. The extreme form of this truth is found in the case of algebra, where the discourse is, so to speak, perfectly dispassionate, and the symbolism perfectly adequate. Similarly, the language employed in mathematical proof is found adequate in proportion as the statements are purely objective. As we ascend in the scale of literary composition the author's personality creeps in, and brings with it a corresponding complexity of language, not merely the complexity of structure of sentences, but of choice of words, use of figures of speech, and all the refinements of elaborate writing. It is true that much more than this has to be taken into consideration; the subjects themselves are infinitely more complex as the scale is ascended, the distinctions are more delicate, the contrasts present more sides to view, the gradations are subtiler. But is not this a corollary from the main principle? Is it not because we are then dealing either with facts of our own or the general consciousness; with ideas, emotions, desires, and so forth; or at any rate with external facts looked at from the point of view of an interested and questioning observer, that there is this increase in complexity, or, in other words, decrease in adequacy of language?

But this idea admits of yet further development. The facts perfectly expressed in algebraical symbols receive a nearly perfect expression in mathematical language. The terminology of science is found very tolerably sufficient, if strictly adhered to, and mostly where expository and descriptive. In history and biography what we may call the subjective element is strong, and there we find all the refinements of composition. These express, not only facts and aspects of facts, not only are there delicate implications of expression, embodied in all the recognized figures of rhetoric, the trope, the simile, and the metaphor; but there are the glimpses at the very self of the author which lurks in unconscious tricks of diction and turns of thought, and emerges in epithets, in repetitions, and in phrases. In poetry the author reigns supreme, and there too the imperfection of language is most manifest. In a very fine passage every word is charged with meaning and riveted to its place; in fact, the vehicle is strained to its utmost to bear the load imposed upon it. Hence Coleridge's well-known definition of poetry as "the best words in the best order." Meanwhile the personality of the poet pervades every line of every poem, a hardly recognized but unfailing presence. He colors each picture, and is a spectator at every scene; he is beside Ulysses in the island of Calypso; with him he witnesses the death of Argus and the insolence of the suitors; he shares the recognition of Penelope and the welcome to home; and when dire retribution seizes the usurpers he looks upon their fall.

Not that this personality is directly obtruded upon the hearer's notice; in the instance of Homer, it is markedly withdrawn, the characters speak of themselves, the descriptions are meant to serve no moral end. But what is never brought before us as an avowed element in the composition is everywhere present in the form of the narrative—we never hear the accents of the voice, though we are always listening to its tones. Take as an illustration of this a passage of pure description from the "Odyssey:"

Πῦρ μὲν ἐπ' ἐσχαρόφιν μέγα καίετο, τηλόθι δ' ὀδμὴ
κέδρου τ' εὐκεάτοιο θύου τ' ἀνὰ νῆσον ὀδώδει
δαιομένων· ἡ δ' ἔνδον ἀοιδιάουσ' ὀπὶ καλῇ,
ἱστὸν ἐποιχομένη χρυσείῃ κερκίδ' ὕφαινεν.
ὕλη δὲ σπέος ἀμφι πεφύκει τηλεθόωσα,
κλήθρη τ' αἴγειρός τε καὶ εὐώδης κυπάρισσος.
ἔνθα δέ τ' ὄρνιθες τανυσίπτεροι εὐνάζοντο,
σκῶπές τ' ἴρηκές τε τανύγλωσσοί τε κορῶναι
εἰνάλιαι, τῇσίντε θαλάσσια ἔργα μέμηλεν.
ἡ δ' αὐτοῦ τετάνυστο περὶ σπείους γλαφυροῖο
ἡμερὶς ἡβώωσα, τεθήλει δὲ σταφυλῇσιν·
κρῆναι δ' ἑξείης πίσυρες ῥέον ὕδατι λευκῷ,
πλησίαι ἀλλήλων τετραμμέναι ἄλλυδις ἄλλη.
ἀμφὶ δὲ λειμῶνες μαλακοὶ ἴου ἠδὲ σελίνου
θήλεον· ἔνθα κ' ἔπειτα καὶ ἀθάνατός περ ἐπελθὼν
θηήσαιτο ἰδὼν καὶ τερφθείη φρεσὶν ᾗσιν.

Odyssey, v., 59–74.

(A large fire was burning on the hearth, and at a distance the smell of well-cleft cedar, and of frankincense, that was burning, shed odor through the island; but she within was singing with a beautiful voice, and going over the web, wove with a golden shuttle. But a flourishing wood sprung up around the grot, alder and poplar, and sweet-smelling cypress. There also birds with spreading wings slept, owls and hawks, and wide-tongued crows of the ocean, to which maritime employments are a care. There a vine in its prime was spread about the hollow grot, and it flourished with clusters. But four fountains flowed in succession with white water, turned near one another each in different ways; but around there flourished soft meadows of violets and of parsley. There indeed even an Immortal coming would admire it when he beheld, and would be delighted in his mind.—*Buckley's Translation.*)

An analysis of this passage which points out its beauties will be found also to draw attention precisely to those parts where the author's presence is latent. The smell of the cedar, and the voice of the divine songstress accompanying the music of her loom, are, by the epithets "fragrant" and "sweet," made part of the real or imagined experience of the poet; while the word *ἐποιχομένη* suggests, and just suggests, glimpses that he catches of her form as she moves at her work within the cave. Then he describes the wood that shades her abode, implying, by an epithet, how that too appeals to another sense, joining with the incense that burns close by in a mixture of pleasant smells. Another feature is introduced: there are birds harboring in the branches, and the word *εὐνάζοντο* that describes this, by an implied comparison with the sleeping-chambers of man, shows a sort of tender way of looking at Nature. It is more than if it were merely said, "There were birds in the branches." Again, the allusion to the sea in the words *τῇσίντε θαλάσσια ἔργα μέμηλεν* is a direct reflection of the poet's, in no way forming part of a description merely meant to call up an actual scene, instead of a particular way of looking at a scene. The same is true of the words that describe the vine, bending with its burden of ripe clusters, of the labyrinth of streams, and the patches of violet and parsley round them; the accompanying adjectives draw attention to beauties the poet has noticed, and wishes us to notice as well. There is hardly need to point out how the words with which the whole concludes are but an exclamation of wonder and admiration on the part of the poet at the scene he has called up.

But this is not all, for besides the selection of these various elements there is the mode of their combination into a definite picture, the order in which the images follow one another, and the gradation and transition of ideas which are all part of the art, that is, of the mind—of the *self*—of the author. At a distance the senses of sight and smell are first caught by the glimmer of the fire and the fragrance of what is burning in it; as Hermes approaches he hears the sound of the goddess singing at her work; coming still closer, he has leisure to mark the minute details of the scene—the cavern, the grove, and the vine; while the words *ἀθάνατός περ* in the concluding lines leave him in amazement at the beauty of the whole.

Now, this may sound like hypercriticism, and it would be hypercriticism if it were meant that all these points were before the mind of the poet, forming part of an intentional study of effect. On the contrary, the implication is the direct reverse. It is because Homer was such or such a man, because he had been in the habit of regarding what he saw after a certain fashion of his own, that when he set himself to compose poetry he composed it as he did. Hence there is a deep meaning in the saying of Milton, that he who would write good poetry must make his life a poem. It is by virtue of a thousand minute traits of character, the gradual deposit of life's experiences, that any one speaks, writes, even walks and moves, as we see him do. For there must be some reason why, if two men set about describing a scene, or giving even a plain, unvarnished account of some event, the mode of their narration differs—differs, too, in such a way that each can be ascribed to its author, as we say, by internal evidence, that is, by its style. While, then, no better explanation appears, that theory of style may perhaps be provisionally accepted which identifies it with character—with unconscious revelations of the hidden self.

This conclusion needs a little further elaboration before it is compared with that view of what is called the philosophy of style, which resolves all the devices of composition into schemes for economizing the reader's attention. It is necessary to point out, and this may be done briefly, how not only is style generally the impress of the author's self, but that there is a correspondence between the distinctive features of any particular passage and the points at which, in the manner just indicated, the writer's personality glides into the discourse. This is not difficult, if what has been already said be accepted. What, indeed, is meant by saying that an author is best where his writing is most natural?

Is it not implied that the happiest touches are those which are original—that those phrases and expressions are most welcome to the reader which set the matter they convey in a new light—and that the light in which the writer himself sees it? If the foregoing passage from the "Odyssey" be reviewed, it will be found that its beauties are coincident with the parts where the presence of the poet seems to be hinted, and this is equally true, though not equally discernible, in all writing that is at all elaborate.

Now, how does all this square with the dictum that "to have a specific style is to be poor in speech?" It will not at first sight appear so very incompatible. In a certain sense, style at all owes its existence to the imperfection of the vehicle of thought. Were language a perfectly adequate means of embodying ideas, what is now to be looked for in the *mode* of statement would be found directly declared in the statement itself. For the countless devices of language, the gestures and tones of discourse, the thousand rhetorical figures of written composition, are really one and all simple propositions not capable of exact expression in the body of the narrative. They are the lights and shades of the picture, or perhaps rather the finer touches, which are to tickle the imagination of the reader with suggested beauties. And it is exactly in these refinements of expression that the deepest meaning of any author, in other words, his *self*, resides. There is something pathetic in the reflection that we walk this world half hidden from one another, a constant struggle going on to make known the thoughts, beliefs, and aspirations of the real but partly-imprisoned being, which never can be known exactly as they are to any but the mind that conceives them. Like savages, we speak mostly by signs, which serve us well enough, but leave much uncommunicated. It is well, however, that this imperfection is an imperfection that produces beauty; that the grating of the machine is not harsh, but musical. Mr. Herbert Spencer is successful in showing that the various devices of language do serve to the economy of the reader's attention, and that beauties of style are beauties partly because they effect this end. But he has not raised a question which seems closely akin to the subject. Why is it needful to have recourse to these expedients at all, and why is there an infinite variety in every man's use of them? The answer to these questions seems to give an insight into a higher law, to which Mr. Spencer's principle stands rather as an empirical generalization. It is this: that each man's inmost nature is a secret to all but himself—and that a secret which in no two cases is the same. Every attempt to communicate it partly fails, and so language is full of compromises and expedients; each nature to be revealed is different, and so there is a countless variety of styles. This, then, is not due to poverty of speech; rather it is due to multiplicity of individualities, each speaking its own language and telling its own tale.

The ideal style, then, is for an ideal being, but for an ideal being who is to be without personality. The perfect writer may write, now like Junius, now like Lamb, now like Carlyle, but like himself he can never write. He cannot, as we say, *express himself*. A significant phrase, for after all it is when a man, as far as he can, expresses *himself*, that his communication is most worth having. It is the one thing of which he certainly knows something, where he can indeed speak with authority. It is not so much what a man knows as how he knows it, not so much the extent as the quality of his information, that gains him a right to be heard. Originality is far oftener originality of expression than idea, a fresh aspect of something old, not a discovery of something new. And so there starts up here an answer to the difficulties encountered at the outset, "Why men are influenced by language at least as much as by ideas;" and "Why power of expression is intimately associated with mental grasp generally." Partly, no doubt, because in language resides the personality of the speaker or writer, and men are influenced by personality—but far more for another reason. The highest form of ability is something which pervades the whole being; it is not restricted to an intellect preternaturally acute, to vividness of imagination, or fineness of feeling; but it is the manifestation of a nature—of a *self*, which is really great. And it has been seen that it is in expression, or style, that the self of the author is to be sought. That, then, is a true instinct which so intimately associates power of expression with power of character generally. Of this power, too, the distinguishing feature is its individuality. Just as in animal life the ascent of the scale of creation is a process of differentiation of functions; just as a higher form of life is marked off from a lower form by greater specialty of shape, by powers more accurately defined, by habits more peculiarly its own: so in the comparison of man with man, something similar to this law is traceable, pointing out that the superiority of genius in degree is mainly a consequence of its difference in kind.

Thus Nature seems to speak in a continued protest against uniformity, by a thousand analogies insisting upon the supreme importance of the individual. And the critical verdict which pronounces that writing best which is the most natural can be affiliated to as wide a law as this. Whether or not it be thought that each man is put into the world the possessor of some particular truth, which his acts or words can set before his fellow-creatures, it is at any rate clear that the inevitable specialty of each man's experiences must present things to him in an aspect which can be exactly the same for no other. There are no real *doubles* in the world, no such thing as identity in constitution and circumstances. While, then, this is so, there is a significance in style, a value in the unconscious self-revelations of traits of personality. However a man may fail of the object he sets before him in what he does or says, yet if there has been in him that conscientious fidelity to his purpose, which is but an attempt to express *himself*, his work will not have been wasted, though its direct worth be unimportant.—*Macmillan's Magazine.*

OUR SIX-FOOTED RIVALS.

II.

EVEN more wonderful than the mere intelligence of the ant is its power of organization—the point, probably, in which it approaches most closely to man. Suppose that ants, instead of forming nations, lived like most creatures, merely in pairs, each endeavoring to rear a young brood, who, when mature, would enter upon a similarly isolated career. Let them be as brave, as intelligent, and as strong, as they now are, still how humble and insecure would be their position! Against the attacks of the giant spiders, centipedes, hornets, and wasps of warm climates, they could make no effectual resistance. Prey, which in their present condition they easily secure, would escape them, or would scarcely even notice their puny efforts. In short, there is every reason to believe that many of their species would become extinct, and that the remainder would live, so to speak, mainly on sufferance, playing no appreciable part in the economy of the globe. Turning from this hypothetical survey of the ant as an individual, unorganized being to its actual condition, we see the most striking contrast. Mr. Belt gives the following graphic account of the excitement caused by a marching column of *Ecitons* in the primeval forests of Nicaragua: "My attention was generally first called to them by the twittering of some small birds belonging to different species. On approaching, a dense body of the ants, three or four yards wide, and so numerous as to blacken the ground, would be seen moving rapidly in one direction, examining every cranny and underneath every fallen leaf. On the flanks, and in advance of the main body, smaller columns would be pushed out. These smaller columns would generally first flush the cockroaches, grasshoppers, and spiders. The pursued insects would rapidly make off, but many, in their confusion and terror, would bound right into the midst of the main body of ants. At first, the grasshopper, when it found itself in the midst of its enemies, would give vigorous leaps, with perhaps two or three of the ants clinging to its legs. Then it would stop a moment to rest, and that moment would be fatal, for the tiny foes would swarm over the prey, and, after a few more ineffectual struggles, it would succumb to its fate, and soon be bitten to pieces and carried off to the rear. The greatest catch of the ants was, however, when they got among some fallen brushwood. The cockroaches, spiders, and other insects, instead of running right away, would ascend the fallen branches and remain there, while the host of ants were occupying all the ground beneath. By-and-by, up would come some of the ants, following every branch, and driving before them their prey to the ends of the small twigs, where nothing remained for them but to leap, and they would alight in the very throng of their foes, with the result of being certainly caught and pulled to pieces.

"The moving columns of *Ecitons* are composed almost entirely of workers of different sizes, but, at intervals of two or three yards, there are larger and lighter-colored individuals that often stop and sometimes run a little backward, stopping and touching some of the ants with their antennæ. They look like officers giving orders and directing the march of the column.

"The ants send off exploring-parties up the trees, which hunt for nests of wasps, bees, and probably birds. If they find any, they soon communicate the intelligence to the army below, and a column is sent up immediately to take possession of the prize. I have seen them pulling out the larvæ and pupæ from the cells of a large wasps' nest, while the wasps hovered about, powerless, before the multitude of the invaders, to render any protection to their young."

Still more formidable are the "driver-ants" of tropical Africa, so called because, on their approach, even the lion, the elephant, and the huge python, at once betake themselves to flight.

Nor are the purely vegetarian ants of less importance in the economy of the countries they inhabit. They decide, in a manner, what trees shall grow and what shall be exterminated, and it is only such as are comparatively distasteful to them that escape. In Nicaragua, they render the acclimatization of any foreign tree or vegetable a task of great difficulty. Mr. Belt was often told, on asking the reason why no fruit-trees were grown at certain places: "It is of no use planting them; the ants eat them up." These ants climb up the trees, when "each one, stationing itself on the edge of a leaf, commences to make a circular cut from the edge with its scissor-like jaws, its hinder feet being the centre on which it turns. When the piece is nearly cut off, it is still stationed upon it, and it looks as though it would fall to the ground with it; but, on being finally detached, the ant is generally found to have hold of the leaf with one foot, and, soon righting itself and arranging its burden to its satisfaction, it sets off at once on its return."

An observer, standing near the ant-hills, "sees from every point of the compass ant-paths leading to them, all thronged with the busy workers carrying their leafy burdens. As far as the eye can distinguish their tiny forms, troops upon troops of leaves are moving up toward the central point and disappearing down the numerous tunneled passages. The ceaseless toiling hosts impress one with their power, and one asks, 'What forests can stand before such invaders?'" Concerning the use to which the ant-leaves are put, some difference of opinion prevails; that they do not directly serve as food is admitted. Mr. Bates, from observations made in Brazil, concludes that "the leaves are used to thatch the domes which cover the entrances to their subterranean dwellings, thereby protecting from the deluging rains the young brood in the nests beneath." Mr. Belt, who has carefully examined the habits of an allied species in Nicaragua, believes that the real use they make of them is as a manure, on which grows a minute species of fungus on which they feed—that they are, in reality, mushroom growers and eaters. The reasons for this view are given in detail in Mr. Belt's work, and appear very satisfactory. But Mr. Bates's view may be correct also. In short, save man alone, there is no creature which can effect such wide-spread and profound alterations in the condition of a country as the tiny ant. It has been indeed mentioned in the *Quarterly Journal of Science* that the pig, the goat, and the rabbit, have succeeded in extirpating the natural flora, and consequently, to a great extent, the fauna, of certain islands, such as St. Helena. Yet this takes place only in countries where there are no carnivorous beasts, birds, and reptiles, to keep them in check. But in every warm and fruitful climate the ant is king. This power, we perceive, is not due to mere numbers; it is, in great part, the result of organization. Other species of insects are perhaps even more numerous, and, individually considered, as capable of destructive action;

but locusts, potato-beetles, mosquitoes, noisome as they may be considered, are, in comparison with ants, what a promiscuous mob is in comparison with a well-trained and organized army. Each ant, like an experienced soldier, knows—whether rationally or instinctively it matters not—that it will be systematically supported by its comrades. What would be the prospects of agriculture in Western Asia, in Northern Africa, or in the Western States of the American Union, if the locusts, when engaged in desolating a field, were to attack, *en masse*, any man or bird who should interfere with them? But, on the contrary, they allow themselves to be slaughtered in detail, each indifferent to the fate of his neighbor.

Ants evince that close mutual sympathy which, to an equal extent, can be traced probably in man alone, and which has, in both these cases, proved one of the primary factors in the development of civilization. Had man been devoid of this impulse, he would have remained a mere wandering savage—perhaps a mere anthropoid, occurring as a rare species in equatorial districts. Without a similar impulse, the *Ecitons* would have ranked among the many solitary species of *Hymenoptera*. Of the mutual helpfulness of these same *Ecitons*, Mr. Belt gives us some most interesting cases which came under his own observation: "One day, when watching a small column of these ants (*Eciton hamata*), I placed a little stone on one of them to secure it. The next that approached, as soon as it discovered its situation, ran backward in an agitated manner, and soon communicated the intelligence to the others. They rushed to the rescue: some bit at the stone and tried to move it; others seized the prisoner by the legs, and tugged with such force that I thought the legs would be pulled off; but they persevered until they got the captive free. I next covered one up with a piece of clay, leaving only the ends of the antennæ projecting. It was soon discovered by its fellows, who set to work immediately, and, by biting off pieces of the clay, soon liberated it. Another time I found a very few of them passing along at intervals. I confined one of these under a little piece of clay, with his head projecting. Several ants passed it, but at last one discovered it and tried to pull it up, but it could not. It immediately set off at a great rate, and I thought it had deserted its comrade; but it had only gone for assistance, for in a short time about a dozen ants came hurrying up, evidently fully informed of the circumstances of the case, for they made directly for their imprisoned comrade, and soon set him free. The excitement and ardor with which they carried on their exertions for the rescue could not have been greater if they had been human beings."

Such cases as these are of the greater moment because many other social and semi-social animals treat an unfortunate companion in a very different manner. It is on record that a rook, which had got entangled among the twigs of a tree, was pecked and buffeted to death by its neighbors, despite the efforts of its mate for its protection.

Facts are not wanting which show that the social organization of ants takes cognizance of sanitary matters. In Australia they have been known to bury their dead, not without some degree of formality[1] according to their caste. In experimental formicaries in this country, ants have been observed to throw the bodies of their dead companions into the water surrounding their dwellings. In the nests of almost all species great care is taken to preserve cleanliness. The agricultural ant of Texas removes any offensive matter placed near its city, and will even take the trouble to carry away the droppings of cattle that have fallen on its cleared ground. Any dung-rolling beetle which brings its ball of ordure within these sacred precincts is at once attacked and put to death, and the nuisance is quickly cut to pieces and carried to a distance.

Nor are laws on other matters wanting. Ants who have, from some unknown cause, refused to work have been observed to be put to death. Among the agricultural ants, prisoners have been known to be brought in by a fellow-citizen and handed over in a very rough manner to the guards, who are always on duty on the level ground before the city, and who carry off the offender into the underground passages. What is his after-fate is not known. It is almost needless to point out that even the faintest rudiment of law proves the existence of some notions of right and wrong, as well as of a power of communication which must go into minute details.

We have now to deal with the great question whether the civilization of ants, like that of man, has been gradually and slowly developed by the accumulation of experience, or whether—as the believers in the fixity of habits and instincts still contend—it is primordial, coexistent with the species in all the details which we now observe. Direct historical evidence is here yet more difficult to obtain than as concerns animal structure. We smile, with just reason, at the French *savants* of the Egyptian Expedition, who imagined that, by the study of the animal-mummies there preserved, they might gain some light on, or rather find some argument *against*, the mutation of species. At the same time, we readily admit that, could we find a complete series of skeletons, anatomical preparations, or even photographs of the best-known animals, made at intervals of a century, and extending backward for say a hundred thousand years, the doctrine of evolution would be brought to a crucial test. But, concerning the former habits and instincts of animals, correct information is far more difficult to obtain. The "stone-book" is silent or oracularly vague. Even if we had written documents left us by some naturalist of the Miocene ages—if we can suppose such a being to have existed—what security should we have for the accuracy and the completeness of his researches?

To meet this difficulty an attempt, remarkable for its subtile in-

[1] *Journal of Linnæan Society*, vol. v., p. 217.

genuity, has been made by Prof. Heer. He points out that, according to the reckoning of the most discreet geologists, at least a thousand centuries must have elapsed since Britain was severed from the Continent of Europe. For this long stretch of time, therefore, British animals must have been cut off from their representatives in France, Belgium, and Switzerland. If, then, the habits of a certain slave-holding ant (*Formica sanguinea*) in England are found identical, as he maintains, with the habits of the same species in Switzerland, there is a strong presumption that its economy has undergone no change for the last hundred thousand years. To this argument, we must reply that the isolation between British and Continental species of insects is by no means so complete as is here assumed. Winged ants travel very considerable distances, and, if our memory does not deceive us, have been met with out at sea. That a part of a swarm should be blown over from the French coast to England, or *vice versa*, is by no means improbable. And it is well known that if a party of working-ants fall in with an impregnated female of their own species, they immediately lead her to their nest and install her in a royal apartment. That there may have been within the last ten thousand—or even one thousand—years direct intercommunication of this kind between the slave-making ants of England and those of Switzerland, seems to us fully more probable than the contrary supposition.

Again, we may ask whether the conditions under which ants would be respectively placed in Switzerland and in England are not so closely analogous that their social development must proceed on parallel lines? In both they would encounter nearly the same climate, the same food, and the same enemies. Surely, therefore, a close correspondence in habits is no decisive proof of their immobility. But, after all, is there such an absolute accord between the habits of the Swiss and of the British ants as the validity of Prof. Heer's argument would require? Mr. Darwin thinks that in the nests of the British *Formica sanguinea* there is a relatively smaller proportion of slaves, which therefore play a less important part in the economy of the ant-hill. Messrs. Kirby and Spence record a fact which, isolated as it is, seems to us to overthrow altogether the hypothesis of absolute stationariness. Ants have been found, namely, to establish their nest in the interval between the double casing of a glass beehive. Now, as such beehives are artificial objects, and of very recent origin, they cannot have come in the way of the ants for any great length of time. They offered, however, a certain advantage in the uniform temperature and the shelter which they supplied. This fact must have been recognized by some prying ant, and the discovery, being communicated to its comrades, was turned to practical account. Is not this case the exact parallel of a step in the development of human civilization? And if, as we see, ants can in one case observe a phenomenon, reason on such observation, and work out their conclusions in their daily life, we can certainly see no grounds for supposing that such processes may not have occurred often. In the case of larger animals, where observation is easier, changes of habits, in accordance with new facilities or new dangers, have been distinctly recognized. There can be no necessity for us to quote the cases of alterations in the nidification of birds given by Mr. Wallace.[1] Recent American observations show that the habits of many birds, mammalia, and even fishes, have undergone a very decided alteration in settled districts as compared with less frequented regions. All species have become more wary and circumspect in their movements, and are decidedly more nocturnal. The birds build their nests on higher trees, or in the densest thickets. Any unusual object placed in a river alarms the fishes more than a similar object would have done some years ago, and more than it does now in solitary parts of the country. A new danger is recognized, and precautions are taken accordingly.

On carefully examining the habits of ants, we find that there exist among closely-allied species, and even in different colonies of one and the same species, gradations which, to our mind, supply powerful evidence that such habits cannot have been primordial. The slave-making propensity, and the reliance placed upon slaves, occur in several species, but not to the same degree. *Polyergus rufescens*, for instance, is absolutely dependent upon its slaves, and would, without them, perish from sheer incompetence to manage its own affairs further than by conducting slave-hunts. It is a military aristocracy, which can fight, but will rather die than work. *Formica sanguinea*, on the other hand, has much fewer slaves, and restricts them to a much narrower sphere of duties, being itself capable of working as well as of fighting. It is curious that the raids of slave-holding ants are confined to worker-pupæ of the species which they subjugate. No instance has reached us of ants carrying off male and female pupæ with a view to raising a stock of slaves in their own city, without the necessity of obtaining them by war. Surely, the most rational way of accounting for this slave-making propensity is to suppose that, as in the human race, it is a gradual outcome of war. Ants, in the wars which they are known to wage against different species, as well as against their own, would take prisoners—an undeniable fact—with the original intention of killing and devouring them. Some few of these victims, escaping immediate slaughter, might, if of a docile and submissive disposition, be found useful, and might hence be allowed to live in servitude. Prisoners of fiercer and more indomitable species, if taken at all, are no doubt killed. The query here naturally arises: "What happens in the not infrequent wars between two cities of the same species? Are the prisoners slaughtered, or are they incorporated with the victorious nation?"

No less variation may be traced in the habits of the cattle-keeping

[1] "Contributions to the Theory of Natural Selection," p. 227.

ants. Of the honey-secreting Aphides, and *Cocci* that serve them as milch-kine, some have large herds, some small ones, while others have none at all, and if they encounter an *Aphis* straightway kill and eat it. Is it not more probable that the ants first sought Aphides, like other insects, for this very purpose, but gradually discovered a way to turn them to better account, than that a flock of Aphides was, by some wonderful coincidence or interposition, placed within the reach of the first ant-hill?

It would, therefore, in our opinion, be exceedingly imprudent to declare that ant-civilization has not advanced, may not now be advancing, and may be destined to take yet further steps in the future, especially if large and fruitful portions of the globe are long allowed to remain in an uncultivated or semi-cultivated state. But such advances must necessarily be slow, as in all cases where there are no means of recording the experience of one generation for the benefit of the succeeding, and where what among mankind would be known as oral intercourse is limited by shortness of life. What direction these future advances may take, it is as difficult to indicate as to foretell the discoveries and inventions to be made by man during the next century. But we may safely say that they will not consist in the introduction of tools or weapons or machinery. Were man, in proportion to his size, about twenty times as strong as he is at present—were he provided by Nature with a pair of forceps, playing laterally, and capable of being used for felling trees, for excavating the ground, or for cutting off the heads of his enemies—he would scarcely have been a tool-inventing and tool-using animal. A being which, like the Sauba ants of Brazil, can construct a tunnel underneath the bed of a river as wide as the Thames at London Bridge, is in no need of shovels, pickaxes, or barrows.

That ants, in tropical climates, occasion much loss and annoyance to man is indisputable; yet the annihilation of all kinds of ants, were such a measure practicable, would scarcely be prudent. Here, as elsewhere, the rule holds good that small carnivora are to be cherished, and small herbivora and omnivora destroyed. The carnivorous ants, such as the *Ecitons*, are invaluable, from the myriads of cockroaches, scorpions, centipedes, venomous spiders, grasshoppers, and even rats and mice, that they destroy. They keep down serpents, also, by devouring their eggs. The plant-eaters, on the contrary, and especially the leaf-cutters, are an unalloyed evil, and their destruction ought to be attempted in a much more systematic way than what takes place at present. Nor can the "cattle-keeping" ants be tolerated. Even though they may not, in their own persons, attack the fruits and the leaves of useful trees, they compass injury to the latter by cherishing and defending swarms of such pernicious vermin as the Aphides of temperate regions and the scale-insects and tree-hoppers of warmer climates. All these live by sucking the juices of plants, and over them the ants watch with a wonderful care, defending them from the attacks of birds, wasps, ichneumons, and other creatures, who would rid the poor plant of its parasites. They have even been known to build galleries of clay over the surface of a pine-apple, in order to shelter the *Cocci* who were destroying the fruit.

Mr. Belt found that a red passion-flower, which secretes honey from glands on its young leaves and on the sepals of its flower-buds, was carefully guarded by a certain species of ant (*Pheidole*), who consumed the honey, and who furiously drove off all leaf-cutters and other intruders. But, after a couple of seasons, a colony of parasitical scale-insects, which secrete honey, established themselves upon the passion-flower, to its great injury. The ants transferred their care and attention to these, and, from the guardians of the plant, became indirectly, but not the less substantially, its enemies. This is a striking proof of the untrustworthy character of our insect—or, more generally speaking, of our animal—allies. At one moment they may be defending our property from depredation, but on a slight change of circumstances their interests may cease to coincide with our own, and they may go over to our enemies. The question what animal species we ought to protect and which to destroy, and how far we ought to go in each case, becomes, on closer inspection, exceedingly complicated.

As an example of an omnivorous ant, we may take the "fire-ant" of the Amazon, of which Mr. Bates gives us a striking account:[1] "Aveyros may be called the headquarters of the fire-ant, which might be fittingly termed the scourge of this fine river. It is found only on sandy soils, in open places, and seems to thrive more in the neighborhood of houses and weedy villages, such as Aveyros; it does not occur at all in the shades of the forest. Aveyros was deserted a few years before my visit on account of this little tormentor, and the inhabitants had only recently returned to their houses, thinking its numbers had decreased. It is a small species, of a shining reddish color, not greatly differing from the common stinging ant of our own country (*Myrmica rubra*), except that the pain and irritation caused by its sting are much greater. The soil of the whole village is undermined by it; the ground is perforated with the entrances to their subterranean galleries, and a little sandy dome occurs here and there, where the insects bring their young to receive warmth near the surface. The houses are overrun with them; they dispute every fragment of food with the inhabitants, and destroy clothing for the sake of the starch. All eatables are obliged to be suspended in baskets from the rafters, and the cords well soaked with copaiba-balsam, which is the only means known of preventing them from climbing. They seem to attack persons out of sheer malice. If we stood for a few moments in the street, even at a distance from their nests, we

[1] "Naturalist on the River Amazon."

were sure to be overrun with them and severely punished, for the moment an ant touched the flesh he secured himself with his jaws, doubled in his tail, and stung with all his might. When we were seated on chairs in the evenings, in front of the house, to enjoy a chat with our neighbors, we had stools to support our feet, the legs of which, as well as those of the chairs, were well anointed with the balsam. The cords of hammocks were obliged to be smeared in the same way to prevent the ants from paying sleepers a visit." The ravages of the leaf-cutting ant (*Oicodona*), or Saubas of the Brazilians, have been already mentioned; but it also invades houses and carries off articles of food on a far wider scale than is ever done by rats or mice. It is capable of carrying off such a quantity as two bushels of mandioca-meal in the course of a single night! Unfortunately, the Sauba has few enemies. The number of these depredators who fall a prey to birds, spiders, wasps, tiger-beetles, etc., is too small to be of any importance. The *Pseudomyrma bicolor* easily repels them if they come to clip the leaves of the bull's-horn acacia on which it resides, but it is not sufficiently numerous to pursue and destroy them. The *Ecitons* have never been known to storm the nests of the Sauba. Thus, as we often find, for the greatest mischiefs Nature provides no remedy, and man must step into the breach, armed with carbolic acid and corrosive sublimate.—*Quarterly Journal of Science.*

SKETCH OF PROFESSOR JOSEPH LE CONTE.

THE subject of the present notice, now Professor of Geology and Natural History in the University of California, bears a family name that has long been distinguished in American science. He was descended from William Le Conte, a Huguenot, who left his native city, Rouen, on account of the political and religious troubles consequent upon the revocation of the Edict of Nantes, in 1685, and settled in the vicinity of New York. Here his ancestors continued to live until about 1810, when his father, Louis Le Conte, removed to Liberty County, Georgia, to take personal charge of a large inherited estate. There Joseph Le Conte was born, February 26, 1823.

His primary education was received in a neighborhood school of his native county; and, among the ten or twelve different teachers who successively directed his education with varying success, the only one whom he recognizes as having left any decided impression upon his mind was Alexander H. Stephens, afterward the distinguished politician.

The germs of much of his future character and career may be traced to these early boyhood days. His father was an ardent devotee of science in all its departments, but especially of natural history. The example of his father, and the splendid botanical garden in the midst of which he lived from infancy, early imbued him with an intense love of Nature, and cultivated in him the habit of scientific observation. The unrestrained freedom of his boyhood life, in a country where game of all kinds abounded, engendered a passionate fondness for field-sports; and this again increased both his love of Nature and the opportunities of observation. In later life this love of field and forest took the more rational form of extensive ramblings for scientific purposes.

After graduating A. B. in the University of Georgia, in 1841, he commenced the study of medicine, and graduated M. D. in the College of Physicians and Surgeons of New York, in 1845. A few years of active practice of his profession in Macon, Georgia (during which, however, he was more interested in the *science of medicine* than in the *art of healing*), served to convince him that he had not yet found his appropriate field of activity. He therefore, in 1850, went to Cambridge, Massachusetts, to pursue a course of practical science in the laboratory of Prof. Agassiz.

His life in Cambridge, and especially his intimate association with the great teacher, powerfully stimulated his enthusiasm for science, and permanently determined its direction. During the winter of 1851, in company with Prof. Agassiz, he spent the months of January and February on the keys and reefs of Florida, engaged in studying their mode of formation. These studies afterward gave origin to a paper "On the Agency of the Gulf Stream in the Formation of the Peninsula and Keys of Florida."

In 1851, after taking the degree of B. S. in the Lawrence Scientific School, he returned to Georgia, and was immediately elected to the chair of Natural Science in Oglethorpe University. As this chair included physics, chemistry, geology, and natural history, he was not unwilling to exchange it for that of geology and natural history in the University of Georgia, which was tendered him in 1852. Four years of laborious class-room work here laid the foundation of his success as a teacher and lecturer, but left little time for research. In 1856 he removed to Columbia, South Carolina, to take charge of the chair of Chemistry and Geology in the South Carolina College.

The years spent in connection with this institution were among the pleasantest and most active of his life. The highly-intellectual and refined society gathered in Columbia was, however, more literary and philosophical than scientific. His activity, therefore, took in some degree this direction, and most of his articles which are not strictly scientific were written at this time.

In 1862 the call of the Confederate Government for all able-bodied males over eighteen years of age entirely broke up the college for want of students. During the war he was engaged first as Chemist of the Government Laboratory for the Manufacture of Medicines, and afterward as Chemist of the Nitre and Mining Bureau.

After enduring the privations and hardships (including the total loss of property) consequent upon the breaking up of the Confederacy, on the reorganization of the college as the University of South Carolina, he was again appointed to the chair of Chemistry and Geology, in the undergraduate department, and of Chemistry and Pharmacy in the medical department. But the utter prostration of the material resources of the State, falling first and most heavily on institutions of higher education, compelled him to seek employment in a more prosperous region. He therefore, in 1868, accepted a call to the chair of Geology and Natural History in the University of California then about to be organized, and removed to that State to assist in the opening of the first session of the new institution, in September, 1869. He has continued to occupy this chair up to the present time.

From this time commenced the most active period of Prof. Le Conte's strictly scientific life. The boundless field for geological studies presented on the Pacific coast incited him to pursue his favorite department with renewed ardor. Every summer vacation was spent in a geological ramble with a party of students and graduates in the high Sierras, or in a geological tour through Oregon, Washington Territory, and British Columbia. As much of the region of the high Sierras is wholly uninhabited, camping-parties were organized; and thus studies of Nature were combined with a life of adventure full of delight, amid the finest scenery in the world. Many scientific papers on the origin and structure of mountain-chains, and on the ancient glaciers of the Sierras, were the result of these studies. Meanwhile other and more abstract subjects were not neglected; for he contributed during this time also many papers on the theory and phenomena of binocular vision.

Prof. Le Conte can hardly be called a specialist in any department, in the narrow sense of that term; for, although his chief activity has been in the field of science, yet his interest in literature, art, and philosophy, is almost equally great. Association alone seems to have determined his life-work in the direction of science. Until thirty years of age his intellectual culture was almost perfectly general. Only after that did it commence to concentrate first on science, and still later on special departments of science. While this may have been a disadvantage in the pursuit of special narrow lines of investigation, it had also its advantage in giving that comprehensiveness so necessary in the more complex departments of science which he had chosen.

In his theory of education, therefore, Prof. Le Conte was always an earnest advocate of the general or liberal education of the cultured man, rather than the special education of the mere expert. His ideal of education was a general culture first, and as high as circumstances will allow, and then a concentration on special cultures suitable to the intellectual plane to which the pupil has been previously raised by the general cultivation.

Deeply religious in his innermost nature, he nevertheless fearlessly pushed scientific ideas to their legitimate conclusions. He believed that truth cannot conflict with itself; that true science is not antagonistic to a true religion, or *vice versa;* that pride and dogmatism on both sides are the only bar to cordial relations.

The following are some of Prof. Le Conte's principal contributions to literature and science:

1. The Science of Medicine, and the Causes which have retarded its Progress, 1849.
2. Agency of the Gulf Stream in the Formation of the Peninsula and Keys of Florida, 1856.
3. Lectures on Coal, and on Coral Reefs. Smithsonian Institution, 1857.
4. Place of Organic Science and Geology in a Scheme of Education, 1857.
5. Morphology, and its Relation to Fine Art, 1858.
6. Principles of a Liberal Education, 1859.
7. Female Education, 1859.
8. Correlation of Physical, Chemical, and Vital Forces, 1859.
9. Relation of Organic Science to Social Science, 1860.
10. Importance of Natural History in the Schools, and the General Relation of the School, the College, and the University, to each other and to Active Life, 1861.
11. The Nature and Uses of Fine Art, 1863.

Phenomena and Theory of Binocular Vision—a series of papers, viz.:

12. I. Adjustments of the Eye, 1868.
13. II. Relation of the Eyes on the Optic Axis in Convergence, 1869.
14. III. The Horoptic, 1869.
15. IV. A New Mode of representing Binocular Phenomena, 1870.
16. V. Theory of Steroscopy, 1871.
17. VI. So-called Images of Illusion, 1872.
18. VII. Position of the Eyes in Sleep, 1875.
19. VIII. Law of Corresponding Points in Relation to the Law of Direction, 1875.
20. IX. Comparative Physiology of Binocular Vision, 1875.
21. X. Structure of the Crystalline Lens, and its Relation to Periscopism, 1877.
22. General Law of Circulation in Nature, 1870.
23. Theory of Formation of the Greater Features of the Earth's Surface, 1872.
24. Ancient Glaciers of the Sierra, 1873.
25. Some Tributaries of Lake Valley Glaciers, 1875.
26. The Great Lava-Flood of the Northwest, and the Structure and Age of the Cascade Mountains, 1874.
27. Structure and Mode of Formation of the Coast Ranges of California, 1876.
28. Instinct and Intelligence, or the Genesis of Instinct, 1875.
29. The True Idea of a University, 1876.
30. Critical Periods in the History of the Earth, and their Relation to Evolution, 1877.

Although his life has been given to the development of original thought in various departments, yet Prof. Le Conte has not had the ambition to be a great book-maker. He, however, published a volume in 1873 on "Religion and Science," and has just issued a comprehensive college text-book of geology, the result of his twenty-five years' experience in teaching that subject.

CORRESPONDENCE.

HOW TO PRACTISE MIND-READING.

To the Editor of the Popular Science Monthly.

IT is interesting to contemplate that curious phase of credulity, closely allied to superstition, which seems to be innate in the human mind, predisposing many intelligent people to attribute to supernatural agencies certain phenomena which are purely subjective. This quality has, doubtless, contributed to the growth of faith in spiritualism, odylism, auras, psychic force, and what not.

One would suppose that the recent exposure in the law-courts of the juggleries of some of the more notorious mediums would have served to convince the most ardent believers that the so-called spirit-manifestations are wholly mundane. This good result, however, does not appear to have been accomplished as yet.

When "Professor" Brown, the *mind-reader*, performed his clever experiments a few years since, many well-educated people maintained that his discoveries could not be explained by any of the known laws of Nature; he was indorsed by several distinguished scientists, at least one of whom stated that he was a firm believer in Brown, and that he regarded "the theory of unconscious muscular action as entirely opposed to the facts observed."

Since that time quite a number of articles have appeared in this and other scientific journals upon the subject; they have all been devoted to elaborating theories, and I propose, therefore, to confine myself to a few practical hints as to the precise methods of observation, hoping thereby to enable persons interested to perform all of Mr. Brown's experiments successfully, as well as others of a more complex and astonishing character, and, at the same time, to answer numerous queries that I have from time to time received.

The main difficulty that the novice in the art of interpreting "ideo-motor movements" encounters is, that he does not know exactly what indications to look for, and often mistakes an accidental or intentional movement of the "subject" for an involuntary one. He also imagines that the indications are confined to muscular contractions in the arm or hand of the subject. This is a fatal mistake, as I have already shown in a letter to Dr. Beard, which he communicated to your journal in the July number, 1877. In that letter I stated that it is quite possible for the mind-reader to select objects hidden or thought of, walk over any route desired, or to perform any similar experiment, without any connection between his subject and himself, even while he is blindfolded. I also referred to several other novelties, and shall now content myself with a simple explanation of the *modus operandi* upon which the whole principle depends; leaving it to the ingenuity of experimenters to complicate the tests according to their ability.

Let us suppose that the mind-reader has been escorted out of the parlor by a committee appointed by the guests to see that all is fair. A "subject" is then selected who will hide a small article, perhaps a pin, under the carpet in the corner of the room. The mind-reader is led in blindfolded, he takes the left hand of the subject in his left (*à la* Brown), grasping the subject's elbow with his right; he tells the subject to fix his mind intently upon the object hidden and the locality; he then makes *a feint* to move away, watching closely to see whether the subject shows any reluctance to follow him; if so, he tries another direction; presently he will find one point toward which the subject will show a disposition to accompany him very readily. This, then, is the first clew; he follows it up, occasionally feigning to diverge, in order to satisfy himself that he is on the right track. In this way he will be guided (not led) past all obstructions to the locality; then he will notice that the subject shows no partiality toward any particular direction. The mind-reader thus infers that he is, in juvenile parlance, *very hot*, and he now, for the first time, directs his attention exclusively to the involuntary movements in the arm of the subject, in order to obtain the indication as to the exact locality of the object hidden. This he accomplishes by moving the subject's arm about until he discovers the direction in which the arm unconsciously *prefers to go*. Should the subject suspect that he may be involuntarily giving the indications, it is a capital *ruse* for the performer, first, to satisfy himself of the position of the object, and, before producing it, to move away from the spot, then suddenly pounce upon it with great show of certainty. The "bull-dozed" subject will at once become the strongest opponent of the involuntary muscular-movement theory!

Apart from the amusement which these performances invariably afford at a social gathering, the subject of the "ideo-motor movements" is one of the highest physiological interest, and very surprising results may be obtained by a careful study of all the conditions, and an ingenious complication of the experiments.

Thus it is quite easy to have half a dozen or more persons engaged in performing parts of an experiment, each one being ignorant of what the other has done. The mind-reader then ravels out the thread by beginning at the end and working backward, or *vice versa*. The rapidity with which the experiments may be performed is remarkable, sometimes occupying less time than is required to arrange them.

The chief points, then, for the beginner to observe are:

1. Impress upon your "subject" the necessity of fixing his mind on the object and its locality.

2. Concentrate your attention on every movement of the subject.

3. Never hazard a guess.

Hoping that these few directions will enable others interested in this entertaining and scientific trick to repeat the experiments successfully, and referring the reader to my previous letter for an explanation of the performances without physical contact, I am, yours, very truly,

Alexander E. Outerbridge, Jr.

Philadelphia, *November* 26, 1877.

"FLORIDA LIZARDS."

To the Editor of the Popular Science Monthly.

Dear Sir: In corroboration of Mr. Gillman's statements regarding the change of color or "chameleonization" of the Florida lizard (the species of which I presume to be *Anolis principalis*), and which is noticed in the December number of The Popular Science Monthly, permit me to say that, in 1871, while in North Carolina, I had a number of these lizards in captivity for the purpose of studying and observing their habits, and in 1873 published in the *Rod and Gun* a short paper as the results of my observations, which fully confirm those made by Mr. Gillman, as the following extract will show: ". . . The first peculiarity noticed about them was their change of color; before retiring for the night a sheet of paper was thrown over the box, and removed the next morning. To my amazement my pets, that had been a vivid green color the day before, were now of a dirty-brown tint, and extremely sluggish in their movements; but, to my great delight, so soon as the rays of the sun fell upon them, the green returned, and they became as lively as ever. This change of color is very curious and peculiar, taking place under a variety of circumstances. For instance, after burrowing in the sods (with which their box was lined) on their return to the light they would at first be brown, but recovered their normal tints shortly afterward. When asleep the green color would frequently be replaced by brown, and, still more curious, if during the day the sun for any length of time was obscured by clouds, the same effect was produced. The manner in which the green tint replaced the brown was very interesting. In some instances a little patch of green would appear on the end of the snout, others would appear in different portions of the body; these would extend and gradually coalesce until the whole body had resumed its usual tint." During the procreative act, there was an ever-varying change of color from the most vivid green to dull, dusky brown. During anger, and while feeding, these changes were very noticeable. I have never seen the colors change so rapidly as Mr. Gillman states, but this may be due to the fact that his observations were made upon individuals free and unrestrained of their personal liberty, mine upon captives.

Respectfully yours,

H. C. Yarrow.

Smithsonian Institution, Washington, D. C., *November* 20, 1877.

EDITOR'S TABLE.

THE DOCTORING OF DARWIN.

The University of Cambridge, with much *éclat*, recently conferred the degree of L L. D. upon Mr. Charles Darwin. This circumstance has elicited much diversity of comment on the part of the press. Some maintain that the conferring of this honor is to be construed as a virtual indorsement of the doctrines that are associated with the name of this eminent naturalist; and they regard the action of the university as a triumph of the advanced biological school over the clerical and conservative party by which the university has been hitherto dominated. Others maintain that the proceeding is susceptible of no such interpretation, but that the degree was awarded simply in recognition of the important services of

Mr. Darwin in the general field of natural history, regardless of those peculiar doctrines which have become identified with his name. There is probably truth in both views sufficient to make out a case. It is not to be denied that Mr. Darwin has done a great deal of valuable original scientific work as an observer that has enriched biological science, quite independent of the hypothesis that he has contributed so much to elucidate. But, on the other hand, it is pretty certain that, notwithstanding the extent of these merits and claims, Cambridge would not have spontaneously honored a man who has come to be the representative of all that is most obnoxious in the inexorable advance of modern science, unless his friends had vigorously bestirred themselves to secure the result; and from this point of view the action of the institution may be fairly looked upon as a victory of liberal ideas over the traditional narrowness, prejudice, and intolerance, which rule in the great seats of English learning. For, if Cambridge meant merely to grant its honor to a distinguished man of science, the question arises, "Why has she not done it long before?" Mr. Darwin's labors were widely known and thoroughly appreciated by the highest scientific bodies. He began his career as a naturalist at the age of twenty-two by joining the expedition of the Beagle, which went on a four years' exploring tour around the world. While absent and at the age of twenty-five, he was elected a Fellow of the Royal Society, and he contributed an elaborate volume narrating his discoveries in natural history and geology, which was issued upon his return, and separately republished in 1845. Other important works followed; in 1853 the Royal Society awarded to him the Royal Medal, and in 1859 he received the Wollaston Medal from the Geological Society. The matured results of all his natural history studies were embodied in a volume on "The Origin of Species," published in the same year. Aside from any question of the truth of the hypothesis there presented, or any question as to the exclusiveness of Mr. Darwin's claims in originating it, there can be no doubt that this book has proved one of the most powerful provocatives of inquiry that have appeared in modern times. If, therefore, Cambridge had been animated with a true spirit of liberal scholarship, it is impossible to see why she did not accord the doctorial honor to Mr. Darwin fifteen or twenty years ago.

It would seem that the current notion that these great schools are influenced by just and generous ideals in the bestowment of their honorary degrees is very much of an illusion. They exhibit little alacrity in detecting merit, and signalizing talent in its early and decisive displays, when their recognition would be of some service to the recipient. They wait until they get more than they give by the transaction. When a man of intellectual power has fought his way to fame, and become indifferent to factitious honors, or when a man of force has won some notoriety that makes him conspicuous, so that everybody is watching and talking about him, the universities are then ready enough to avail themselves of the advantages that may arise from their association with his name. Cambridge was probably reluctant in this particular case, as its short-sighted authorities probably thought that they might lose more than they should gain by crowning Darwin with the doctorate; but, as remarked by the editor of *Nature*, the university seemed conscious of the honor Mr. Darwin was conferring upon it, and the enthusiasm of the performance will no doubt satisfy the authorities that they have done a good stroke of business, as coming generations will assuredly view the matter in a very different light from the way it has been viewed in the past.

THE SUN-SPOTS AND THEIR EFFECTS.

The phenomena of sun-spots are now familiar: multitudes of people have seen them, and everybody has read about them. It is well known that the surface of the sun is not that uniform disk of light that it was formerly supposed to be, but abounds in gulfs, dark chasms, up-rushing streams of flaming gases, and lurid prominences, sometimes 100,000 miles high. But these striking effects are not uniform: the sea of solar fire, like our own oceans, is sometimes violently agitated and sometimes quiet. The spots are variable, being now many and enormous in size, and again few and small. This periodicity, moreover, is proved to be regular. Prof. Schwabe, of Dessau, discovered that, instead of being uniform in number and intensity from year to year, spots increase and decline at definite rates for a term of years. As a result of 9,000 observations, during which he discovered 4,700 groups, he traced three complete oscillations from maximum to minimum, which he estimated to take place in about ten years. Prof. Wolf, of Zurich, went into an exhaustive history of the subject, and, by collating a vast number of observations and records from 1750 to 1860, he verified Schwabe's general results, but showed that the period of oscillation is about eleven years. His data, scattered through a course of 140 years, comprehended observations in the seventeeth century made on 2,113 days; in the eighteenth century, on 5,490 days; and in the nineteenth century, on 14,860 days, or a total of 22,463 days. On this broad basis of observation, made with no reference to any hypothesis of variation, it is established that the solar energy changes in intensity by a regular law of rise and fall from a maximum to a minimum of effect; and that the maximum, or greatest activity, coincides with the period of violent perturbation when there is the greatest number of eruptions of heated matter from below, and the most conspicuous display of sun-spots and prominences; while at the minimum periods these manifestations are greatly reduced, or almost entirely wanting.

It is now an admitted fact of science that the earth is dependent upon the sun for the chief portion of the energy by which terrestrial effects are produced. With the exception of the ebb and flow of the tides, all the forms of earthly power are recognized as having, directly or indirectly, a solar origin. Wind-power, water-power, steam-power, the activities of organic growth, all animal energy, and the great phenomena of changes in the crust of the globe, due to the circulation of waters through atmospheric agency, are caused by the forces of solar radiation. But if the solar energy is variable, the question naturally arises, "Is that variation manifested in terrestrial effects, and, if so, in what manner, and to what extent?" The subject is vast and new, but the indomitable energy of modern scientific inquiry has rapidly accumulated evidence which answers the first question in the affirmative, and gives instructive replies to the others. The sun-spots, for thousands of years unknown, and for centuries after they were known regarded as mere matters of curious and idle speculation, are now linked indissolubly to the whole scheme of activity which we observe upon earth, and of which we are ourselves a part. Even the famines by which nations are periodically desolated seem to be connected with this intermittence of solar energy. The evidence upon the subject has been summed up in an able and impressive paper contributed by Messrs. Lockyer and Hunter to *The Nineteenth Century*, and which will be found in full in No. VIII. of The Popular Science Supplement. We can here do little more than indicate the remarkable connections that have been disclosed between the variations of solar activity and resulting terrestrial phenomena:

1. The first coincidence observed was in the field of terrestrial magnetism. "A freely-suspended magnet, although it points in one direction, is nevertheless, within small limits, always in motion. Certain of these motions depend, as is well known, upon the hour of the day; but the magnet is also liable to irregular, abrupt fluctuations, which cannot be connected with the diurnal oscillations. While Hofrath Schwabe was engaged in delineating the sun-spots, Sir Edward Sabine was conducting a series of observations with regard to these spasmodic affections of the needle, and he found that such fluctuations are most frequent in years of high sun-spot activity." Nearly a hundred years ago, Van Swinden had suggested a periodicity in these irregular magnetic movements. Gauss, Arago, Lamont, and Gautier, pursued the research, and established the existence of a cycle of magnetic variation having an eleven-year period, the maxima and minima agreeing with the maxima and minima of sun-spot activity. Schiaparelli and Broun have confirmed these results, and the latter observer concludes that, while the sun-spot activity is not an exact measure of magnetic action, "each is a distinct result due to the same cause." This disturbance is so great that, in years of maximum sun-spots, the working of the telegraph has been powerfully interfered with.

2. Connected with these effects there have been observed corresponding disturbances of electrical activity. A magnetic storm never rages without various accompanying signs of electrical excitement. These are seen in auroral displays that in their varying intensities conform to the magnetic cycles. Prof. Loomis, of Yale College, after a critical study of the subject, "concluded that the auroras observed in Europe and America exhibit a true periodicity closely following the magnetic periods, but not perfectly identical with them;" and Mr. Charles V. Walker, telegraphic superintendent, holds as an established fact that "earth-currents, disturbed magnetometers, and aurora, are parts of the same phenomenon."

3. There is evidence of thermometric variations, or fluctuations of temperature, in periods coinciding with the sun-spot cycles. The observations in this case are, however, much complicated and obscured by the agency of the atmosphere, which acts as a screen upon the earth's surface, disturbing the radiations that would affect our thermometers. But a large number of observers, among whom are Baxendell, Blandford, Stewart, Roscoe, Piazzi Smyth, Stone, and Köppen, have accumulated numerous observations both in the temperate zones and in the tropics, showing that "the calorific intensity of the sun's rays is subject to periodical changes, the maxima and minima of which correspond respectively with those of sun-spot frequency."

4. The wind-disturbances of the earth's atmosphere follow the same law; there being a coincidence between the frequency of cyclones and sun-spots. Observations on opposite sides of the world, and in the tropics where wind-disturbances are most violent, lead to the conclusion, as stated by Mr. Meldrum, that "the whole question of cyclones is a question of solar activity; and that, if we write down in one column the number of cyclones in any given year, there will be a strict relation between them—many sun spots, many hurricanes; few sun-spots, few hurricanes."

5. Confirmatory evidence of this is found in the records of shipping-disasters. From the returns of marine casualties posted on Lloyd's loss-book it was found that they disclose "a cycle closely corresponding with the sun-spot period. The percentage of casualties on

the registered vessels of the United Kingdom (Great Britain) was 17½ per cent. greater during the maximum two years in the common cycle than during the minimum two years."

6. It has been further shown by the observations of Baxendell, Meldrum, Rawson, Jelinck, Wex, Dawson, Hennessey, Broun, and Brockelsby, that there is a fluctuation in the fall of rain in which the same law may be traced; that is, "a connection between the variations of the sun-spot area and the annual rainfall; the rainfall rising above the mean when the sun-spot area is in excess, and falling below the mean when in periods of small sun-spots." The monsoons are the great sources of rain-supply at Madras, in India. The rainfall cycle has been traced out in that country, and the deficiency and excess of rain connected with the great solar periodicities. The writers whom we are following say, for example, that "the water-supply brought to Madras by the southern monsoon is 26½ per cent. greater in ordinary years than in the years of minimum sun-spots." And again, "there is a rain-cycle of eleven years at Madras which coincides with the cycle of sun-spots; the periods of maxima and minima in these two cycles disclosing a striking coincidence."

7. The variation in the rainfall of India involves the food-supply of that country, and is a question of famine and starvation. Observations on the variation of water-supply, in India, of course go no further back than the introduction of rain-gauges. Commencing the inquiry in the year 1810, Messrs. Lockyer and Hunter say: "The years of famine in Madras since that date have been 1811, 1824, 1833, 1854, 1866, and 1877. These famines were caused by deficient rainfall in the preceding years, namely, in 1810, 1823, 1832, 1853, 1865, and 1876. Now, five out of these six years of drought fell within the three years' group of minimum rainfall and sun-spots (shown in the foregoing tables); the remaining drought (1853–'55) extended over a year immediately preceding the minimum group, and two years within that group; the famine itself resulting within the minimum group. Three of the six years of drought fell exactly in years of minimum sun-spots; one fell in the year preceding a year of minimum sun-spots; one fell in the second year preceding a year of minimum sun-spots; the remaining drought, 1853–'55, fell in the first, second, and third years preceding a year of minimum sun-spots. . . . No famine in Madras has been recorded from 1810 to 1877, caused by a drought lying entirely outside the minimum group of sun-spots and rainfall."

We have here been able only to hint at the points made in the paper referred to. The case is strong, in fact much of it demonstrative, yet it is, of course, most incomplete. Though important practical conclusions have been reached, the investigation is in its crude, preliminary stage, where the truth is caught vaguely and by glimpses rather than seen clearly and by a steady gaze. Yet it is a magnificent research, with already-assured results and a splendid promise. We commend the subject to the consideration of those who hold that science, to be genuine, must have become exact, certain, and perfect.

THE SCIENCE OF SOCIETY.

We have taken the ground in this periodical, and we abide by it, that the most important of all subjects for general consideration, and especially for the American people, is the application of science to questions of society and government. When the Monthly started, we obtained from the foremost thinker of our times in this growing department of inquiry a series of papers, in popular form, designed to present the character and claims, difficulties, limits, and expectations, of a true social science, so as to fix public attention upon the subject, and prepare for the more systematic consideration of its principles. The result was those able articles on "The Study of Sociology," by Herbert Spencer, which appeared in our pages, and which, collected in a volume, have been subsequently translated into nearly all the languages of Europe. The subject is one of rapidly-increasing interest, to which this book has in no small measure contributed; and we have now the pleasure of announcing another arrangement with the same author, of equal significance and promise, in the popular exposition of social science.

Of Mr. Spencer's present unrivaled position as the elucidator of the laws of man's social progress there is no longer a question. He was the first to grasp the subject in its full breadth, the first to trace out the completeness of its dependence upon the sciences, and the first to carry his system of thought into practical execution. When he began to publish methodically upon this topic seventeen years ago, his project was regarded as a hopeless chimera; but the work has steadily gained upon public confidence, until its successive volumes have been all reproduced in the leading civilized countries. The interest in the subject is, indeed, now so strong and so general that Mr. Spencer has been urgently called upon to publish in future in such a manner as to bring his views more promptly and generally before the reading world. To this he has so far consented that we shall be able, jointly with the English and Continental periodicals, to represent for a considerable time the advancement of his sociological work.

The volume of "The Principles of Sociology," just published, deals with the primordial conditions of the subject, and with the genesis of those early ideas and feelings which give origin to primary social cohesions and groupings. The next volume is to treat of the evolution of the various forms of government by which society is ruled—Ceremonial, Political, Ecclesiastical. We shall publish next month the introductory essay on Ceremonial Government, its nature, extent, and relation to other forms of control. This will be followed by papers dealing with the various elements and divisions of the subject, such as "Trophies," "Mutilations," "Presents," "Obeisances," "Forms of Address," "Titles," "Badges and Costumes," "Further Class Distinctions," "Fashion," and the "Past and Future of Ceremony."

It need hardly be said that these articles will be in a high degree original and instructive, and will throw an important light upon the historic unfolding of one of the largest divisions of social regulation. They will be invaluable to all who care to understand the agencies by which human conduct is controlled, and the modifications which those agencies undergo in social development. We ask our readers to bear in mind that The Popular Science Monthly is the only magazine in the United States which tries to keep its patrons informed of the advances in this great field of thought; and we earnestly appeal to them to do their share in helping us, by forming clubs among their friends and in their neighborhoods that shall extend the circulation of the Monthly. We are trying to do a work of education which our colleges and our periodicals grossly neglect; and our power of accomplishment must depend upon the vigor and liberality with which we are sustained by those who appreciate the importance of the labor.

LITERARY NOTICES.

The Methods of Ethics. By Henry Sidgwick, M. A. Second edition. Macmillan & Co., London. Pp. 469. Price, $4.

This work, which upon its first appearance made a strong impression upon philosophical minds, has passed to a second edition, with numerous alterations and additions; the main part of which, as the author says, are of an explanatory and supplementary nature. The improvements are here manifest, and we cordially testify that the second edition is much less intricate and obscure in statement than the first. It will be remembered, by those who happen to have read it, that the book is rather critical in character, and is devoted to an examination of the grounds and sufficiency of existing ethical methods, rather than to the propounding of any new system. From this circumstance, together with the infelicity of statement which so marked the first edition, there was often much perplexity to know what Sidgwick himself believed, and what he was driving at. In the preface to the second edition, the author refers to the character of his new matter, and indicates various points in which his views have been modified under the influence of the critical attention his volume has received. One thing is somewhat significant: Mr. Sidgwick is a man given to highly-abstract studies, and he therefore occupies a province that has been thus far least affected by the progress of physical and biological science. He heard a great din in an adjacent field about evolution, but as it did not seem to affect him, he paid little attention to it. When, however, the claim was made that ethics, like almost everything else in this world, must be influenced by evolutionary doctrine, he put in a mild but decisive protest; and in an article in *Mind* maintained, virtually, that it makes no difference as to the present exposition of ethical science how its phenomena came about. In the new edition, however, this judgment is modified. In the preface he says, "I have further been led, through study of the theory of evolution and its application to practice, to attach somewhat more importance to this theory than I had previously done;" to which we mayadd that, in his still further study of that theory, he will attach still more importance to it. Possibly, indeed, his views may become so much more evolved that he will wonder how he could at first have treated the subject with so little reference to that doctrine. If ethics refers to the obligations of conduct, and if the American eagle and the American citizen are not required to conform to the same standard—if organization comes into the question, and man himself, in his organic and racial modifications, illustrates the same principle—then may it become a prime question in ethics as to the right and wrong of conduct in different stages of social unfolding. Should it in fact turn out that the factor which Mr. Sidgwick at first excluded from ethical inquiry, becomes, at length, its dominant factor, it will be but another illustration of that inversion of values of which we have already so many examples in the history of progressive thought.

Isis Unveiled: A Master-Key to the Mysteries of Ancient and Modern Science and Theology. By H. P. Blavatsky. New York: J. W. Bouton, 1877. Two volumes. Pp. 1365. Price, $7.50.

After a patient examination of these massive volumes, we confess our inability to find what it is that is "unveiled." The dominant aim of the work seems to be to establish the identity between ancient magic and modern spiritualism, and to show that here alone is the ground of a possible compromise in the contest between religion and science. It is but fair to say that the author declines to be considered an ordinary spiritualist, which is certainly creditable to her, but we must refer those who are curious to know in what manner she differs from them to the book itself, with the hope that they will be more successful than we have been. The first volume professes to be devoted to science, and the second to theology; and, in dealing with science, much space is given to the refutation of the idea that it is infallible. When that assumption is set up, this part of the author's effort will become pertinent, and will be, no doubt, appreciated. Scientific men are scolded by her, in a copious variety of diction, because they will not "investigate" the spiritualistic hypothesis. This is quite in the vein of the ordinary spiritualist, and is far from new. When the so-called spiritualist's hypothesis is offered for investigation on the same terms and conditions as the other problems of Nature, there will be no difficulty in getting it investigated. Two or three things are essential to a legitimate scientific hypothesis: It must be expressed in intelligible terms; it must present a definite subject-matter for solution or determination; and it must be one by which predictions can be made that can be proved or disproved by experiment. In regard to the phenomena, or the alleged facts, the whole question hinges, of course, upon the character of evidence; but here we must say that the author of "Isis Unveiled" shows not the slightest discrimination. There is displayed a great familiarity with magic lore, and a deal of industry in getting together a vast medley of materials. Bible-stories, legends from all lands, from all times, ancient and modern accounts of witchcraft, newspaper reports of table-turning, mind-reading, levitation, the psychological vagaries of a novelist, like Bulwer, and the results of scientific research, are all raked together promiscuously and accorded equal weight. There is no attempt toward a systematic arrangement of these multitudinous materials, nor are they held together by anything deserving the name of reasoning or argument. We are reminded by the book of nothing so much as the rush of *débris* which passes through a sewer after a summer shower. Everything is washed along—garbage, remnants of things once valuable, with now and then something that might be of real worth if sifted out —and the whole borne on by a turbid watery medium which takes its quality from the dirt it carries.

We should say that the work evinces great reading in certain directions, much ill-digested learning, a curious credulity in these times, and a strong tendency to mysticism. It is sure to find readers, as it deals with questions which interest all, and in a manner that will be satisfactory to many. Unhappily, education has not been carried far enough to teach the people to distinguish between the valuable and the worthless among things printed, and we have no doubt there are many who have gone through college and acquired nothing that will protect them from accepting "Isis Unveiled" as pretty fair gospel for these days. We may add that, aside from the uses for which the author designs them, there is a large amount of curious information, facts, and opinions, in her volumes which will be interesting to many, and are elsewhere inaccessible to ordinary readers.

Bulletins of the U. S. Entomological Commission. Nos. 1 and 2. Washington, 1877.

These pamphlets are issued under the auspices of the U. S. Geological Survey, and are designed to contain such special information of interest or importance in connection with the objects of the commission as may from time to time seem useful. The first bulletin was published in April, and gave instruction as to the destroying of the young insects, which should be done throughout the West during April, May, and June. Number 2 is filled with the natural history of the locust. It is a good compendium of the habits of the pest, and is illustrated by woodcuts and a map. Prof. C. V. Riley is presumably the writer of both numbers.

Outlines of Modern Chemistry, Organic, based in Part upon Riches' Manuel de Chimie. By C. Gilbert Wheeler, Professor of Chemistry in the University of Chicago. A. S. Barnes & Co., New York. Pp. 231. Price, $1.75.

This is a practical work, and has been prepared with especial reference to the requirements of medical students. The author remarks that it would have been easier to compile a larger book, from the bewildering wealth of results afforded by the labors in this branch of science, but he has preferred to prepare a concise and perspicuous outline of the subject, designed to follow some previous work on inorganic chemistry. The book is very neat in form; parenthetical references are given to authorities and original papers; pains are taken to give due prominence to the researches of American chemists; and the volume is supplemented by a careful and copious index.

Through Rome on: A Memoir of Christian and Extra-Christian Experience. By Nathaniel Ramsay Waters. New York: Charles P. Somerby. Pp. 452. Price, $1.75.

By Rome, the author here means the Roman Catholic form of Christianity. He early migrated out of Protestantism, and, having settled for a while in Catholicism, moved out into the region of religious doubt and denial, where he claims that he first found true peace. The book is a sort of theological autobiography, in which he visibly and forcibly delineates his mental experiences as a Protestant, a Catholic, and a skeptic. It is earnest in spirit, keenly controversial, and contains many views which mark the author as a man of reflection and originality.

The World's Progress: A Dictionary of Dates; being a Chronological and Alphabetical Record of All Essential Facts in the Progress of Society, from the Creation of the World to the Present Time. With a Chart. Edited by George P. Putnam, A. M. Revised and continued to August, 1877, by F. B. Perkins. New York: G. P. Putnam's Sons. Pp. 1020. Price, $4.50.

This old and standard book of reference has been revised, brought up to time, and is now reported as in its twenty-first edition. It contains a great amount of information, and, when the method of it is understood, it is conveniently available for use; but it may be observed that if the world's progress had taken place in accordance with the plan of this work, it would have been a somewhat mixed and chaotic affair. The chronological tables conform to the idea of historical progression, but the main body of the book consists of Hayden's "Dictionary of Dates," in which the events of the world are represented, not in the order of time, succession, and causality, but in the alphabetical order, and to this the progress of things has fortunately not conformed.

History of the Ottoman Turks from the Beginning of their Empire to the Present Time. By Sir Edward S. Creasy, M. A., late Chief-Justice of Ceylon. First American edition, from the new revised English edition. New York: Henry Holt & Co. Pp. 558.

The interest of the Eastern question in England has risen to such a point as greatly to stimulate the demand for works relating to the countries now implicated in war. Sir Edward Creasy has thus been led to revise and republish his history of the Turks, which has been long out of print, and Mr. Holt has done a good service to American literature in adding the book to his valuable series on the Oriental countries. The reputation of its author is a guarantee of its excellence, and in making the book over he seems to have spared no pains in the consultation of all authentic sources of information. Judge Creasy says, in his preface, that the most important historical work on the Turks is by the German Von Hammer, who has dealt with the subject so exhaustively that his history, if translated, would make at least twenty English octavo volumes. He has followed this author closely in the reconstruction of his own work, and he speaks of the German treatise to which he is so much indebted in the following terms:

"Von Hammer's 'History of the Ottoman Empire' will always be the standard European book on this subject. The history was the result of the labors of thirty years, during which Von Hammer explored, in addition to the authorities which his predecessors had made use of, the numerous works of the Turkish and other Oriental writers on the Ottoman history, and other rich sources of intelligence which are to be found in the archives of Venice, Austria, and other states that have been involved in relations of hostility or amity with the Sublime Porte. Von Hammer's long residence in the East, and his familiarity with the institutions and habits as well as with the language and the literature of the Turks, give an additional attractiveness and value to his volumes. His learning is as accurate as it is varied; his honesty and candor are unquestioned; and his history is certainly one of the best productions of the first half of our century."

Ethnography and Philology of the Hidatsa Indians. By Washington Matthews. Pp. 245. Washington: Government Printing-Office. (No. 7 of "Miscellaneous Publications" of Hayden's Survey.)

The author of this monograph, while stationed at a military post in Dakota Territory as assistant surgeon, availed himself of the opportunity thus afforded of studying the manners and customs and the language of the neighboring Indian tribe—the Hidatsas or Minnetarees. Among the subjects treated under the head of ethnography are ceremonies, mythology, marriage, relationships, hunting, divisions of time, etc. The philological section is very elaborate, containing a systematic grammar of the language, a pretty full Hidatsa-English dictionary, an English-Hidatsa vocabulary, and a list of local names.

Bulletins of the U. S. Geological and Geographical Survey of the Territories. Vol. III., No. 4. Washington, 1877.

The bulletins of the U. S. Geological Survey, issued by Dr. Hayden to facilitate the publication of the work done by the scientific men of his staff, and to place before the public speedily the results of his explorations, have now reached the completion of their third volume. The last number is mainly of interest to entomologists, containing an account of the first discovered traces of fossil insects in the American Tertiaries, by Mr. S. H. Scudder. This paper, of 20 pages, is a complete statement of past and present investigations, showing a record of forty-six described fossil species, of which more than half belong to the *Diptera*. Mr. Scudder also describes two species of *Carabidæ* from interglacial deposits near Toronto, C. W. The remaining papers in the number are a description of a new crawfish (*Cambarus Couesi*) from Dakota, by Dr. Thomas H. Streets; and three paleontological papers, by Prof. E. D. Cope, upon reptiles and fishes from Colorado and Wyoming. A very minute index to the whole volume concludes this number.

I. Annual Report of the New York Meteorological Observatory for 1876. By Daniel Draper, Director. Central Park.

II. Report on the Central Park Menagerie, for 1876. New York: by W. A. Conklin, Director.

The first of these handsome pamphlets consists chiefly of tables giving the results of the daily observations at the park, as to the heights of the barometer; force and direction of the wind; rainfall; temperature, etc. The value of a single volume of this kind is very small, but the great importance of such records when extending over a great length of time and a wide area is beginning to be duly appreciated, not only by scientific men, but by the business community generally, being often consulted, Director Draper tells us, for legal and other purposes.

Last year the director was engaged in examining the question, "Has there been in late years any change in the rainfall of New York City, or its vicinity, to affect seriously its water-supply?" His conclusions are, that for a series of years, up to 1869, the rainfall was increasing; "it then showed a tendency to decrease. There are, undoubtedly, cycles of rainfall, as there are cycles in sun-spots and other astronomical phenomena, occupying years for their completion." No predictions are ventured as to the date when the diminution will have reached its minimum and the ascent recommence, the observations being too incomplete for that purpose.

The "Report on the Menagerie" does not show that feature of the park to be in a growing condition. During the year 1876 but nineteen dollars was expended for the purchase of animals, while additions by donation, births, exchanges, and losses, have all fallen off. The number of animals on exhibition at the close of 1876 was: mammals, 184; birds, 394; reptiles, 5: total, 583. The value of those owned by the department is $15,554; owned by exhibitors, $47,390. This result is doubtless due to a reduction in appropriations. It would seem that the menagerie was deserving of a little more fostering care, for that it is a feature which largely interests the public is shown by the great number of visitors, estimated at 3,000,000 for the year.

I. On Some Unexplained Phenomena in the Geyser Basins of the Yellowstone Park.

II. The Two-Ocean Water: The Union of the Atlantic and Pacific Oceans in the Rocky Mountains. By Theodore B. Comstock, B. S.

The object of the first of these papers is to call attention to the importance of improving all opportunities for research, in the region of the National Park on the Yellowstone, concerning the rare phenomena presented by the geysers. These striking features are rapidly waning, and must be studied soon if studied at all.

The "Two-Ocean Water" is, it would seem, a verity, the fact having been established by the expedition of Captain W. F. Jones in 1873. Between Flat Mountain and the Yellowstone Range, and near the headwaters of the Snake and the Upper Yellowstone Rivers, there is a rivulet which was found to divide, "one portion gliding silently into the river behind us, to find its way at last into the Gulf of Mexico, while the other branch descended in front to join the westward-flowing waters of the Columbia, *via* Snake River, finally reaching the Pacific Ocean." The stream bears the name of "Two-Ocean Creek," and its two branches are named respectively Atlantic and Pacific Creeks.

The American Palæozoic Fossils: A Catalogue of the Genera and Species, with the Names of Authors, Dates, Places of Publication, Groups of Rocks in which found, and the Etymology and Signification of the Words, and an Introduction devoted to the Stratigraphical Geology of the Palæozoic Rocks. By S. A. Miller. Cincinnati, Ohio: The Author, No. 8 W. Third Street, 1877. Pp. 253.

We give this long title in full, as it explains in as few words as possible the scope and contents of a very useful book. It is a check-list of American Palæozoic fossils, but it is something more; and the added features are those which will make it specially welcome to students and amateurs who do not have access to large libraries and collections.

The labor of collecting and arranging the materials for such a work is very great, and will, we hope, be appreciated sufficiently to reward the author in some degree for his painstaking zeal.

A paper on the "Construction of Systematic Names in Paleontology," by Prof. E. W. Claypole, forms an important part of the book.

Serpent and Siva Worship. By Hyde Clark, M. A. I., and C. S. Wake, M. A. I. Edited by Alexander Wilder, M. D. New York: J. W. Bouton. Pp. 48. Price, 50 cents.

These papers, reprinted from the *Journal of the Anthropological Institute of Great Britain*, are examinations into the nature of the worship of the serpent, with a view to tracing its origin and connections, and are important as contributions to the material from which alone a philosophical theory of sociology can be formulated. The facts cited confirm Mr. Spencer's conclusions as to the intimate relations between ophiolatry and ancestor-worship.

On a Scientific Course of Study. A Paper read before the State Teachers' Association of Iowa, by Prof. C. E. Bessey. Pp. 11.

This seems to be in some measure an effort to reconcile the antagonism between the languages and science as means of culture.

The author is not disposed to underrate the importance of the sciences, and makes some excellent remarks as to the methods of teaching them to the young; the necessity of beginning the science-teaching early; and also as to the value of the languages as tools for the scientific man. But he seems to miss the real question at issue in the "conflict." It is not "What kind of training is best to produce a scientific specialist?" but "What are the relative claims of the study of language and of natural science in giving the discipline and culture which will be useful in the ordinary walks of life?" Upon this point we would refer Prof. Bessey to Prof. Bain's article on "Language-Culture and the Civil Service," in the December number of The Popular Science Monthly.

I. Proceedings of the Davenport Academy of Natural Sciences. Vol. II., Part 1. Davenport, Iowa. Pp. 148. Price, $3.

II. Proceedings of the Boston Society of Natural History. Vol. XVIII., Part 4. Boston. Pp. 104.

The first of the above volumes is largely taken up with records of the business meetings of the Davenport Academy, its condition, etc., interspersed with some papers of interest. The majority of these are archæological, being descriptive of mounds and their contents, illustrated by several fine photographic plates of inscribed tablets. Iowa is rich in these relics of the mound-builders, and there is a fitness in the Academy devoting itself to a study of these remains, which are fast disappearing.

The Boston "Proceedings" is filled with the results of more steady-going, thorough work, as might be expected from its greater age, and its locality in a centre where scientific men congregate. The table of contents includes papers on "The Origin of the Domestic Sheep," by G. W. Bond; "Genetic Relations of Stephanoceras," by Prof. A. Hyatt; "Reptiles and Batrachians from the Isthmus of Panama," by S. W. Garman; "Notes on Noctuæ from Florida," by A. R. Grote.

Ninth Annual Report on the Noxious, Beneficial, and other Insects of the State of Missouri. By Charles V. Riley, State Entomologist. Jefferson City, 1877. Pp. 130.

This continuation of Prof. Riley's labors in the field in which he has become so well known covers observations on the currant, gooseberry, strawberry, and pine worms; the army-worm, Colorado potato-beetle, Rocky Mountain locust, etc.; together with the insects which, acting as parasites, help to diminish the number of these pests.

The illustrations are numerous, drawn mostly by the author from Nature; the suggestions are practical, and make the reports valuable to the agriculturist as well as to the scientific entomologist. The locust, or so-called grasshopper, naturally receives the fullest attention, and certainly the facilities for observation have been ample enough for the accumulation of information that will be of use, should the West be again visited by that scourge.

Savings-Banks. A Paper read before the American Social Science Association, September 5, 1877. By John P. Townsend. New York, 1877.

This, as might be expected from the long experience of the author, is a valuable addition to savings-banks literature.

In the history of the rise and progress—we had almost said decline—of the system; the criticism of past and present management; and the suggestions as to the proper way to run such institutions, a thorough familiarity with the subject is shown. The remarks on the nature of investments are to be commended to presidents and trustees, and the plan for winding up insolvent institutions would, if adopted, do much to mitigate the loss and suffering which the present mode of procedure involves.

Some space is given to the details of a plan for school penny savings-banks, which is simple and perfectly practicable, having been found to work well both in England and on the Continent, cultivating habits of thrift in the young, and exercising an excellent influence in the communities where they have been started.

Egypt as it is. By J. C. McCoan. New York: Henry Holt & Co., 1877. Pp. 417. Price, $3.75.

The task which Mr. McCoan has undertaken is, to describe and explain the economic conditions of the New Egypt, as will appear from the titles of the chapters, which include those on the territory, population, administration, finance, commerce, agriculture, public instruction, public works, manufactures, etc., with a series of appendices giving statistical information about the government, finances, trade, cost of living, etc.

The author says that he found this corner of the field of book-making on Egypt almost untouched. No material lay ready to his hand, but his facilities for getting it were good, and he has made excellent use of them. The Government of Egypt is the khedive. Legislative bodies, ministers, and cabinets, are mere agents of his personal will, and the recent progress is due mainly to his wisdom and energy. His highness is now forty-six years old, below the middle height, stout, though not unwieldy, and with nothing of an Eastern but the native dignity and easy polish of his manners. He devotes fourteen hours a day for at least three hundred days in the year to the work of administration, is familiar with all the details of national affairs, and in the extent and variety of his information is as encyclopedic as Dom Pedro himself.

The book corrects some common misapprehensions. Taxation of the peasantry, for example, though heavy, is not so oppressive nor enforced so brutally as we have been given to understand; and the system of slavery, though in itself indefensible, is not at all such as formerly obtained in the United States, and still exists in Cuba and Brazil. In both these respects the condition of Egypt is vastly better than that of the nominally ruling country, Turkey. An excellent map and a copious index add to the value of the book.

Heredity: Its Influence upon the Progress and Welfare of Mankind. By E. N. Brush, M. D. Buffalo, 1877. Pp. 12.

Heredity as a Factor in Pauperism and Crime. By E. H. Parker, A. M., M. D. Poughkeepsie, N. Y., 1877. Pp. 12.

Criminality. By W. G. Stevenson, M. D. Poughkeepsie, N. Y., 1877. Pp. 23.

These pamphlets are all reprints of papers read before medical societies, and have a common object, which is to show the importance of heredity in fixing the organic characteristics of the individual, and so determining the part which he shall play in society—characteristics which are, of course, modified to a greater or less extent by the environment. They are chiefly interesting as showing how wide is the recognition that is being accorded to the important labors of Mr. Darwin and his co-workers.

PUBLICATIONS RECEIVED.

Proteus; or, Unity in Nature. By C. B. Radcliffe, M. D. London and New York: Macmillan. Pp. 222. $2.50.

Deed and Creed. By Dr. Felix Adler. New York: Putnam's Sons. Pp. 248. $1.50.

Determination of Rocks. By E. Jannetaz. New York: Van Nostrand. Pp. 165. $1.50.

Creed of Christendom. By W. R. Greg. Boston: Osgood & Co. 2 vols. $7.

Report of the Nashville Board of Health. Pp. 230.

Biology. By J. Cook. Boston: Osgood & Co. Pp. 337. $1.50.

The Signal Boys. By G. C. Eggleston. New York: Putnam's Sons. Pp. 218.

Doubleday's Children. By D. Cook. New York: Putnam's Sons. Pp. 430.

Myths and Marvels of Astronomy. By R. A. Proctor. New York: Putnam's Sons. Pp. 371. $4.

Report of the Commissioners of Agriculture (1876). Washington: Government Printing-Office. Pp. 447.

Methods of Ethics. By H. Sidgwick. London and New York: Macmillan. Pp. 497. $4.

Geology of Wisconsin. By T. C. Chamberlin, Chief Geologist. Vol. II. Pp. 787. With Atlas.

Vital Magnetism. By F. T. Parson. New York: Adams, Victor & Co. Pp. 235. $1.25.

At the Court of King Edwin. By W. Leighton, Jr. Philadelphia: J. B. Lippincott & Co. Pp. 157. $1.25.

The Electric Register. By Le R. C. Cooley. From the *Journal of the Franklin Institute*. Pp. 5.

The Convection Thermoscope for Projection. By Le R. C. Cooley. Pp. 4.

Five Entomological Papers. By C. V. Riley, Ph. D. From "Transactions of the St. Louis Academy of Sciences." Pp. 34.

Functional Dystocia. By Dr. E. M. Hale. Pp. 36.

Birds of Connecticut. By C. H. Merriam. From "Transactions of the Connecticut Academy." Pp. 165.

Circular of Bureau of Education. Washington: Government Printing-Office. Pp. 28.

Transactions of the Kansas Academy of Science. Topeka: G. W. Martin. Pp. 75.

Contributions from the Chemical Laboratory of Harvard College. By J. P. Cooke, Jr. Pp. 131. With Plates.

Admission of Girls to the Boston Latin School. By President Warren. Pp. 8.

Why Scientists are not Christians. By E. A. Beaman. New York: E. H. Swinney. Pp. 16.

Medical Intolerance. By Dr. R. A. Gunn. New York: Munroe & Metz. Pp. 23.

What Anæsthetic shall we use? By Dr. J. J. Chisolm. Baltimore: *Sun* print. Pp. 23.

Reptiles, Fishes, and Leptocardians of the Bermudas. By G. Brown Goode. From *American Journal of Science*. Pp. 10.

Report of the Philadelphia Water Department (1876). Pp. 125.

List of Writings on Method of Least Squares. By M. Merriman, Ph. D. From "Transactions of the Connecticut Academy." Pp. 82.

American Archæology. By Dr. A. J. Howe. Pp. 8.

Sanitary Condition of Portland. By Dr. F. H. Gerrish. Portland: S. Berry print. Pp. 30.

Illinois State Historical Library. Springfield: D. W. Lusk print. Pp. 7.

Notes on Leather. By Lieutenant D. A. Lyle, U. S. A.

Medical Jurisprudence. By Dr. S. E. Chaillé. From "Transactions of the International Medical Congress." Pp. 40.

Catalogue of Minerals in the Naval Academy Cabinet, Annapolis. Washington: Government Printing-Office. Pp. 21.

Budge and Toddle. By L. G. Morse. New York: Putnam's Sons. Pp. 303.

Syllabus of Lectures in Anatomy and Physiology. By T. B. Stowell. Syracuse, N. Y.: Davis, Bardeen & Co. Pp. 82.

A Layman's Experience in Homœopathy. By W. H. Furness. Pp. 8.

Money and Legal Tender. By H. R. Linderman. New York: Putnam's Sons. Pp. 173. $1.25.

POPULAR MISCELLANY.

Our Current Weights and Measures.—The absurdities of our present no-system of weights and measures surpass belief: they have their parallel in the absurdities of our present no-system of "orthography," but hardly anywhere else. The question of reducing to rule the current English orthography is now receiving attention, but the prospects of anything being done are gloomy enough. So, too, we hear occasionally of the necessity of reforming our weights and measures, but as yet no real progress has been made in any of the English-speaking countries. Our excellent contemporary, the *Engineering and Mining Journal*, in the course of an article favoring the adoption of the "metrical" system, gives the following apt illustration of the deplorable multiplicity of standard tons now in use:

"In a copper-works ore is measured and paid for by the (tribute) ton of 2,352 pounds, from the mine through the mill, till it comes out of the jigs, when suddenly it is transformed into a ton of 2,240 pounds (the difference, perhaps, going out in the tailings), which is the ton of the roasting and smelting furnaces and of the teamsters. This continues till the copper is sold or carried over some roads, when the ton shrinks again and becomes 2,000 pounds. At the iron-works there are still more tons, different from these, and on the railroads one will report the coal carried in tons of 2,240 pounds, and another connecting road uses the ton of 2,000 pounds. And in order to maintain the beautiful symmetry of our system, they, of course, rarely, if ever, state what kind of a ton is used in either case. Coal is mined and miners are paid by tons of various weights, from 3,000 pounds to 2,000 pounds. It is sold by tons of 2,240 and 2,000 pounds, and by tons running all the way down to 1,500 pounds. The use of the ton less than 2,000 pounds is called cheating, but the large purchasers, those who buy from a car-load (six tons) up, may get 2,240 pounds to the ton; but, if they buy from the same company's retail yard, they find the ton weighs no more than 2,000 pounds, if it does that. Coal is sold by bushels of 76 pounds and 80 pounds, by barrels, loads, hogsheads, and other 'standards,' the weights of which depend originally on the fancy of the individual, and subsequently on 'immemorial custom.'"

A Kansas Gas-Well.—About three years ago a company prospecting for coal discovered at Wyandotte, Kansas, a fountain of combustible gas. This gas, as we learn from the *Western Review of Science and Industry*, is now used by the company for steam-making, and by the owner of the farm where it is located for cooking and illuminating purposes. The gas, whether flowing or burning, is almost odorless, and its entire freedom from sulphur adapts it very well for use in the reduction of gold and silver ores. Notwithstanding a coal-vein of considerable thickness was discovered, the company has concluded to abandon coal-mining for the present, and utilize this new gas-fuel. Nor is the latter adapted for heating purposes alone; it is also very valuable for light, inasmuch as it burns with a clear, bright flame, even without purification, and is free from the disagreeable odor accompanying coal-gas. The city of Wyandotte will soon be lighted by this gas, which, as it comes from the well, is of twelve-candle power. At small cost it can be purified so as to make it sixteen-candle power. The brine ejected from the well by the escaping gas is not strong enough for the manufacture of salt; it is recommended as a medicinal agent for the treatment of sundry diseases. The company contemplate erecting an extensive establishment for mineral baths.

A Plague of Rats.—Shortly after the settlement of the Bermudas by the British, the colony was infested with rats, which, in the space of two years, had increased so alarmingly that none of the islands were free from them, and even fish were taken with rats in their bellies. A writer in the *Academy* recalls some of the horrors of this plague of rats. The rats, we are told, had nests in almost every tree, and burrowed in most places in the ground like rabbits. They devoured everything that came in their way—fruits, plants, and even trees. Where corn was sown they would come by troops in the night and scratch it out of the ground; "nay," writes a contemporary chronicler, "they so devoured the fruits of the earth that the people were destitute of bread for a year or two." Every expedient was tried to destroy them. Dogs were trained to hunt them, who would kill a score or more in an hour. Cats, both wild and tame, were employed in large numbers for the same purpose; poisons and traps—every man having to set twelve traps—were brought into requisition; and even woods were set on fire, to help to exterminate them. Every letter written at this period by the plague-stricken colonists contains some account of the dreadful scourge. "Our great enemies the rats threaten the subversion of the plantation," writes one colonist in July, 1616. "Rats are a great judgment of God upon us," wrote another a year later. "At last it pleased God, but by what means is not well known, to take them away, insomuch that the wild cats and many dogs that lived on them were famished." There was universal joy at the sudden removal of such destructive vermin; and the all but despairing planters were enabled once more to resume their neglected occupations with spirit and energy.

Composition of Pumpkins.—Analyses of pumpkins, made by Prof. F. H. Storer, of the Bussy Institution, show that the rind of that vegetable is nearly three and a half times as rich in albuminoids as the flesh. The weight of albuminoids in the flesh is only about one-fifth as much as that of the carbohydrates, a proportion that has sometimes been found in turnips. Again, the inside or offal portion (including the seeds) of the pumpkin contains a large proportion of nitrogen, and the seeds yield a high percentage of oil. "The presence of such large amounts of oil, and of albuminous matters," adds Prof. Storer, in the *Bulletin of the Bussy Institution*, "would naturally go to show that pumpkin-seeds must be a highly-nutritious kind of food; and it may well be true that they are valuable for some kinds of animals, when administered carefully and in moderate quantity. But it has often been urged that the seeds are apt to do harm to animals that have eaten them. . . . There is little question that this idea is to a certain extent founded in fact." The dangers of using the seeds must, however, be both small and remote, since, as the author shows, New England farmers usually feed out the seeds with the flesh; still they should not be fed to milch-cows. Regarding the use of these seeds as articles of human food, the author quotes Pumpelly as saying that the kernels are eaten by the Chinese. In Egypt, too, pumpkin-seeds are eaten in the same way that nuts are eaten in other countries.

Ancient Man in Japan.—Prof. E. S. Morse has made an important discovery in the study of ancient man in this part of the world, lighting on evidence of the remains of prehistoric inhabitants of Niphon who apparently must have antedated even the Ainos. The eyes of this distinguished scholar, possessing as they do the rare quality of seeing, observed, while he was on his first trip to the capital from Yokohama, one of those significant shell-heaps which have been found in many countries and prove the high antiquity of the human race. This particular *kjockkenmoedding* is situated near Omori, on the line of the railroad, and is rich in evidence of a rude people that dwelt in Japan at a very early age. Prof. Morse has been engaged for many years in the study of these mounds, as found in Maine, North Carolina, and Florida. This heap, which is about ten feet in thickness at its greatest diameter, under a loam-deposit of six feet, and half a mile from the present shore of the bay, exhibits all the peculiarities of its type, containing bone, both in fragment and rudely fashioned into implements, and characteristic pottery. Some of the earthenware is curious enough, and is thoroughly representative of a development of the race coinciding with that of the ancient savages of America and Europe. The professor has made an exhaustive study of the deposit, and there seems little doubt of its true character. As, however, he has consented to address the Asiatic Society on the subject at its approaching meeting, we will not enlarge more particularly upon it at present, only advising all to avail themselves of the rare opportunity to hear one of the most fascinating of American lecturers on a theme of novel and great local interest.—*Tokio Times.*

Interesting Ethnological Specimens.—At a meeting of the Natural History Section of the Long Island Historical Society, Mr. Elias Lewis, of Brooklyn, exhibited several remarkable specimens of smoked Indian heads, brought by Mr. Ernest Morris from the hitherto little known region near the source of the Tapajos River, in Central South America. Some account of these heads was given by Mr. Lewis, and published in the *Brooklyn Eagle*. They are ten in number, and of great ethnological interest. The natives seemed to well understand the art of preserving them, but were exceedingly unwilling that Mr. Morris should get possession of the peculiar wood or root by the smoke of which they are preserved. A piece, however, was obtained and hidden by Mr. Morris in his luggage. The flesh and muscles of the smoked heads are shrunken somewhat, and quite hard, but the features are not distorted, and have a singularly life-like appearance. All the lineaments of the face are clear and well defined. Most of the faces are tattooed. The hair is long, black, and very thick on the scalps, and the red paint with which the natives adorn themselves still remains in the hair of several of the specimens. The heads are ornamented with feathers, strings, and other appendages. In most cases the front teeth are wanting, having been knocked out previous to the smoking. Mr. Morris obtained the heads from the chief or principal man of one of the tribes in exchange for knives and other articles, and brought them away with great difficulty and some risk. In a letter from Mr. Morris it is stated that "the heads are those of the Parrebeate Indians, better known as the Parrintintins, who inhabit the land of the upper Tapajos. They are mostly taken in war and kept as trophies, and are preserved by smoke from a root which they call *carrocopowpow*. "They are very much as they appear in life, except that a cord is put in the mouth to carry them by, and the eyes are covered with a mass of wax. The practice was current among the Mundurucu tribe long since, but now appears to be practised only among the wild tribes which inhabit the country near the sources of the Tapajos and Hingu Rivers. The heads were taken about two years ago." One of the heads is that of a woman. Mr. Morris is now on his way to the Amazon for further exploration, and a part of the collection is offered for sale in his interest; the rest will be placed in the museum of the Long Island Historical Society.

A New Japanese Fruit-Tree.—We have received from Prof. R. H. Wildberger, of the Kentucky Military Institute, some of the fruit of the *Guikgo biloba*. This fruit was matured on a tree growing in the institute grounds, and is supposed to be the first ever produced in the United States. In a communication to the editor, Prof. Wildberger says that the tree is a native of Japan, and has been largely introduced into the United States and Europe, on account of its ornamental appearance. The one in the Military Institute flowered and fruited in June; in September the fruit began to turn yellow, and, after one or two frosts in October, to fall. This tree, which is about thirty feet in height, stands about eighteen feet from another of the same species which bore no fruit. Being absent at the period of flowering, our correspondent was unable to determine whether the species is diœcious, i. e., bearing pistillate flowers on one tree and staminate on another. Of the fruit he writes that it is a *drupe* or stone-fruit, about the size of a common wild-plum, much resembling it while green; but when mature it has a shriveled appearance, and is yellow in color. The sarcocarp, or fleshy part, is easily separable, disclosing the *putamen*, or stone, which is smooth and thin-walled, containing a kernel as large as a plum-stone, which has a pleasant taste. The sarcocarp has an acid, astringent taste, and a rather fetid odor. The kernel is said to be highly prized in Japan, and to be served at all banquets, being supposed to promote digestion and prevent flatulence.

New Order of Extinct Reptilia.—The museum of Yale College lately received the greater portion of a huge reptilian skeleton, found on the eastern flank of the Rocky Mountains, in beds that have been regarded by Prof. Marsh as corresponding nearly to the Wealden of Europe, and which may be classed as Upper Jurassic. Prof. Marsh writes that the remains are well preserved, but imbedded in so hard a matrix that considerable time and labor will be required to prepare them for a full description. The characters already determined point to affinities with the Dinosaurs, Plesiosaurs, and more remotely with the Chelonians, and indicate a new order which may be termed *Stegosauria*. The animal was probably thirty feet long, and aquatic; the body was protected by large bony dermal plates, which appear to have been in part supported by the elongated neural spines of the vertebræ. One of these dermal plates was over three feet in length.

Origin of the Moral Sense.—According to Darwin's theory the moral sense, conscience, is a development of the animal instinct of self-preservation. The scope of this instinct was at first confined within the individual; it was next extended to the group of animals in which it lived. In a low stage of human development, man would be bound by the ties of moral obligation at the most to those of his own tribe; but as he advances in civilization, and small tribes are united into larger communities, "the simplest reason," says Darwin, "would tell each individual that he ought to extend his social instincts and sympathies to all the members of the same nation. This point once reached, there is only an artificial barrier to prevent his sympathies extending to the men of all nations and races." Moral sense, in this theory, is an enlargement of an animal instinct, illumined by the light of reason. To many persons this way of accounting for the origin of morality is an abomination; it is supposed that thereby something is taken from the preëminent dignity of man. The objection is well met by Mr. J. A. Allen, who writes as follows in the *Canadian Monthly:* "I should be satisfied to resign my free-will to do wrong for a nature so constituted that I must always love and do the right. What, by instinct? Yes, by instinct, or by anything else. I should like to be always *instinctively* inclined to good, as the bee to make honey. But if I am denied this—if our nature is not yet adjusted to the requirements of the golden age—it is something to possess an unchangeable instinct of right at the very core of our being, which can neither be plucked out nor enslaved by the will, nor silenced by terror or bribes or flattery. But instinct! How undignified to be forced to do right by compulsion! What? By the compulsion of our own nature, by the imperious and imperial sense of our obligations to our fellow-men? On the contrary, I think that we should be ennobled by the possession of such a moral force." Of the mode in which the principles of morality are propagated Mr. Allen writes: "The maxims of morality, more or less true, come down to us by tradition, and root themselves in our youthful minds; but the solidified moral sense is transmitted by heredity, and forms an integral part of our very selves. It is, so to speak, our experiences, not *from* but *in* our grandfathers; the result stereotyped in our constitutions of all the ictuses of the various forces in this direction which had affected the whole line of our ancestry from the very first—transmitted feelings in transmitted structures."

The Waste of Wire-Works.—We are indebted to the *Polytechnic Review* for an account of a process in use at Worcester, Massachusetts, for utilizing the waste of a great wire-working establishment. Formerly the dilute sulphuric acid used for cleaning the wire was allowed to run into the sewer when it had become so charged with iron scale as to cease to "bite," and large quantities of refuse wire were employed only to fill up hollows in grading, or thrown into a heap. All of this waste material is, however, now converted into articles of commercial value by simple and comparatively inexpensive processes. The diluted acid, charged with iron, is heated in lead-lined tanks by means of steam passing through coils of copper pipe, the waste wire being thrown in. In about five days the acid, under the influence of heat, has taken up a large proportion of iron and become liquid sulphate of iron, which is then evaporated until it deposits the crystals known in commerce as copperas. Three tons of this solid sulphate are made per day from about twelve tons of the waste acid. The remaining liquid is returned to the receiving-tank, to be mixed with more of the waste acid and refuse wire; and so the work goes on in a continuous round. Even the waste of this product from waste is utilized. The settlings of the boiling-tank—oxide of iron—together with the waste copperas, an alkali, and an inexpensive substance to give "body," are roasted, ground, and transformed into a pigment equal to imported Venetian red. Of this the company makes about 500 barrels per month.

Spongy Iron Filters.—Dr. Gustav Bischof, inventor of the method of purifying water by filtration through spongy iron, recently detailed to the London Royal Society the results of sundry experiments on this and other filtering media. In the experiments fresh meat was placed on the perforated bottom of a stone-ware vessel, which was then filled to about two-thirds with the materials to be experimented upon, and lastly with water, care being taken to prevent the access of bacteria to the meat from any source save the filtered water. In Experiment I., spongy iron was used as the filter: after a fortnight's steady percolation of the water, the meat was fresh. Experiment II. was with animal charcoal: after a fortnight the meat gave signs of incipient putrefaction. Experiment III. was with spongy iron again, the water being allowed to flow for four weeks: the meat was perfectly fresh. In Experiment IV., which reproduced Experiment II., with the exception that the length of time was doubled, the meat was found to be soft and putrid. In the foregoing two experiments with spongy iron, the fine dust of that material had not been separated: in Experiment V. this was done: after four weeks the meat, again, was fresh. To prove that iron in solution was not in these cases the preserving agent, in Experiment VI. a stone-ware vessel was charged underneath the spongy iron with pyrolusite and sand, so as to abstract the iron from the water before it came in contact with the meat: again the meat was fresh after four weeks' filtration. Experiment VII.: by a separate experiment it had been ascertained by Dr. Bischof that the oxygen is completely abstracted from water during its passage through spongy iron. To determine whether the absence of oxygen is the cause of the preservation of the meat, and whether the bacteria or their germs are killed or can be revived when supplied with oxygen, an evaporating basin was inverted over the meat. Though this must have retained a quantity of air in its cavity, the meat still was found fresh after four weeks. In the final experiment, fresh meat was placed at the bottom of a glass vessel and left standing covered, with about four inches of spongy iron and water. After three weeks the meat was very bad, thus showing that the action of the bacteria of putrefaction adhering to the meat was not prevented by the spongy iron above; and if, during the previous experiments with spongy iron, agencies capable of causing putrefaction had at any time come in contact with the meat—in other words, if the bacteria had not been killed in their passage through the spongy iron—the meat must have shown marks of their action.

The author accounts as follows for the action of this material: "I believe that the action of spongy iron on organic matter largely consists in a reduction of ferric hydrate by organic impurities in water. . . . Ferric hydrate is always found in the upper part of a layer of spongy iron, when water is passed through that material. The ferrous hydrate resulting from the reduction by organic matter may be reoxidized by oxygen dissolved in the water, and thus the two reactions repeat themselves. This would explain why the action of the spongy iron continues so long."

Marine Fishes in Lake Nicaragua.—The fish fauna of Lake Nicaragua has long been known to include a few species elsewhere found only in salt-water, as a *Megalops*, a shark, and a sawfish. How did these marine forms first enter the lake? Dr. Theodore Gill and Dr. J. F. Bransford, in a "synopsis" of the fishes of this lake, communicated to the Academy of Natural Sciences of Philadelphia, remark that this combination of species may have resulted—1. From the intrusion of the salt-water types into the fresh waters; or, 2. From the detention and survival of the salt-water fishes in inlets of the sea that have become isolated, and so, in course of time, fresh-water lakes. The latter hypothesis is declared the more probable one. By the uplift of the land an inlet of the Pacific might have been shut off from communication with the ocean, and the character of the water would be soon changed by the copious showers of that tropical country. The shark, sawfish, *Megalops*, and other species, mostly found in the sea, would have time to accommodate themselves to the altered conditions. At the same time, it must be remembered that most of the marine types in question are wont to ascend high up streams, and even into fresh water. Still, the numerous rapids of the river discharging from the lake discourage the idea that the species enumerated have voluntarily ascended the river and entered the lake. Of these fresh-water sharks of Lake Nicaragua, Squier says that "they are called *tigrones* from their rapacity," and that "instances are known of their having attacked and killed bathers within a stone's-throw of the beach at Granada."

Individual Hygiene.—Among the subjects discussed at a recent Educational Conference held in London was the importance of a knowledge of the laws of health. Mr. Thomas Bond, assistant surgeon to Westminster Hospital, asserted that, on an average, one-half of the number of out-patients treated by a hospital-surgeon suffer from diseases due primarily to a want of knowledge of the laws of health and cleanliness, chiefly in regard to *dress*, *ablution*, and *ventilation*. Varicose ulcers are most frequently caused by the use of elastic garters: these should never be worn by children, as the stocking can be perfectly well kept up by attachment of elastic straps to the waistband. If elastic garters are worn at all, they should be applied *above* the knee, and not below, where they obstruct all the superficial veins. Tight lacing, too, predisposes to varicose veins, in consequence of the abdominal viscera being pushed downward into the pelvis, causing undue pressure on the veins of the lower extremities. The hygienic use of clothes, the author said, is not so much to keep cold out as to keep heat in. In robust persons it is not at all necessary to put on extra clothing when preparing for out-door exercise: sufficient heat to prevent all risk of chill is generated in the body by exercise. But care should be taken to retain sufficient clothing after exercise, and, when at rest, to prevent the heat passing out of the body. The wearing of false hair prevents evaporation of the perspiration from the scalp, and so predisposes to baldness and other scalp-diseases.

Mr. Bond calls Urquhart, who introduced into England the Turkish bath, one of the benefactors of the age: this bath is, he says, stimulating and strengthening—a preventive as well as a curative in disease. Nor is this all: it promotes purity of mind and morals. He then suggests certain necessary precautions to be observed in the use of the Turkish and other baths. Coming to the subject of ventilation, he remarks on the feeling of lassitude felt by many persons in getting up in the morning. This is very often due to defective ventilation of the bedroom, or to the use of an undue amount of bedclothes. It is an error to suppose that a room can be ventilated by simply opening a window a little at the top: there must be an outlet as well as an inlet for the air. The best outlet is an ordinary fireplace, especially if there is a fire burning. Mr. Bond recommends for ventilation purposes the use of vertical pipes, communicating at the level of the floor with the outer air, and rising vertically to the height of four or five feet.

Marbleized Iron Utensils.—Sundry cooking-utensils of so-called "marbleized iron" have been subjected to chemical tests by Mr. William H. Dougherty, with the results given below, as stated in the "Proceedings" of the Academy of Natural Sciences of Philadelphia. The author, having heard reports that the enamel contained lead and arsenic, poured into a new dish of this ware a pint of good ordinary "white-wine" vinegar. This was then slowly evaporated nearly to dryness; then distilled water was added, and the whole treated with hydrosulphuric acid. The resulting precipitate of sulphide of lead was now dissolved in nitric acid and reprecipitated with sulphuric acid in presence of alcohol as sulphate of lead, and weighed over $2\frac{3}{4}$ grains. This result was further confirmed by reducing the sulphate to metallic lead with the blowpipe. From this it appears that the vinegar had dissolved out of the enamel enough lead to make about three grains of acetate of lead. Similar results were obtained from another experiment, in which citric acid took the place of the vinegar. A can of tomatoes in an acid condition was digested in another dish of this ware and filtered, the filtrate being treated as in the foregoing experiments. In this instance slight but positive evidence was found of the presence of lead. The author could detect no arsenic. He states the composition of the enamel to be as follows: oxide of lead, 12 per cent.; silica, 47; alumina, iron, lime, potash, and soda, 41 per cent.

Was Man preglacial?—The Anthropological Institute of London lately held a conference on "the present state of the question of the antiquity of man," in the course of which the evidences of man's antiquity in England were very fully considered. The papers read at the conference by Prof. Boyd Dawkins, Prof. McKendrick Hughes, and Mr. R. H. Tiddeman, as also the highly-interesting discussion which followed, are reported in *Nature*. Our contemporary devotes several pages to the proceedings of the conference, but we have only space to indicate one or two of the more important lines of argument. First, as regards the validity of the arguments of Croll, Geikie, and others, that because in river-deposits and caves the bones of animals which now live only in hot climates are associated with the bones and other memorials of man, and as *after* the glacial period there is no evidence of such hot climate in England, therefore all these remains are preglacial or interglacial. To this it was objected that these animals of hot climates had preyed on such boreal animals as the reindeer; that the hippopotamus and rhinoceros in the Regent Park Zoölogical Garden do not suffer even in very cold weather; and that in the isle of Saghalien, to the north of Japan, the reindeer is preyed upon by the tiger, which crosses the ice in pursuit of its victim. Hence it follows that mammals are not good indicators of temperature. Mr. Tiddeman rested his argument for man's antiquity in Britain on the occurrence of a (supposed) human fibula and two hacked bones of goats in deposits older than the post-glacial. But Prof. Busk objected that the "fibula" was probably ursine, and, at all events, that it was altogether too insignificant a fragment on which to base any far-reaching conclusion. The goat-bones, hacked as if by the hand of man, were found in Victoria Cave, at the depth of fifteen and twenty-five feet respectively. But it was urged that these bones really belonged to a superficial stratum, and had fallen down to a lower level while the work of excavation was going on. But, even supposing them to belong to the levels from which they were taken, these bones are not decisive as to the age of the deposit in which they were found—a matter which is still in dispute. Arguments *pro* and *contra* were advanced by sundry members of the Institute, and the various evidences of the antiquity of man were considered in the light of geology, anatomy, the science of language, and paleontology. But no positive result was reached one way or the other; nevertheless, the conference was not without fruit, inasmuch as it has done much to remove misapprehensions, and to indicate the proper lines of research.

Electricity in War.—Mr. H. Baden Pritchard, in one of his communications to *Nature* on scientific principles involved in the art of war, gives a sketch of the employment of electricity in military operations. He says that the employment of electricity for exploding charges of powder was suggested by Franklin and Priestley; only very recently, however, have we been in a position to make proper use of this valuable agent as a means of firing charges at a distance. One of the first applications made of the subtile fluid was in the removal of the wreck of the Royal George at Spithead, nearly fifty years ago, when the explosion of the charges was brought about by what is termed a wire fuse, a short piece of platinum thread stretched between two copper wires. The platinum bridge, having less conducting power than the copper wires, presents a considerable resistance to any current of electricity that passes, and so becomes heated sufficiently to ignite gunpowder. "But for many purposes," remarks Mr. Baden Pritchard, "the wire fuse is ill adapted to the military and naval services. A voltaic battery is necessary to evolve the low-tension electricity required to yield sufficient resistance and heat, and such a battery made up of metal plates, and involving the use of acids, is a cumbersome apparatus. In 1853 Colonel Verdu, of the Spanish army, with the aid of a Ruhmkorff coil, succeeded in firing half a dozen charges simultaneously. Wheatstone and Abel followed in Verdu's footsteps, and while the former directed his attention to the construction of a portable frictional apparatus, the latter busied himself in the preparation of a fuse inclosing a compound more easily explosible than gunpowder—a fuse which still holds an important place among warlike stores."

Alternation of Seasons and Tree-Growth.—The fact that the exogenous plants of the preglacial epoch show concentric growth-rings has been by many writers regarded as proof positive that in these times the earth's axis must have been inclined as at present, and that there must have been then, even as now, alternating seasons. But is alternation of seasons necessary to the formation of rings?

This question is considered by Dr. C. B. Warring, in a paper read before the New York Academy of Sciences, an extract from which has appeared in the *American Journal of Science and Arts*. The problem might be solved experimentally, says Dr. Warring, if we could secure for plants a uniform temperature throughout the year. The nearest approach to such a condition in this latitude is found in greenhouses. Exogenous plants so placed, e. g., the orange and lemon, *form growth-rings as regularly as do forest-trees*. The author has found it difficult to obtain any information as to the formation of these *annual markings* in exogenous plants growing in tropical regions.

But the facts appear to show that, in the *uniformly warm climate* of the tropics, rings are formed as regularly as in our own latitudes. True, in the tropics there are semiannual changes from wet to dry, and from dry to wet, dependent on the earth's axial inclination; but, as the author remarks, even when there is *absolutely no variation*, the rings are formed. For instance, mangroves, growing on the muddy margins of tropical rivers, having from year's end to year's end uniform temperature and moisture, present clearly-defined rings of growth. Then the *Cycads* require several years to form one ring. The author's conclusion is, that "these circles have their origin in cycles of activity and repose, implanted in the constitution of the plant, which would continue to manifest themselves although there were no climatic variations. It is true," he adds, "that where seasonal variations exist, the successive stages of activity and rest are for obvious reasons synchronous with them, but they are not absolutely dependent on them. . . . The existence, therefore, of these markings in the ancient flora gives no information as to the existence at that time of seasons, and, so far as they are concerned, we are left free to adopt any conclusion as to the inclination of the earth's axis which may appear to us most reasonable."

Preservation of Wood under Water.—The effects of long-continued submergence in water on oak-wood are remarkable, and several instances are cited in the "Annales des Ponts et Chaussées," by M. Charrié-Marsaines, of oak being transformed so as very closely to resemble ebony. Thus, some pieces of oak taken in 1830 from an old bridge at Rouen, which had stood about 700 years, were found to resemble ebony, the modification being due to the presence of peroxide of iron. M. Charrié-Marsaines himself having occasion, in constructing a discharge-sluice on the Rhine, to demolish an old military dam constructed in 1681 by Vauban, and based on a platform of oak, found this wood to have a dark color quite like that of ebony, and very great hardness, as was found on trying to cut it for use in the new works. The wood had then been 146 years in a soil constantly soaked by water, owing to the permeability of the layer of gravel here forming the bed of the Rhine.

NOTES.

In the gas-works at Rahway, New Jersey, a simple and ingenious method of upward filtration through coke and "breeze" is in use for removing from the waste residuum the injurious products which otherwise would pollute the streams into which the waste might flow. This method is fully described, with accompanying sketch, by Mr. J. R. Shotwell in a letter to Prof. Spencer F. Baird, Fish Commissioner. Mr. Shotwell's communication is published in full in the *Gas-Light Journal*.

General F. C. Cotton remarked, at the "Domestic Economy Congress," upon the mental inactivity of the army and navy, officers and men, in foreign parts. It was remarkable, he said, how little additional knowledge was brought home by these bodies from their visits to foreign countries. The speaker pictured "men sitting with their hands before them, or, what was worse, drinking brandy-and-water, who, if they had a slight knowledge of science given them at school, would have taken up some branch, and brought back valuable knowledge, instead of dyspepsia and discomfort."

Died, on Lake Titicaca, Peru, toward the end of September, James Orton, late Professor of Natural History in Vassar College. The deceased was born in 1830, graduated from Williams College in 1855, and a few years later became a Congregational minister. He was an instructor in natural sciences in Rochester University in 1866, and in 1869 went to Vassar College. He thrice visited South America for the purpose of studying its natural history. First, in 1867, he led an expedition from Williams College across the continent by Quito, the Napo, and the Amazon. Again, in 1873, he made a journey across South America from Para up the Amazon to Lima and Lake Titicaca. He once more returned to the same fields of exploration last year. He was the author of several works, the best known being "The Andes and the Amazon" (1870), and "Comparative Zoology" (1875).

Mr. Thomas Barrett, mate of the American whaling-bark A. Houghton, has arrived in New York, bearing with him a silver spoon with the arms of Sir John Franklin, which he obtained from an Esquimau at Whale Point, Hudson's Bay. From a party of Esquimaux, who camped during the winter of 1876–'77 near the winter quarters of the A.

Houghton, Mr. Barrett received a great deal of valuable information concerning the fate of Franklin and his men. It is proposed to send an expedition next spring to Hudson's Bay, and thence by sleds to the place where the men of the Erebus and Terror are buried —about 500 miles distant inland. The Esquimaux state that the white men left behind a lot of books with writing in them, which were buried in the cairns.

A correspondent of the *American Manufacturer* records as an "innovation in technical education" a recent visit paid to the Phœnixville Iron-Works by the classes in civil and dynamic engineering of the Pennsylvania University, under the charge of their professors. It is the intention of the professors to make frequent visits with their classes to all establishments of interest within convenient distance of the university. Each student will be required to take notes and make an elaborate report of his observations.

Died, September 17th, at his seat of Lacock Abbey, Wiltshire, England, William H. Fox Talbot, one of the discoverers of the art of photography. He was born in 1800, and received his education at Harrow School and the University of Cambridge. The course of experiments, which resulted in the production of a photographic image, were begun by him in 1833. His results were first published in February, 1839. Daguerre's researches had, however, been published a short time before. Of late years Mr. Fox Talbot took a deep interest in cuneiform inscriptions.

Having made exact measurements of 172 crania of known sex, Morselli reaches the following conclusions: 1. The cranium in man is to the cranium in woman as 100 : 85.7. 2. The lower jaw in man, compared with the same in woman, is in the proportion 100 : 78.5. 3. This last difference is noticed also in anthropomorphous apes. 4. Individual variations are more extensive in women than in men. 5. Taking into consideration the relation between the weight and the capacity of the cranium, it may be inferred that woman has a less development of osseous tissue. 6. In the ratio of the weights of the cranium and the lower maxillary, we have a new zoölogical difference between man and ape, the latter always presenting a heavier jaw relatively to the cranium than the former.

At Cassel, in Prussia, there is a Live-Stock Insurance Company which insures live-stock against disease. The books of this company furnish conclusive evidence of the very great frequency of trichinosis in swine. In the district of Cassel the proportion of cases of trichinosis to the total number of swine insured was one in 300; in East and West Prussia, one in 450; in Silesia and Posen, one in 230. Since July, 1876, the proportion of affected animals in the provinces near the Russian frontier has been even more unfavorable, and many of the insured have found 10 or even 15 per cent. of their pigs thus diseased.

Mention is made in Addison's *Spectator* of an odd character in Italy who had a chair-balance made for himself, so that he might be able to keep his bodily weight constantly the same. A like idea has recently occurred to a French investigator, who has constructed a "registering balance," showing in curves the gains or losses of any matter placed in one or other of its scales. In one experiment made by the inventor, an adult man seated in the balance, was first quiet for twenty minutes, then read in a loud voice for twenty minutes, then was perfectly quiet for twenty minutes more. The curve of variations in the weight of the body during this hour shows a considerably greater loss in the second twenty minutes than in the first, a loss partly compensated by a diminution in emission of water and carbonic acid during the third twenty minutes.

Two processes for preserving fish from decay were detailed in a recent communication to the Paris Academy of Sciences by R. M. d'Amélio. The first process was as follows: The fish, whether raw or cooked, is immersed in a strong solution of citric acid in water. After two or three hours, the fish is taken from the bath and dried in the open air, or by artificial heat, the latter course being preferable. Fish so prepared will keep fresh anywhere for years. To restore its original flexibility it must be steeped in fresh water four or five days. The other method consists in the employment of a bath of silicate of potash and glycerine, in equal quantities. The fish, the intestines having first been removed, is steeped in this bath for a day or two, washed in fresh water, and dried slowly. By the use of this process the author has succeeded in preserving intact the color of the fishes and the eyes.

It is proposed to erect at Stockholm a monument to Linnæus, consisting of a statue of the great naturalist, surrounded by allegorical figures of the four sciences to which he devoted himself, namely, botany, zoölogy, mineralogy, and medicine.

The Marquis of Bute has on one of his estates near Cardiff, Wales, a flourishing vineyard of some 6,000 vines. A French vineyard-proprietor, who has inspected these vines, expresses his conviction that this experiment of a vineyard in that climate was destined to be entirely successful.

WALTER BAGEHOT.

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EVOLUTION OF CEREMONIAL GOVERNMENT.

By HERBERT SPENCER.

I. INTRODUCTORY.

IF, excluding all purely private actions, we include under the name "conduct" all actions which involve direct relations with other persons; and if under the name "government" we include all control of such conduct, however arising; then we must say that the earliest kind of government, the most general kind of government, and the government which is ever spontaneously recommencing, is the government of ceremonial observance. More than this is true. Not simply does this kind of government precede other kinds, and not only has it in all places and times approached nearer to universality of influence, but it has ever had, and continues to have, the largest share in regulating men's lives.

Proof that the modifications of conduct called "manners" and "behavior" arise long before those which political and religious restraints cause, is yielded by the fact that, besides preceding social evolution, they precede human evolution: they are traceable among the higher animals. The dog afraid of being beaten, comes crawling up to his master, clearly manifesting the desire to submit. Nor is it solely to human beings that dogs use such propitiatory actions: they do the like one to another. All have occasionally seen how, on the approach of some formidable-looking Newfoundland or mastiff, a small spaniel, in the extremity of its terror, throws itself on its back with legs in the air. Instead of threatening resistance by growls and showing of teeth, as it might have done had not resistance been hopeless, it spontaneously assumes the attitude that would result from defeat in battle, tacitly saying, "I am conquered, and at your mercy." Clearly, then, besides certain modes of behavior expressing affection, which are established still earlier in creatures lower than man, there are established certain modes of behavior expressing subjection.

After recognizing this fact, we shall be prepared to recognize the fact that daily intercourse among the lowest savages, whose small, loose groups, scarcely to be called social, are without political or religious regulation, is under a considerable amount of ceremonial regulation. No ruling agency, beyond that arising from personal superiority, characterizes the scattered hordes of Australians; but they have imperative ceremonies. Strangers meeting have to remain some time silent; a mile from an encampment approach must be heralded by loud "cooeys;" a green bough is used as an emblem of peace; and brotherly feeling is indicated by exchange of names. So the Tasmanians, similarly without government save that implied by predominance of a leader during war, had settled ways of indicating peace and defiance. The Esquimaux, too, though without social ranks or anything like chieftainship, have understood usages for the treatment of guests.

Kindred evidence may be joined with this. Ceremonial control is highly developed in many places where the other forms of control are but rudimentary. The wild Comanche "exacts the observance of his rules of etiquette from strangers," and "is greatly offended" by any breach of them. When Araucanians meet, the inquiries, felicitations, and condolences, which custom demands are so elaborate, that "the formality occupies ten or fifteen minutes." Of the ungoverned Bedouins we read that "their manners are sometimes dashed with a strange ceremoniousness;" and the salutations of Arabs are such that the "compliments in a well-bred man never last less than ten minutes." "We were particularly struck," says Livingstone, "with the punctiliousness of manners shown by the Balonda." "The Malagasy have many different forms of salutation, of which they make liberal use. . . . Hence in their general intercourse there is much that is stiff, formal, and precise." A Samoan orator, when speaking in parliament, "is not contented with a mere word of salutation, such as 'gentlemen,' but he must, with great minuteness, go over the names and titles, and a host of ancestral references, of which they are proud."

That ceremonial restraint, preceding other forms of restraint, continues ever to be the most widely-diffused form of restraint, we are shown by such facts as that in all intercourse between societies, civilized, semi-civilized, or barbarous, as well as in all intercourse between members of each society, the decisively governmental actions are usually prefaced by this government of observances. The embassy may fail, negotiation may be brought to a close by war, coercion of one society by another may set up wider political rule with its peremptory commands; but there is habitually this more general and vague regulation of conduct preceding the more special and definite.

So within a community, acts of relatively stringent control coming from ruling agencies, civil and religious, begin with and are qualified by this ceremonial control, which not only initiates but in a sense envelops all other. Functionaries, ecclesiastical and political, coercive as their proceedings may be, conform them in large measure to the requirements of courtesy. The priest, however arrogant, fulfills the usages of civility; and the officer of the law performs his duty subject to certain propitiatory words and movements.

Yet another indication of primordialism may be named. This species of control establishes itself anew with every fresh relation among individuals. Even between intimates those greetings which are requisite to signify continuance of respect, precede each renewal of intercourse. Though their particular form may be settled by custom, such greetings are in substance direct results of the desire not to offend. And in presence of a stranger, say in a railway-carriage, a certain self-restraint, joined with some such act as the offer of a newspaper, shows the spontaneous rise of a propitiatory behavior such as even the rudest of mankind are not without.

So that the modified forms of action produced in men by the presence of their fellows, and which are seen alike in the otherwise-uncontrolled members of the lowest social groups and in the otherwise-controlled members of the highest social groups, constitute that comparatively vague control out of which other more definite controls are evolved—the primitive undifferentiated kind of government from which the political and religious governments are differentiated, and within which they ever continue immersed.

This proposition looks strange mainly because, when studying less-advanced societies, we carry with us our developed conceptions of law and religion. Swayed by them, we fail to perceive that what we think the essential parts of sacred and secular regulations were originally subordinate parts, and that the essential parts consisted of ceremonial observances.

It is clear, *a priori*, that this must be so if social phenomena are evolved. A political organization or a settled cult cannot suddenly come into existence, but implies prëestablished subordination. Before there are laws, there must be submission to some potentate enacting and enforcing them. Before religious obligations are recognized, there must be acknowledged one or more supernatural powers. Evidently, then, the behavior expressing obedience to a ruler, visible or invisible, must precede in time the civil or religious restraints he imposes. And this inferable precedence of ceremonial government is a precedence we everywhere find.

How in the political sphere fulfillment of forms signifying subordination is the primary thing, early European history shows us. During times when the question, who should be master, was in course of settlement, now in small areas and now in larger areas uniting them, there was scarcely any of the regulation which developed civil government brings; but there was insistance on allegiance humbly expressed. While each man was left to guard himself, and blood-feuds between families were unchecked by the central power—while the right of private vengeance was so well recognized that the Salic law made it penal to carry off enemies' heads from the stakes on which they were exhibited near the dwellings of those who had killed them; there was a rigorous demanding of oaths of fidelity to political superiors and periodic manifestations of loyalty. Simple homage, growing presently into liege homage, was paid by smaller rulers to greater; and the vassal who, kneeling ungirt and swordless before his suzerain, professed his subjection and then entered on possession of his lands, was little interfered with so long as he continued to display his vassalage in court and in camp. Refusal to go through the required observances was tantamount to rebellion; as at the present time in China, where disregard of the forms of behavior prescribed toward each grade of officers "is considered to be nearly equivalent to a rejection of their authority." Among peoples in lower stages this connection of social traits is still better shown. Referring to the extreme ceremoniousness of the Tahitians, Ellis writes: "This peculiarity appears to have accompanied them to the temples, to have distinguished the homage and the service they rendered to their gods, to have marked their affairs of state, and the carriage of the people toward their rulers, to have pervaded the whole of their social intercourse." Meanwhile, he says, they were destitute "of even oral laws and institutes:" so verifying the statement of Cook that there was no public administration of justice. Again, from Mariner we learn that if any one in Tonga were to neglect the proper salutation in presence of a superior noble, some calamity from the gods would be expected as a punishment for the omission; and his list of Tongan virtues commences with "paying respect to the gods, nobles, and aged persons." When to this we add his statement that many actions reprobated by the Tongans are not thought intrinsically wrong, but are wrong merely if done against gods or nobles, we get proof that, along with high development of ceremonial control, the sentiments, ideas, and usages, out of which civil government comes, were but feebly developed. Similarly in the ancient American states. The laws of the Mexican king, Montezuma I., mostly related to the intercourse of, and the distinctions between, classes. In Peru, "the most common punishment was death, for they said that a culprit was not punished for the delinquencies he had committed, but for having broken the commandment of the Ynca." There had not been reached the stage in which the transgressions of man against man are the wrongs to be redressed, and in which there is consequently a proportioning of penalties to injuries; but the real crime was insubordination: implying that insistance on marks of subordination constituted the essential part of government. A statement of Thunberg shows us that in Japan, so elaborately ceremonious in its life, exactly the same theory led to exactly the same result. And here we are reminded that even in societies so advanced as our own there continue the traces of a kindred early condition. "Indictment for felony," says Wharton, "is" (for a transgression) "against the peace of our lord the king, his crown and dignity in general;" the injured individual being ignored. Evidently the implication is that obedience was the primary requirement, and behavior expressing it the first modification of conduct insisted on.

Religious control, still better, perhaps, than political control, shows us this general truth. When we find that rites performed at graves, becoming afterward religious rites performed at altars in temples, were at first acts done for the benefit of the ghost, either as originally conceived or as ideally expanded into a deity—when we find that the sacrifices and libations, the immolations and blood-offerings and mutilations, all begun to profit or to please the double of the dead man, were continued on larger scales where the double of the dead man was especially feared—when we find that fasting as a funeral rite gave origin to religious fasting, that praises of the deceased and prayers to him grew into religious praises and prayers—we are shown why primitive religion consisted almost wholly of propitiatory observances. Though in certain rude societies now existing, one of the propitiations is the repetition of injunctions given by the departed father or chief, joined in some cases with expressions of penitence for breach of them, and though we are shown by this that from the first there exists the germ out of which grow the sanctified precepts eventually constituting important adjuncts to religion; yet, since the supposed supernatural beings are at first regarded as retaining after death the desires and passions that distinguished them during life, this rudiment of a moral code is originally but an insignificant part of the cult: due rendering of those offerings, and praises, and marks of subordination, by which the good-will of the ghost or god is to be obtained, forming the chief part. Everywhere we meet with proofs. We read of the Tahitians that "religious rites were connected with almost every act of their lives;" and we read kindred statements respecting the uncivilized and semi-civilized in general. The Sandwich-Islanders, along with scarcely any of that ethical element which the conception of religion includes among ourselves, had a rigorous and elaborate ceremonial. Noting that *tabu* means literally "sacred to the gods," I quote the following account of its observance in Hawaii from Ellis:

"During the season of strict tabu, every fire or light in the island or district must be extinguished; no canoe must be launched on the water, no person must bathe; and except those whose attendance was required at the temple, no individual must be seen out-of-doors; no dog must bark, no pig must grunt, no cock must crow. . . . On these occasions they tied up the mouths of the dogs and pigs, and put the fowls under a calabash, or fastened a piece of cloth over their eyes."

And how completely the idea of transgression was associated in the mind of the Sandwich-Islander with breach of ceremonial observance, is shown in the fact that "if any one made a noise on a tabu-day . . . . he must die." Through stages considerably advanced, religion continues to be thus constituted. When questioning the Nicaraguans concerning their creed, Oviedo, eliciting the fact that they confessed their sins to an appointed old man, asks what sort of sins they confessed; and the first clause of the answer is, "We tell him when we have broken our festivals and not kept them." Similarly of the Peruvians, we read that "the most notable sin was neglect in the service of the huacas" (spirits, etc.); and a large part of life was spent in propitiating the apotheosized dead. How elaborate the observances, how frequent the festivals, how lavish was the expenditure, by which, among the ancient Egyptians, the good-will of supernatural beings was sought, the records everywhere show us; and that with them religious duty consisted in thus ministering to the desires of ancestral ghosts, deified in various degrees, we are shown by the prayer of Rameses to his father Ammon, in which he claims his help in battle because of the many bulls he has sacrificed to him. With the Hebrews in pre-Mosaic times it was the same. As Kuenen remarks, the "great work and enduring merit" of Moses was that he gave dominance to the moral element in religion. In his reformed creed, "Jahveh is distinguished from the rest of the gods in this, that he will be served, not merely by sacrifices and feasts, but also, nay, in the first place, by the observance of the moral commandments." That the piety of the Greeks included diligent performance of rites at tombs, and that the Greek god was especially angered by non-observance of propitiatory ceremonies, are familiar facts; and credit with a god was claimed by the Trojan as by the Egyptian, not on account of rectitude, but on account of oblations made; as is shown by Chryses's prayer to Apollo. So, too, Christianity, originally a renewed development of the ethical element at the expense of the ceremonial element, losing as it spread those early traits which distinguished it from lower creeds, displayed, in mediæval Europe, a relatively large amount of ceremony and a relatively small amount of morality. Of the seventy-three chapters constituting the Rule of St. Benedict, nine concern the moral and general duties of the brothers, while thirteen concern the religious ordinances. And how the idea of criminality attached to disregard of ordinances is proved by the following passage from the Rule of St. Columbanus:

"A year's penance for him who loses a consecrated wafer; six months for him who suffers it to be eaten by mites; twenty days for him who lets it turn red; forty days for him who contemptuously flings it into water; twenty days for him who brings it up through weakness of stomach; but, if through illness, ten days. He who neglects his Amen to the Benedicite, who speaks when eating, who forgets to make the sign of the cross on his spoon, or on a lantern lighted by a younger brother, is to receive six or twelve stripes."

That from the times when men condoned crimes by building chapels and going on pilgrimages, down to present times, when barons no longer invade one another's territories or torture Jews, there has been a decrease of ceremony along with an increase of morality, is clear; though if we look at unadvanced parts of Europe, such as Naples or Sicily, we see that even now observance of rites is in them a much larger component of religion than obedience to moral rules. And when we remember how modern is the rise of Protestantism, which, less elaborate and imperative in its forms, does not habitually compound for transgressions by performance of acts expressing subordination, and how very recent is the spread of dissenting Protestantism, in which this change is carried further; we are shown that the subordination of ceremony to morality characterizes religion only in its later stages.

Mark, then, what follows. If the two kinds of control which eventually grow into civil and religious governments, originally include scarcely anything beyond observance of ceremonies, the precedence of ceremonial control over other controls is a corollary.

Divergent products of evolution betray their kinship by severally retaining certain traits which belonged to that from which they were evolved; and the implication is, that whatever traits they have in common, arose earlier in time than did the traits which distinguish them from one another. If fish, reptiles, birds, and mammals, all possess vertebral columns, it follows, on the evolution hypothesis, that the vertebral column became a part of the organization at an earlier period than did the four-chambered heart, the teeth in sockets, and the mammæ, which distinguish one of these groups, or than did the toothless beak, the tri-locular heart, and the feathers, which distinguish another of these groups, and so on. Applying this principle in the present case, it is inferable that if the controls classed as civil, religious, and social, have certain common characters, these characters, older than are these now differentiated kinds of control, must have belonged to the primitive control out of which they developed. Ceremonial acts, then, have the highest antiquity; for these differentiated kinds of control all exhibit them.

There is the making of presents: this is one of the acts showing subordination to a ruler in early stages; it is a religious rite, performed originally at the grave and later on at the altar; and from the beginning it has been a means of showing consideration in social intercourse and securing good-will. There are the obeisances:

these, of their several kinds, serve to express reverence in its various degrees, to gods, to rulers, and to private persons; here the prostration is habitually seen, now in the temple, now before the monarch, and now to a powerful man; here there is genuflection in presence of idols, rulers, and fellow-subjects; here the salaam is more or less common to the three cases; here uncovering of the head is a sign alike of worship, of loyalty, and of respect; and here the bow serves the same three purposes. Similarly with titles: father is a name of honor applied to a god, to a king, and to an honored individual; so too is lord; and so are sundry other names. The same thing holds of humble speeches: professions of inferiority and subjection on the part of the speaker are used to secure divine favor, the favor of a ruler, and the favor of a private person. Once more, it is thus with words of praise; telling a deity of his greatness constitutes a large element of worship; despotic monarchs are addressed in terms of exaggerated eulogy; and where ceremony is dominant in social intercourse, extravagant compliments are addressed to private persons.

In many of the less-advanced societies, and also in the more advanced that have retained early types of organization, we find various other examples of observances expressing subordination, that are common to the three kinds of control—civil, religious, and social. Among the Malayo-Polynesians the offering of the first fish, and of first fruits, is used as a mark of respect alike to gods and to chiefs; and the Feejeeans make the same gifts to their gods as they do to their chiefs—food, turtles, whales' teeth. In Tonga, "if a great chief takes an oath, he swears by the god; if an inferior chief takes an oath, he swears by his superior relation, who, of course, is a greater chief." In Feejee, "all are careful not to tread on the threshold of a place set apart for the gods: persons of rank stride over; others pass over on their hands and knees. The same form is observed in crossing the threshold of a chief's house." In Siam, "at the full moon of the fifth month, the talapoins" (priests) "wash the idol with perfumed water. . . . The people also wash the sancrats and other talapoins; and then in the families children wash their parents." China affords good instances. "At his accession, the emperor kneels thrice and bows nine times before the altar of his father, and goes through the same ceremony before the throne on which is seated the empress dowager. On his then ascending his throne, the great officers, marshaled according to their ranks, kneel and bow nine times. And the equally ceremonious Japanese furnish kindred evidence. "From the emperor to the lowest subject in the realm there is a constant succession of prostrations. The former, in want of a human being superior to himself in rank, bows humbly to some pagan idol; and every one of his subjects, from prince to peasant, has some person before whom he is bound to cringe and crouch in the dirt:" that is, religious, political, and social subordination are expressed by the same form of behavior.

These indications of a general truth, which will be abundantly exemplified when treating of each kind of ceremonial observance, I here give in brief, as further showing that the control of ceremony precedes in order of evolution the civil and religious controls, and has therefore to be first dealt with.

On passing from the most general to the less general aspects of ceremonial government, we are met by the question, "How do there arise those modifications of behavior which constitute it?" Commonly it is assumed that they are consciously fixed upon as symbolizing reverence or respect. In pursuance of the usual method of speculating about primitive practices, developed ideas are read back into undeveloped minds. The supposition is of the same kind as that which gave origin to the social-contract theory: a kind of conception that has become familiar to the civilized man is supposed to have been familiar to man in his earliest state. But, just as little basis as there is for the belief that primitive men deliberately made social contracts, is there for the belief that primitive men deliberately adopted symbols. The current error is best seen on turning to the most developed kind of symbolization—that of language. The savage does not sit down and knowingly coin a word; but the words which he finds in use, and the new ones which come into use during his life, grow up unawares by *onomatopœa*, or by vocal suggestions of qualities, or by metaphor which some observable likeness suggests. Among civilized peoples, however, who have learned that words are symbolic, new words are frequently chosen to symbolize new ideas. So, too, is it with written language. The early Egyptian never thought of choosing a sign to represent a sound, but his records began, as those of North American Indians begin now, with rude pictures of the transactions to be kept in memory; and, as the process of recording extended, the pictures, abbreviated and generalized, lost more and more their likenesses to objects and acts, until, under stress of the need for expressing proper names, some of them were used phonetically, and signs of sounds came unawares into existence. But, in our days, there has been reached a stage at which, as short-hand shows us, special signs are consciously chosen to symbolize special sounds. The lesson taught is obvious. Just as it would be an error to conclude that, because we knowingly choose sounds to symbolize ideas, and marks to symbolize sounds, the like was originally done by savages and by barbarians; so is it an error to conclude that, because among the civilized, certain ceremonies (say those of freemasons) are arbitrarily fixed upon, so ceremonies were arbitrarily fixed upon by the uncivilized. Already, in indicating the primitiveness of ceremonial control, I have named some modes of behavior expressing subordination which have a natural genesis; and here the implication to which I would draw attention is that, until we have found a natural genesis for a ceremony, we may be sure that we have not discovered its origin. The truth of this implication will seem less improbable on observing sundry ways in which spontaneous manifestations of emotion initiate formal observances.

The ewe bleating after her lamb that has strayed, and smelling now at at one and now at another of the lambs near her, but at length, by its odor, identifying as her own one that comes running up, doubtless, thereupon, experiences a wave of gratified maternal feeling; and, by repetition, there is established between this odor and this pleasure such an association that the first habitually produces the last; the smell becomes, on all occasions, agreeable by serving to bring into consciousness more or less of the philoprogenitive emotion. That, by some races of mankind, individuals are similarly identified, the Bible yields proof. Though Isaac, with senses dulled by age, fails thus to distinguish his sons from one another, yet the fact that, unable to see Jacob, and puzzled by the conflicting evidence his voice and his hands furnished, "he smelled the smell of his raiment, and blessed him," shows that different persons, even members of the same family, were perceived by the Hebrews to have their specific odors. And that perception of the odor possessed by one who is loved, yields pleasure, proof is given by another Asiatic race. Of a Mongol father, Timkowski writes: "He smelt from time to time the head of his youngest son, a mark of paternal tenderness usual among the Mongols, instead of embracing." Describing the Philippine-Islanders, Jagor says: "The sense of smell is developed among the Indians to so great a degree that they are able, by smelling at the pocket-handkerchiefs, to tell to which persons they belong ('Reisesk,' page 39); and lovers at parting exchange pieces of the linen they may be wearing, and during their separation inhale the odor of the beloved being, besides smothering the relics with kisses." So, too, is it with the Chittagong Hill people. Lewin tells us that "their manner of kissing is peculiar. Instead of pressing lip to lip, they place the mouth and nose upon the cheek and inhale the breath strongly. Their form of speech is not, 'Give me a kiss!' but 'Smell me!'" And now note a sequence. Inhalation of the odor given off by a loved person coming to be a mark of affection for him or for her, it happens that since men wish to be liked, and are pleased by display of liking, the performance of this act which signifies liking initiates a complimentary observance, and gives rise to certain modes of showing respect. The Samoans salute by "juxtaposition of noses, accompanied, not by a rub, but a hearty smell. They shake and smell the hands also, especially of a superior." And there are like salutes among the Esquimaux and the New-Zealanders.

The alliance between smell and taste being so close, we may naturally expect a class of acts which arise from tasting, parallel to the class of acts which smelling originates; and the expectation is fulfilled. That the billing of doves or pigeons and the like action of love-birds indicate an affection which is gratified by the gustatory sensation, cannot well be questioned. No act of this kind on the part of an inferior creature, as of a cow licking her calf, can have any other origin than the direct prompting of a desire which gains by the act satisfaction; and in such a case the satisfaction is obviously that which vivid perception of offspring gives to the maternal yearning. In some animals like acts arise from other forms of affection. Licking the hand, or, where it is accessible, the face, is a common display of attachment on a dog's part; and when we remember how keen must be the olfactory sense by which a dog traces his master, we cannot doubt that to his gustatory sense, too, there is yielded some impression—an impression associated with those pleasures of affection which his master's presence gives. The inference that kissing as a mark of affection in the human race has a kindred origin, is sufficiently probable. Though kissing is not universal—though the negro races do not appear to understand it, and though, as we have seen, there are cases in which sniffing replaces it—yet, being common to unlike and widely-dispersed races, we may conclude that it originated in the same manner as the analogous action among lower creatures. Here, however, we are chiefly concerned to observe the indirect result. From kissing as a natural sign of affection, there is derived the kissing which, as a means of simulating affection, gratifies those who are kissed, and, by gratifying them, propitiates them. Hence an obvious root for the kissing of feet, hands, garments, as a part of ceremonial.

Feeling, sensational or emotional, causes muscular contractions, which are strong in proportion as it is intense; and, among other feelings, those of love and liking have an effect of this kind, which takes on its appropriate form. The most significant of the actions hence originating is not much displayed by inferior creatures, because their limbs are unfitted for prehension; but in the human race its natural genesis is sufficiently manifest. Mentioning a mother's embrace of her child will remind all that the strength of the embrace (unless restrained to prevent mischief) measures the strength of the feeling; and while reminded that the feeling thus naturally vents itself in muscular actions, they may further see that these actions are directed in such a way as to give satisfaction to the feeling by yielding a vivid consciousness of possession. That among adults the allied feelings originate like acts, scarcely needs adding. It is not so much these facts, however, as the derived facts, which we have to take note of. Here is another root for a ceremony: an embrace, too, serving to express liking, serves to propitiate in cases where it is not negatived by those other observances which subjection entails. We find it where governmental subordination is but little developed. Of some Snake Indians they met, we read in Lewis and Clarke, that "the three men immediately leaped from their horses, came up to Captain Lewis, and embraced him with great cordiality." Marcy tells of a Comanche that, "seizing me in his brawny arms while we were yet in the saddle, and laying his greasy head upon my shoulder, he inflicted upon me a most bruin-like squeeze, which I endured with a degree of patient fortitude worthy of the occasion." So, too, Snow says the Fuegian "friendly mode of salutation was anything but agreeable. The men came and hugged me, very much like the grip of a bear."

Discharging itself in muscular actions which, in cases like the foregoing, are directed to an end, feeling in other cases discharges itself in undirected muscular actions. The resulting changes are habitually rhythmical. Each considerable movement of a limb brings it to a position at which a counter-movement is easy; both because the muscles producing the counter-movement are then in the best positions for contraction, and because they have had a brief rest. Hence the naturalness of striking the hands together or against other parts. We see this as a spontaneous manifestation of pleasure among children; and we find it giving origin to a ceremony among the uncivilized. Clapping of the hands is "the highest mark of respect" in Loango; and it occurs with kindred meaning among the Coast Negroes, the East Africans, the Dahomans. Joined with other acts expressing welcome, the people of Batoka "slap the outsides of their thighs;" the Balonda people, besides clapping their hands, sometimes "in saluting drum their ribs with their elbows;" while among the Coast Negroes and in Dahomey, snapping the fingers is one of the salutes. Rhythmical muscular motions of the arms and hands, thus expressing pleasure, real or pretended, in presence of another person, are not the only motions of this class: the legs come into play. Children often "jump for joy," and occasionally adults may be seen to do the like. Saltatory movements are therefore apt to grow into compliments. In Loango "many of the nobility salute the king by leaping with great strides backward and forward two or three times and swinging their arms." The Fuegians also, as the United States explorers tell us, show friendship "by jumping up and down."[1]

Feeling, discharging itself, contracts the muscles of the vocal organs, as well as other muscles; so that, along with bodily motions signifying pleasure, there go sounds, loud in proportion as the pleasure is great. Hence shouts, indicating joy in general, indicate the joy produced by meeting one who is beloved, and serve to give the appearance of joy before one whose good-will is sought. Among the

[1] In his "Early History of Mankind" (second edition, pp. 51, 52), Mr. Tylor thus comments on such observances: "The lowest class of salutations, which merely aim at giving pleasant bodily sensations, merge into the civilities which we see exchanged among the lower animals. Such are patting, stroking, kissing, pressing noses, blowing, sniffing, and so forth. . . . Natural expressions of joy, such as clapping hands in Africa, and jumping up and down in Tierra del Fuego, are made to do duty as signs of friendship or greeting." Mr. Tylor does not, however, indicate the physio-psychological sources of these actions.

Feejeeans, respect is "indicated by the *tama*, which is a shout of reverence uttered by inferiors when approaching a chief or chief town." In Australia, as we have seen, it is necessary on coming within a mile of an encampment to make loud *cooeys*—an action which, while primarily indicating pleasure at the coming reunion, further indicates those friendly intentions which a secret approach would render more than doubtful.

One more example may be named: Tears result from strong feeling—mostly from painful feeling, but also from pleasurable feeling when extreme. Hence, as a sign of joy, weeping occasionally passes into a complimentary observance. The beginning of such an observance is shown us by Hebrew traditions in the reception of Tobias by Raguel, when he finds him to be his cousin's son: "Then Raguel leaped up and kissed him and wept." And among some races there grows from this root a social rite. In New Zealand a meeting "led to a warm *tangi* between the two parties; but, after sitting opposite to each other for a quarter of an hour or more, crying bitterly, with a most piteous moaning and lamentation, the *tangi* was transformed into a *hungi*, and the two old ladies commenced pressing noses, giving occasional satisfactory grunts." And then we find it becoming a public ceremony on the arrival of a great chief: "The women stood upon a hill, and loud and long was the *tangi* to welcome his approach. Occasionally, however, they would leave off, to have a chat or a laugh, and then mechanically resume their weeping." Other Malayo-Polynesians do the like.

To these illustrations of the way in which natural manifestations of emotion originate ceremonies, may be added a few illustrations of the way in which ceremonies, not originating directly from spontaneous actions, nevertheless originate by natural sequence—not by intentional symbolization. Brief indications must suffice.

Livingstone tells us that blood-relations are formed in Central South Africa by imbibing a little of each other's blood. A like way of establishing brotherhood is used in Madagascar, in Borneo, and in many places throughout the world, and it was used among our remote ancestors. This is assumed to be a symbolic observance. On studying early ideas, however, and finding, as we have done, that the primitive man regards the nature of anything as inhering in all its parts, and therefore thinks he gets the courage of a brave enemy by eating his heart, or is inspired with the virtues of a deceased relative by grinding his bones and drinking them in water, we see that, by absorbing each other's blood, men are supposed to establish actual community of nature, and are also supposed to gain power over each other by possessing parts of each other.

Similarly with the ceremony of exchanging names. "To bestow his name upon a friend is the highest compliment that one man can offer another," among the Shoshones. The Australians exchange names with Europeans, as a proof of brotherly feeling. This, which is a widely-diffused practice, arises from the belief that the name is a part of the individual. Possessing a man's name is equivalent to possessing something that forms a portion of his being, and enables the possessor to work mischief to him; and hence, among numerous peoples, a reason for studiously concealing names. To exchange names, therefore, is to establish some participation in one another's being, and at the same time to trust each with power over the other, implying great mutual confidence.

It is a usage among the people of Vate, "when they wish to make peace, to kill one or more of their own people, and send the body to those with whom they have been fighting to eat;" and, in Samoa, "it is the custom, on the submission of one party to another, to bow down before their conquerors, each with a piece of fire-wood and a bundle of leaves, such as are used in dressing a pig for the oven" (bamboo-knives being sometimes added), "as much as to say, 'Kill us and cook us, if you please.'" These facts I name because they clearly show a point of departure from which there might arise an apparently artificial ceremony. Let the traditions of cannibalism among the Samoans disappear, and this surviving custom of presenting fire-wood, leaves, and knives, as a sign of submission, would, in pursuance of the ordinary method of interpretation, be taken for an observance deliberately devised.

That peace should be signified among the Dakotas by burying the tomahawk, and among the Brazilians by a present of bows and arrows, may be cited as instances of what is in a sense symbolization, but what is in origin a modification of the action symbolized; for cessation of fighting is necessitated by putting away weapons, or by giving weapons to an antagonist. If, as among the civilized, a conquered antagonist delivers up his sword, the act of so making himself defenseless is an act of personal submission; but eventually it comes to be, on the part of a general, a sign that his army surrenders. Similarly, when, as in parts of Africa, "some of the free blacks become slaves voluntarily by going through the simple but significant ceremony of breaking a spear in the presence of their future master," we may properly say that the relation thus artificially established is as near an approach as may be to the relation established when an enemy, whose weapon is broken, is made a slave by his captor: the symbolic transaction simulates the actual transaction.

An instructive example comes next. I refer to the bearing of green boughs as a sign of peace, as an act of propitiation, and as a religious ceremony. As indicating peace the custom occurs among the Araucanians, Australians, Tasmanians, New Guinea people, New Caledonians, Sandwich-Islanders, Tahitians, Samoans, New-Zealanders; and branches were used by the Hebrews also for propitiatory approach (2 Maccabees xiv. 4). In some cases we find it employed to signify not peace only but submission. Speaking of the Peruvians, Cieza says, "The men and boys came out with green boughs and palm-leaves to seek for mercy;" and among the Greeks, too, a suppliant carried an olive-branch. Wall-paintings left by the ancient Egyptians show us palm-branches carried in funeral processions to propitiate the dead; and, at the present time, "a wreath of palm-branches stuck in the grave" is common in a Moslem cemetery in Egypt. A statement of Wallis respecting the Tahitians shows it passing into a religious observance: a pendant left flying on the beach the natives regarded with fear, bringing green boughs and hogs, which they laid down at the foot of the staff. And that a portion of a tree was anciently an appliance of worship in the East is shown by the direction in Leviticus xxiii. 40, to take the "boughs of goodly trees, branches of palm-trees," etc., and "rejoice before the Lord:" a verification being furnished by the description of the chosen in heaven, who stand before the throne with "palms in their hands" (Revelation vii. 9). The explanation, when we get the clew, is simple. Many travelers' narratives illustrate the fact that laying down weapons on approaching strangers is taken to imply pacific intentions: the obvious reason being that opposite intentions are thus negatived. Of the Kaffirs, for instance, Barrow says, "'A messenger of peace' is known by this people from his laying down his *hassagai* or spear on the ground, at the distance of two hundred paces from those to whom he is sent, and by advancing thence with extended arms:" the extension of the arms evidently having the purpose of showing that he has no weapon secreted. But how is the absence of weapons to be shown when so far off that weapons, if carried, are invisible? Simply by carrying other things which are visible; and boughs covered with leaves are the most convenient and generally available things for this purpose. A verification is at hand. The Tasmanians had a way of deceiving those who inferred from the green boughs they were bringing in their hands that they were weaponless. They practised the art of holding their spears between their toes as they walked: "The black . . . . approaching him in pretended amity, trailed between his toes the fatal spear." Arbitrary, then, as this usage seems when observed in its later forms only, it proves to be by no means arbitrary when traced back to its origin. Taken as evidence that the advancing stranger is without arms, the green bough is primarily a sign that he is not an enemy. It is thereafter joined with other marks of friendship. It survives when the propitiation passes into submission. And so it becomes incorporated with various other actions which express reverence and worship.

One more instance I must add, because it conspicuously shows us how there grow up the interpretations of ceremonies as artificially-devised actions, when their natural origins are unknown. Describing Arab marriages, Baker says: "There is much feasting, and the unfortunate bridegroom undergoes the ordeal of whipping by the relations of his bride, in order to test his courage. . . . If the happy husband wishes to be considered a man worth having, he must receive the chastisement with an expression of enjoyment, in which case the crowds of women in admiration again raise their thrilling cry." Here, instead of the primitive abduction violently resisted by the woman and her relatives—instead of the actual capture required to be achieved, as among the Kamtchadales, spite of the blows and wounds inflicted by "all the women in the village"—instead of those modifications of the "form of capture" in which, along with mock pursuit, there goes receipt by the abductor of more or less violence from the pursuers; we have a modification in which the pursuit has disappeared, and the violence is passively received. And then there arises the belief that this castigation of the bridegroom is a deliberately chosen way "to test his courage."

These facts are not given as adequately proving that, in all cases, ceremonies are modifications of actions which had at first direct adaptations to desired ends, and that their apparently symbolic characters result from their survival under changed circumstances. Here I have aimed only to indicate, in the briefest way, the reasons for rejecting the current hypothesis that ceremonies originate in conscious symbolization, and for justifying the belief that we may in every case expect to find them originating by evolution. This expectation we shall hereafter find abundantly fulfilled.

A chief reason why little attention has been paid to phenomena of this class, all-pervading and conspicuous as they are, is that while to most social functions there correspond structures too large to be overlooked, functions which make up ceremonial control have correlative structures so small as to seem of no significance. That ceremonial government has its special organization, just as the political and ecclesiastical governments have, is a fact habitually passed over, because, while the last two organizations have developed, the first has dwindled—in those societies, at least, which have reached the stage at which social phenomena become subjects of speculation. Originally, however, the officials who direct the rites expressing political subordination have an importance second only to that of the officials who direct religious rites; and the two officialisms are homologous. To whichever class belonging, these functionaries conduct propitiatory acts: the visible ruler being the propitiated person in the one case, and the ruler no longer visible being the propitiated person in the other case. Both are performers and regulators of worship—worship of the living king and worship of the dead king. In our advanced stage the differentiation of the divine from the human has become so great that this proposition looks scarcely credible. But on going back through stages in which the attributes of the conceived deity are less and less unlike those of the visible man, and eventually reaching the early stage in which the other-self of the dead man, considered indiscriminately as ghost and god, is not to be distinguished, when he appears, from the living man; we cannot fail to see the alliance in Nature between the functions of those who minister to the ruler who has gone away and those who minister to the ruler who has taken his place. What remaining strangeness there may seem in this assertion of homology disappears, on remembering that in sundry ancient societies living kings were literally worshiped as dead kings were, and that the adoration of the living king by priests was but a more extreme form of the adoration habitually paid by all who served him.

Social organizations that are but little differentiated clearly show us several aspects of this kinship. In common with those below him, the savage chief proclaims his own great deeds and the achievements of his ancestors; and that in some cases this habit of self-praise long persists, Egyptian and Assyrian inscriptions prove. Advance from the stage at which the head-man lauds himself to the stage at which laudation of him is done by deputy is well typified in the contrast between the recent usage in Madagascar, where the king in public assembly was in the habit of relating "his origin, his descent from the line of former sovereigns, and his incontestable right to the kingdom," and the usage that existed in past times among ourselves, when the like distinctions and powers and claims of the king were publicly asserted for him by an appointed officer. As the ruler, extending his dominions and growing in power, gathers round him an increasing number of agents, the utterance of propitiatory praises, at first by all of these, becomes eventually distinctive of certain among them: there arise official glorifiers. "In Samoa, a chief in traveling is attended by his principal orator." In Feejee each tribe has its "orator, to make orations on occasions of ceremony." Dupuis tells us that the attendants of the chiefs of Ashantee eagerly vociferate the "strong names" of their masters; and a more recent writer describes certain of the king's attendants, whose duty it is to "give him names"—cry out his titles and high qualities. In kindred fashion a Yoruba king, when he goes abroad, is accompanied by his wives, who sing his praise. Now, when we meet with facts of this kind—when we read that in Madagascar "the sovereign has a large band of female singers, who attend in the court-yard, and who accompany their monarch whenever he takes an excursion, either for a short airing or distant journey;" when we are told that in China "his imperial majesty was preceded by persons loudly proclaiming his virtues and his power;" when we learn that among the ancient Chibchas the *hogotá* was received with "songs in which they sung his deeds and victories"—we cannot deny that these assertors of greatness and singers of praises do for the living king exactly that which priests and priestesses do for the dead king, and for the god who evolves from the dead king.

In societies that have their ceremonial governments largely developed, the homology is further shown. As such societies ordinarily have many gods of various powers, severally served by their official glorifiers, so they have various grades of living potentates, severally served by men who assert their greatness and demand respect. In Samoa, "a herald runs a few paces before, calling out, as he meets any one, the name of the chief who is coming." With a Madagascar chief in his palanquin, "one or two men with *assagais*, or spears, in their hands, ran along in front shouting out the name of the chief." In advance of an embassador in Japan there "first walked four men with brooms, such as always precede the retinue of a great lord, in order to admonish the people with cries of 'Stay, stay!' which means, 'Sit, or bow you down;'" and in China a magistrate making a progress is preceded by men bearing "red boards having the rank of the officer painted on them, running and shouting to the street-passengers: 'Retire, retire! keep silence, and clear the way!' Gong-strikers follow, denoting at certain intervals by so many strokes their master's grade and office."

Another parallelism exists between the official who proclaims the king's will and the official who proclaims the will of the deity—between the interpreter who conveys statements to the king and brings back his reply, and the priest who conveys the petitions or questions of worshipers, and explains the oracular response. In many places where regal power is extreme, the monarch is either invisible or cannot be directly communicated with: the living ruler thus simulating the dead and divine ruler, and requiring kindred intermediators. It was thus in ancient Mexico. Of Montezuma II. it is said that "no commoner was to look him in the face, and if one did, he died for it;" and further, that he did not communicate with any one "except by an interpreter." In Nicaragua the caziques "carried their exclusion so far as to receive messages from other chiefs only through officers delegated for that purpose." So of Peru, where some of the rulers "had the custom not to be seen by their subjects but on rare occasions," we read that at the first interview with the Spaniards, "Atahuallpa gave no answer, nor did he even raise his eyes to look at the captain (Hernando de Soto). But a chief replied to what the captain had said." With the Chibchas "the first of the court officers was the crier, as they said that he was the medium by which the will of the prince was explained." Throughout Africa at the present time like customs have generated like appliances. Speke tells us that, "in conversation with the King of Uganda, the words must always be transmitted through one or more of his officers." Among the inland negroes "it is quite beneath the dignity of an *attàh* to reply from the throne except through his 'mouth,' or prime-minister." In Dahomey, "the sovereign's words are spoken to the *meu*, who informs the interpreter, who passes it on to the visitor, and the answer must trickle back through the same channels." And, concerning Abyssinia, where even the chiefs sit in their houses in darkness, so "that vulgar eyes may not gaze too plainly upon" them, we are told the king was "not seen when sitting in council," but "sat in a darkened room," and "observed through a window what was going on in the chamber without;" and also that he had "an interpreter, who was the medium of communication between the king and his people on state occasions; his name meant the voice or word of the king." I may add that this parallelism between the secular and sacred agents of communication is in some cases recognized by peoples whose institutions display it. Thomson tells us that the New Zealand priests were regarded as the embassadors of the gods.

There is a further evidence of this homology. Where, along with social development considerably advanced, ancestor-worship has remained dominant, and where gods and men are, consequently, but little differentiated, the two organizations are but little differentiated. China furnishes a good instance. Huc tells us that "the Chinese emperors are in the habit of deifying . . . . civil or military officers, whose life has been characterized by some memorable act, and the worship rendered to these constitutes the official religion of the mandarins." Further, we read in Gutzlaff that the emperor "confers various titles on officers who have left the world, and shown themselves worthy of the high trust reposed in them, creating them governors, presidents, overseers, etc., in Hades, and thus establishing his government even among the manes." And then we learn from Williams that the Li pu, or Board of Rites, examines and directs concerning the performances of the five kinds of ritual observances—those of a propitious and those of a felicitous nature, military and hospitable rites, and those of an infelicitous nature. Among its departments is that of ceremonial forms—the etiquette to be observed at court, the regulations of dresses, of carriages and riding-accoutrements, of followers and insignia, personal and written intercourse between the various ranks of peers. Another department superintends the rites to be observed in worshiping deities and spirits of departed monarchs, sages and worthies, etc.—statements showing that the same board regulates both religious ceremonial and civil ceremonial. To which summarized account I may add this quotation: "In court, the master of ceremonies stands in a conspicuous place, and with a loud voice commands the courtiers to rise and kneel, stand or march"—that is, he directs the worshipers of the monarch as a chief priest directs the worshipers of the god. Equally marked were, until lately, the kindred relations in Japan. With the sacredness of the mikado, and with his divine inaccessibility, travelers have familiarized us; but the implied confusion between the divine and the human went to a much greater extent—an extent which would be scarcely credible, did not independent witnesses testify to it. Dickson says:

"The Japanese generally are imbued with the idea that their land is a real 'shin koku, a kami no kooni'—that is, the land of spiritual beings or kingdom of spirits. They are led to think that the emperor rules over all, and that, among other subordinate powers, he rules over the spirits of the country. He rules over men, and is to them the fountain of honor; and this is not confined to honors in this world, but is extended to the other, where they are advanced from rank to rank by the orders of the emperor."

Similarly we are told by Mitford that—

"In the days of Shogun's power the mikado remained the Fountain of Honor, and, as chief of the national religion and the direct descendant of the gods, dispensed divine honors. So recently as last year [1870] a decree of the Mikado appeared in the Government *Gazette*, conferring posthumous divine honors upon an ancestor of the Prince of Coshiu."

And then we read that under the Japanese cabinet, one of the eight administrative boards, the Ti bu shio, "deals with the forms of society, manners, etiquette, worship, ceremonies for the living and the dead," etc.: the propitiation of living persons and the propitiation of dead persons and deities have a supreme regulative centre in common.

Western peoples, among whom during the Christian era differentiation of the divine from the human has become very decided, show us in a less marked manner the homology between the ceremonial organization and the ecclesiastical organization. Still it is, or rather, was once, clearly traceable. In feudal days, beyond the lord-high chamberlains, grand-masters of ceremonies, ushers, and so forth, belonging to royal courts, and the kindred officers found in the households of subordinate rulers and nobles—officers who conducted propitiatory observances—there were the heralds. These formed a class of ceremonial functionaries, in various ways resembling a priesthood. Just noting as significant the remark of Scott that, "so intimate was the union betwixt chivalry and religion esteemed to be, that the several gradations of the former were seriously considered as parallel to those of the Church," I go on to point out that these officers, pertaining to the institutions of chivalry, formed a body which, where it was highly organized, as in France, had five ranks: *chevaucheur*, *poursuivant d'armes*, *heraut d'armes*, *roi d'armes*, and *roi d'armes de France*. Into these ranks its members were successively initiated by a species of baptism—wine being substituted for water. They held periodic chapters in the church of Saint-Antoine. When bearing mandates and messages they were similarly dressed with their masters, royal or noble, and were similarly honored by those to whom they were sent, having thus a deputed dignity akin to the deputed sacredness of priests. By the chief king-at-arms and five others, local visitations were made for inquiry and discipline, as ecclesiastical visitations were made; and in various other ways the functions of the organization were allied to priestly functions. Heralds verified the titles of those who aspired to the distinctions of chivalry, as priests decided on the fitness of applicants for the sanctions of the Church; and on the occasions of their visitations they were to "correct things ill and dishonest," and to advise princes—duties allied to those of priests. Besides announcing the wills of earthly rulers, as priests of all religions announce the wills of heavenly rulers, they were glorifiers of the first, as priests were of the last—part of their duty to those they served being "to publish their praises in foreign lands." At the burials of kings and princes, where observances for honoring the living and observances for honoring the dead came in contact, the kinship of a herald's function to the function of a priest was again shown; for, besides putting in the tomb the insignia of rank of the deceased potentate, and in that manner sacrificing to him, the herald had to write, or to get written, a eulogy—had to initiate that worship of the dead out of which grow higher forms of worship. Similar, if less elaborate, was the system in England. Heralds wore crowns, had royal dresses, and used the plural "we." Anciently, there were two heraldic provinces, with their respective chief heralds, like two dioceses. Further development produced a garter king-at-arms, with provincial kings-at-arms presiding over minor heraldic officers; and, in 1483, all were incorporated into the College of Heralds. As in France, visitations were made for the purpose of verifying existing titles and honors, and authorizing others; and funeral rites were so far under heraldic control that, among the nobility, no one could be buried without the assent of the herald.

Why these structures which discharged ceremonial functions once conspicuous and important dwindled, while civil and ecclesiastical structures developed, it is easy to see. Propitiation of the living has been, from the outset, necessarily more localized than propitiation of the dead. The existing ruler can be worshiped only in his presence, or, at any rate, within his dwelling or in its neighborhood. Though in Peru adoration was paid to images of the living Yncas; and though in Madagascar King Radama, when absent, had his praises sung in the words, "God is gone to the west, Radama is a mighty bull;" yet, generally, the obeisances and laudations expressing subordination to the great man while alive, are not made when they cannot be witnessed by him or his immediate dependents. But when the great man dies and there begin the awe and fear of his ghost, conceived as able to reappear anywhere, propitiations are no longer so narrowly localized; and in proportion as, with formation of larger societies, there comes development of deities greater in supposed power and range, dread of them and reverence for them are felt simultaneously over wide areas. Hence the official propitiators, multiplying and spreading, severally carry on their worships in many places at the same time—there arise large bodies of ecclesiastical officials. Not for these reasons alone, however, does the ceremonial organization fail to grow as the other organizations do: their development causes its decay. Though, during early stages of social integration, local rulers have their local courts with appropriate officers of ceremony, the process of consolidation and increasing subordination to a central government, results in decreasing dignity of the local rulers, and disappearance of the official upholders of their dignities. Among ourselves in past times, "dukes, marquises, and earls, were allowed a herald and pursuivant; viscounts, and barons, and others not ennobled, even knights bannerets, might retain one of the latter;" but, as the regal power grew, "the practice gradually ceased; there were none so late as Elizabeth's reign." Yet further, the structure carrying on ceremonial control slowly falls away, because its functions are gradually encroached upon. Political and ecclesiastical regulations, though at first insisting mainly on conduct expressing obedience to rulers, divine and human, develop more and more in the directions of equitable restraints on conduct between individuals, and ethical precepts for the guidance of such conduct; and in doing this they trench more and more on the sphere of the ceremonial organization. In France, besides having the semi-priestly functions we have noted, the heralds were "judges of the crimes committed by the nobility;" and they were empowered to degrade a transgressing noble, confiscate his goods, raze his dwellings, lay waste his lands, and strip him of his arms. In England, too, certain civil duties were discharged by these officers of ceremony. Till 1688, the provincial kings-at-arms had "visited their divisions, receiving commissions for that purpose from the sovereign, by which means the funeral certificates, the descents, and alliances of the nobility and gentry, had been properly registered in this college" (of heralds). "These became records in all the courts at law." Evidently the assumption of functions of these kinds by ecclesiastical and political agents has joined in reducing the ceremonial structures to those rudiments which now remain, in the almost-forgotten Heralds' College, and in the court officials who regulate intercourse with the sovereign.

Before passing to a detailed account of ceremonial government under its various aspects, it will be well to sum up the results of this preliminary survey. They are these:

That control of conduct which we distinguish as ceremony precedes the civil and ecclesiastical controls. It begins with sub-human types of creatures; it occurs among otherwise ungoverned savages; it often becomes highly developed where the other kinds of rule are little developed; it is ever being spontaneously generated afresh between individuals in all societies; and it envelops the more definite restraints which state and church exercise. The primitiveness of ceremonial government is further shown by the fact that, at first, political and religious governments do little more than maintain systems of ceremony, directed toward particular persons living and dead: the codes of law enforced by the one, and the moral codes enunciated by the other, come later. There is, again, the evidence derived from the possession of certain elements in common by the three controls, social, political, and religious; for the forms observable in social intercourse occur also in the political and religious intercourse as forms of homage and forms of worship. More significant still is the circumstance that ceremonies may mostly be traced back to certain spontaneous acts which manifestly precede legislation, civil and ecclesiastical. Instead of arising by dictation or by agreement, which would imply the preëstablished organization required for making and enforcing rules, they arise by modifications of acts performed for personal ends; and so prove themselves to grow out of individual conduct before social arrangements exist to control it. Lastly, we note that when there arises a political head, who, demanding subordination, is at first his own master of the ceremonies, and who presently collects round him subservient attendants performing propitiatory acts, which by repetition are made definite and fixed, there arise ceremonial officials. Though, along with the growth of organizations which enforce civil laws and enunciate moral precepts, there has been such a decay of the ceremonial organization as to render it among ourselves inconspicuous; yet in early stages the body of officials who conduct propitiation of living rulers, supreme and subordinate, homologous with the body of officials who conduct propitiation of dead apotheosized rulers, major and minor, is a considerable element of the social structure; and it dwindles only as fast as the structures, political and ecclesiastical, which exercise controls more definite and detailed, usurp its functions.

Carrying with us these general conceptions, let us now pass to the several components of ceremonial rule. We will deal with them under the heads—Trophies, Mutilations, Presents, Obeisances, Forms of Address, Titles, Badges and Costumes, Further Class Distinctions, Fashion, Past and Future of Ceremony.

GEYSERS AND HOW THEY ARE EXPLAINED.[1]

By Prof. JOSEPH LE CONTE.

A GEYSER may be defined as a *periodically eruptive spring.* They are found only in Iceland, in the Yellowstone Park, United States, and in New Zealand. The so-called geysers of California are rather fumaroles. Those of Iceland have been long studied; we will, therefore, describe these first.

[1] From Le Conte's "Elements of Geology."

Iceland is an elevated plateau about two thousand feet high, with a narrow marginal habitable region sloping gently to the sea. The elevated plateau is the seat of every species of volcanic action, viz., lava-eruptions, solfataras, mud-volcanoes, hot springs, and geysers.

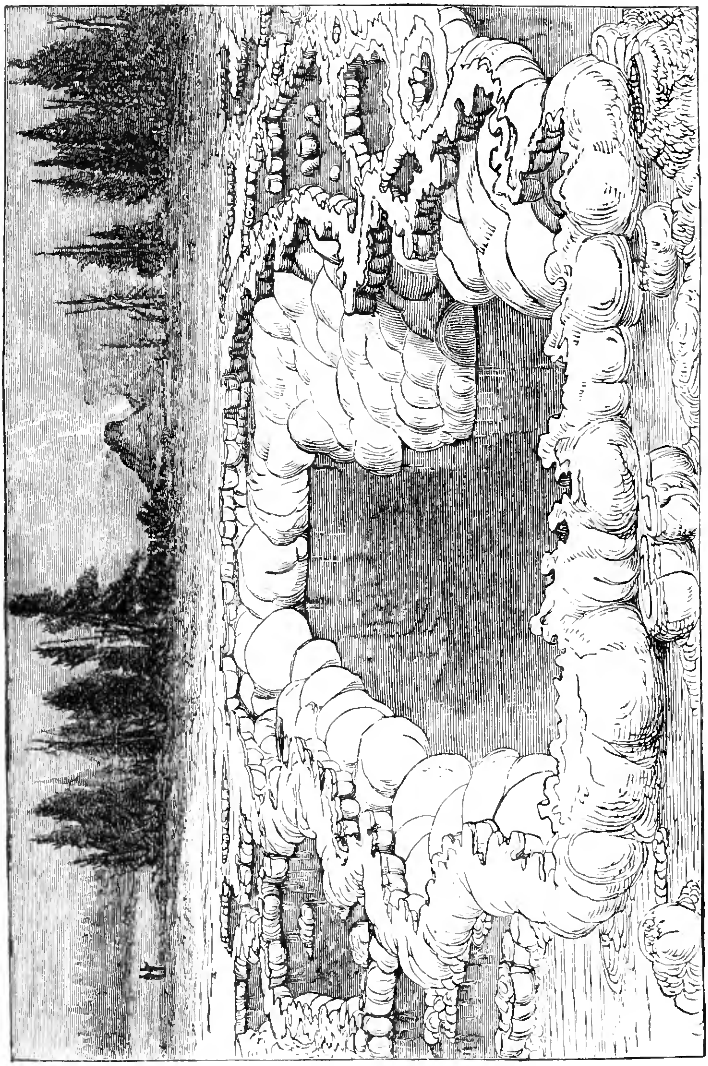

Fig. 1.—Geyser near the Giant, showing the Ornamental Character of the Border (after Hayden).

These last exist in great numbers; more than one hundred are found in a circle of two miles diameter. One of these, the Great Geyser, has long attracted attention.

The Great Geyser is a basin or pool fifty-six feet in diameter, on the top of a mound thirty feet high. From the bottom of the basin descends a funnel-shaped pipe eighteen feet in diameter at top, and seventy-eight feet deep. Both the basin and the tube are lined with silica, evidently deposited from the water. The natural inference is, that the mound is built up by deposit from the water, in somewhat the same manner as a volcanic cone is built up by its own ejections. In the intervals between the eruptions the basin is filled to the brim with perfectly transparent water, having a temperature of about 170° to 180°.

1. Immediately preceding the eruption sounds like cannonading are heard beneath, and bubbles rise and break on the surface of the water. 2. A bulging of the surface is then seen, and the water overflows the basin. 3. Immediately thereafter the whole of the water in the tube and basin is shot upward one hundred feet high, forming a fountain of dazzling splendor. 4. The eruption of water is immediately followed by the escape of steam with a roaring noise. These last two phenomena are repeated several times, so that the fountain continues to play for several minutes, until the water is sufficiently cooled, and then all is again quiet until another eruption. The eruptions occur tolerably regularly every ninety minutes, and last six or seven minutes. Throwing large stones into the tube has the effect of bringing on the eruption more quickly.

In magnificence of geyser displays, however, Iceland is far surpassed by the Yellowstone geysers in the basin of Firehole River. This wonderful geyser region is situated in the northwest corner of Wyoming, on an elevated volcanic plateau near the head-waters of the Madison River, a tributary of the Missouri, and of the Snake River, a tributary of the Columbia. The basin is only about three miles wide. About it are abundant evidences of prodigious volcanic activity in former times, and, although primary volcanic activity has ceased, secondary volcanic phenomena are developed on a stupendous scale and of every kind, viz.: hot springs, carbonated springs, fumaroles, mud-volcanoes, and geysers. In this vicinity there are more than 10,000 vents of all kinds. In some places, as on Gardiner's River, the hot springs are mostly lime-depositing; in others, as on Firehole River, they are geysers depositing silica.

FIG. 2.—CHIMNEY-LIKE VENTS (after Hayden).

In the upper geyser basin the valley is covered with a snowy de-

FIG. 3.—THE TURBAN (after Hayden).

FIG. 4.—GIANT GEYSER (after Hayden).

posit from the hot geyser-waters. The surface of the mound-like, chimney-like, and hive-like elevations, immediately surrounding the vents, is, in some cases, ornamented in the most exquisite manner by deposits of the same, in the form of scalloped embroidery set with pearly tubercles; in others, the siliceous deposits take the most fan-

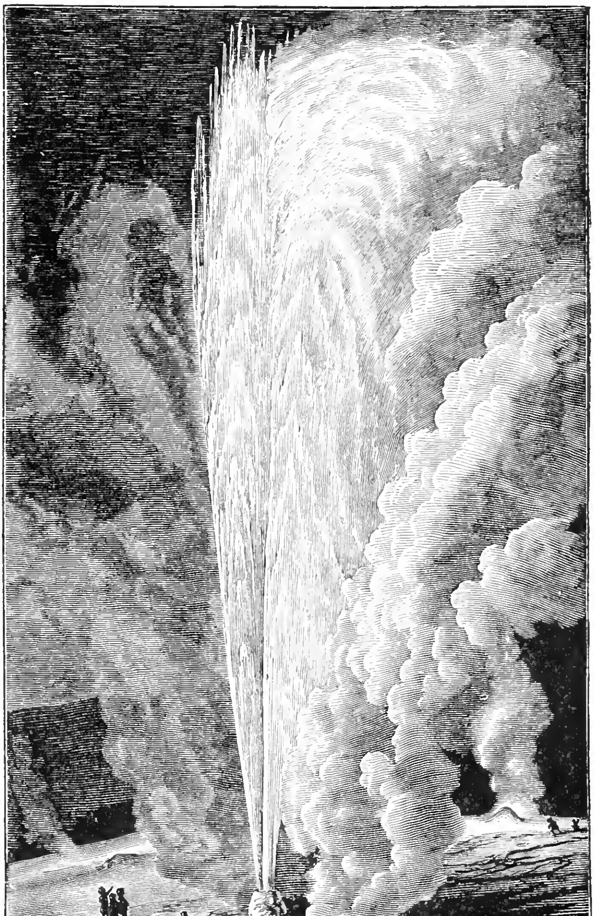

FIG. 5.—BEEHIVE GEYSER (from a Drawing by Holmes).

tastic forms (Figs. 1, 2, 3). In some places the silica is deposited in large quantities, three or four inches deep, in a gelatinous condition like starch-paste. Trunks and branches of trees immersed in these waters are speedily petrified.

We can only mention a few of the grandest of these geysers:

1. The "Grand Geyser," according to Hayden, throws up a col-

umn of water six feet in diameter to the height of 200 feet, while the steam ascends 1,000 feet or more. The eruption is repeated every thirty-two hours, and lasts twenty minutes. In a state of quiescence the temperature of the water at the surface is about 150°.

2. The "Giantess" throws up a large column twenty feet in diameter to a height of sixty feet, and through this great mass it shoots up five or six lesser jets to a height of 250 feet. It erupts about once in every eleven hours, and plays twenty minutes.

3. The "Giant" (Fig. 4) throws a column five feet in diameter 140 feet high, and plays continuously for three hours.

4. The "Beehive" (Fig. 5), so called from the shape of its mound, shoots up a splendid column two or three feet in diameter to the height by measurement of 219 feet, and plays fifteen minutes.

5. "Old Faithful," so called from the frequency and regularity of its eruptions, throws up a column six feet in diameter to the height of 100 to 150 feet regularly every hour, and plays each time fifteen minutes.

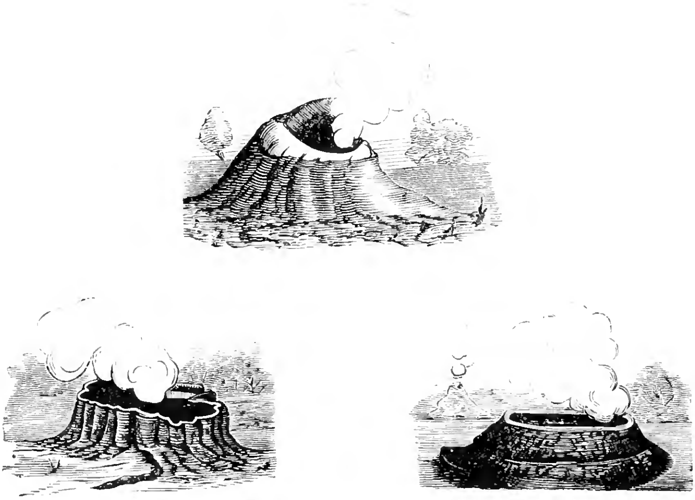

Fig. 6.—Forms of Geyser-Craters (after Hayden).

The water of geysers is not volcanic water, but simple spring-water. A geyser is not, therefore, a volcano ejecting water, but a true spring. There has been much speculation concerning the cause of their truly wonderful eruptions.

According to Mackenzie, the eruptions of the Great Geyser may be accounted for by supposing its pipe connected by a narrow conduit with the lower part of a subterranean cave, whose walls are heated by the near vicinity of volcanic fires. Fig. 7 represents a section through the basin, tube, and supposed cave. Now, if meteoric water should run into the cave through fissures more rapidly than it can evaporate, it would accumulate until it rose above, and therefore closed, the opening at *a*. The steam, now having no outlet, would condense in the chamber *b* until its pressure raised the water into the pipe, and caused it to overflow the basin. The pressure still continuing, all the water would be driven out of the cave, and partly up the pipe. Now, the pressure which sustained the whole column *a d* would not only sustain, but eject with violence, the column *c d*. The steam would escape, the ejected water would cool, and a period of quiescence would follow. If there were but one geyser in Iceland, this would be rightly considered a very ingenious and probable hypothesis, for without doubt we may conceive of a cave and conduit so constructed as to account for the phenomena. But there are many eruptive springs in Iceland, and it is inconceivable that all of them should have caves and conduits so peculiarly constructed. This theory is therefore entirely untenable.

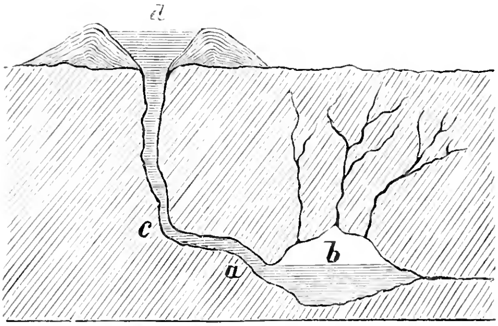

Fig. 7.—Mackenzie's Theory of Eruption.

The investigations of Bunsen and his theory of the eruption and the formation of geysers are among the most beautiful illustrations of scientific induction which we have in geology. We therefore give it, perhaps, more fully than its strict geological importance warrants.

Bunsen examined all the phenomena of hot springs in Iceland. 1. He ascertained that geyser-water is meteoric water, containing the soluble matters of the igneous rocks in the vicinity. He formed identical water by digesting Iceland rocks in hot rain-water. 2. He ascertained that there are two kinds of hot springs in Iceland, viz., *acid springs* and *alkaline-carbonate springs*, and that only alkaline-carbonate springs contain any silica in solution. The reason is obvious: alkaline waters, especially if hot, are the natural solvents of silica. 3. He ascertained that *only the silicated springs form geysers*. Here is one important step taken—one condition of geyser-formation discovered. Deposit of silica is necessary to the existence of geysers. The tube of a geyser is not an accidental conduit, but is built up by its own deposit. 4. Of silicated springs, *only those with long tubes erupt*—another condition. 5. Contrary to previous opinion, the silica in solution does not deposit on cooling, but only by drying. This would make the building-up of a geyser-tube an inconceivably slow process, and the time proportionally long. This, however, is not true, for the Yellowstone geyser-waters, which deposit abundantly by *cooling*, evidently because they contain much more silica than those of

Iceland. 6. The temperature of the water in the basin was found to be usually 170° to 180°, and that in the tube to increase rapidly, though not regularly, with depth. Moreover, the temperature, both at the surface and at all depths, increased regularly as the time of eruption approached. Just before the eruption it was, at the depth of about forty-five feet, very near the boiling-point *for that depth.*

1. It is well known that the boiling-point of water rises as the pressure increases. This is shown in the adjoining table. 2. It follows from the above that if water be under strong pressure, and at high temperature, though below its boiling-point for that pressure, and the pressure be diminished sufficiently, it will immediately flash into steam. 3. Water heated beneath, if the circulation be unimpeded, is *very nearly* the same temperature throughout. That it is never the same temperature precisely is shown by the circulation itself, which is caused by difference of temperature, producing difference in density. The phenomenon of simmering is also a well-known evidence of this difference of temperature, since it is produced by the collapse of steam-bubbles rising into the cooler water above. 4. But if the circulation be *impeded*, as when the water is contained in long, narrow, irregular tubes, and heated with great rapidity, the temperature may be greater below than above to any extent, and the boiling-point may be reached in the lower part of the tube, while it is far from this point in the upper part.

Pressure in Atmospheres.	Boiling-Point.
1 Atmos.	212°
2 "	250°
3 "	275°
4 "	293°

We will suppose a geyser to have a simple but irregular tube, without a cave, heated below by volcanic fires, or by still hot volcanic ejections. Now, we have already seen that the temperature of the water in the tube increases rapidly with the depth, but is, at every depth to which observation extends, short of the boiling-point for that depth. Let abscissa *a d* (Fig. 8) represent depth in the tube, and also pressures; and the corresponding temperature be measured on the ordinate *a n*. If, then, *a b*, *b c*, *c d*, represent equal depths of thirty-three or more feet, which is equal to one atmospheric pressure, the curve *e f* passing through 210°, 250°, 275°, and 293°, at the horizontal lines, representing one atmosphere, two atmospheres, three atmospheres, etc., would correctly represent the increasing boiling-points as we pass downward. We shall call this line, *e f*, *the curve of boiling-point.*

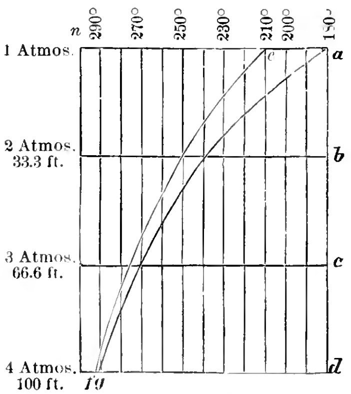

Fig. 8.

The line *a g* commencing at the surface at 180°, and gradually approaching the boiling-point line, but everywhere within it, would represent the actual temperature in a state of quiescence. Now, Bunsen found that, as the time of eruption approached, the temperature at every depth approached the boiling-point for that depth, i. e., the line *a g* moved toward the line *e f*. There is no doubt, therefore, that, at the moment of eruption, at some point below the reach of observation, the line *a g* actually touches the line *e f*—the boiling-point for that depth is actually reached. As soon as this occurs, a quantity of water in the lower portion of the tube, or perhaps even in the subterranean channels which lead to the tube, would be changed into steam, and the expanding steam would lift the whole column of water in the tube, and cause the water in the basin to *bulge and overflow*. As soon as the water overflowed, the pressure would be diminshed in every part of the tube, and consequently a large quantity of water before very near the boiling-point would flash into steam and instantly eject the whole of the water in the pipe; and the steam itself would rush out immediately afterward. The premonitory cannonading beneath is evidently produced by the collapse of large steam-bubbles rising through the cooler water of the upper part of the tube; in other words, it is *simmering on a huge scale*. An eruption is more quickly brought on by throwing stones into the throat of the geyser, because the circulation is thus more effectually impeded.

The theory given above is substantially that of Bunsen for the eruption of the Great Geyser, but modified to make it applicable to all geysers. In the Great Geyser, as already stated, Bunsen found a point, forty-five feet deep, where the temperature was nearer the boiling-point than at any *within* reach of observation, though doubtless *beyond* the reach of observation the temperature again approached and *touched the boiling-point*. This point, forty-five feet deep, plays an important part in Bunsen's theory. To illustrate: if *e f* (Fig. 9) represent again the curve of boiling-point, then the curve of actual temperature in the Great Geyser tube would be the irregular line *a g h*. At the moment of eruption, this line touched boiling-point at some depth, *h*, beyond the reach of observation. Then followed the lifting of the column, the overflow of the basin, the relief of pressure by which the point *g* was brought to the boiling-point, the instantaneous formation of steam at *g*, and the phenomena of an eruption. But it is extremely unlikely that this

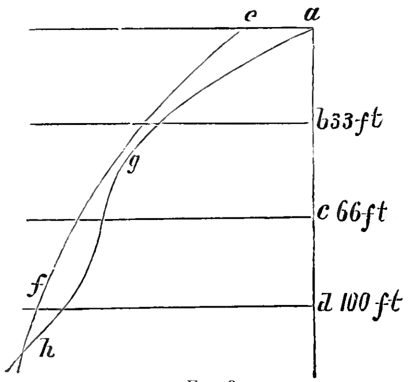

Fig. 9.

condition should exist in all geysers; neither is it at all necessary in order to explain the phenomenon of an eruption.

To prove beyond question the truth of his theory, Bunsen constructed an artificial geyser. The apparatus (Fig. 10) consisted of a tube of tinned sheet-iron about ten feet long, expanded into a dish above for catching the erupted water. It may or may not be expanded below for the convenience of heating. It was heated, also, a little below the middle, by an encircling charcoal chauffer, to represent the point of nearest approach to the boiling-point in the geyser-tube. When this apparatus was heated at the two points, as shown in the figure, the phenomena of geyser-eruption were completely reproduced; first, the violent explosive simmering, then the overflow, then the eruption, and then the state of quiescence. In Bunsen's experiment, the eruptions occurred about every thirty minutes.

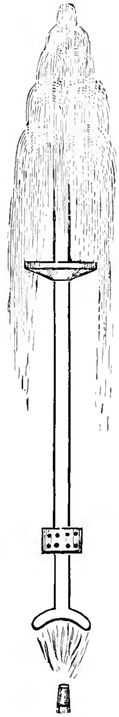

Fig. 10.—Artificial Geyser.

According to Bunsen, a geyser does not find a cave, or even a perpendicular tube, ready made, but, like volcanoes, makes its own tube. Fig. 11 is an ideal section of a geyser-mound, showing the manner in which, according to this view, it is formed. The irregular line, *b a c*, is the original surface, and *a* the position of a hot spring. If the spring be not alkaline, it will remain an ordinary hot spring; but, if it be alkaline, it will hold silica in solution, and the silica will be deposited about the spring. Thus the mound and tube are gradually built up. For a long time the spring will not be eruptive, for the circulation will maintain a nearly equal temperature in every part of the tube—it may be a *boiling*, but not an eruptive spring. But, as the tube becomes longer, and the circulation more and more impeded, the difference of temperature between the upper and lower parts of the tube becomes greater and greater, until, finally, the boiling-point is reached below, while the water above is comparatively cool. Then the eruption commences. Finally, from the gradual failure of the subterranean heat, or from the increasing length of the tube repressing the formation of steam, the eruptions gradually cease. Bunsen found geysers in every stage of development—some playful springs without tubes; some with short tubes, not yet eruptive; some with long tubes, violently eruptive;

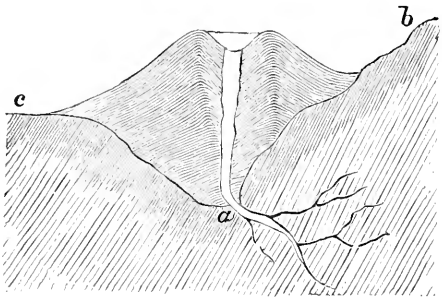

Fig. 11.—Ideal Section of a Geyser-Tube (according to Bunsen).

some becoming old and indisposed to erupt unless angered by throwing stones down the throat.

It is evident, however, that Bunsen's theory of geyser-eruption is independent of his theory of geyser-formation. A tube or fissure of any kind, and formed in any way, if long enough, would give rise to the same phenomena. The Yellowstone geysers have mounds or chimney-like cones, but it is by no means certain that the whole length of their eruptive tubes has been built up by siliceous deposit. Bunsen's theory of eruption none the less, however, applies to these also. The more chimney-like form of the craters in the case of the Yellowstone geysers is probably due to the greater abundance of silica in solution.

THE HYGIENIC INFLUENCE OF PLANTS.

By MAX VON PETTENKOFER.

THE animal kingdom is, as we know, dependent on the vegetable kingdom, which must have existed on the earth before men and animals could live upon it. We may, therefore, rightly call plants children of the earth. But, in so doing we use the language of metaphor, as when we speak of "Mother Earth." The earth does not directly bring forth either plants or animals. Every plant is the child of a mother-plant, descends from one of its own kind like ourselves; but plants derive their nourishment directly from earth, air, and water, and, although generated by plants, are nourished directly by the inorganic breasts of Nature, and imply no other organic life but their own. Had plants a voice, they would more correctly speak of "Mother Earth" than ourselves.

Plants live directly on the lifeless products of earth, and we live directly on the products of plants or on animals which live on them; our existence implies other organic life, and our nourishment is not derived so directly from the earth as that of plants. Since the vegetable world comes between us, *we* should rather call earth our grandmother than our mother. At all events it is an affectionate relationship.

We have a natural feeling of close affinity with the vegetable world, which expresses itself not only in our love of foliage and flowers, but in our fondness for metaphors derived from the vegetable world and its processes. If we were to reckon up how many metaphors in every-day life and in poetry are derived from the vegetable world, and how many from other spheres of Nature, we should find a great excess of the former.

Our material relations to plants are also very numerous. The question we are now concerned with is not what food or what medicinal remedies plants provide us with, but the value of plants and plantations in dwellings and in the open air in conducing to health or preventing disease. We have given the subject very little consideration until quite recently, just as we have thought very little of the way in which the pleasures of the table, fine raiment, comfortable dwellings, and many other things, conduce to our well-being. Meanwhile we have been guided by our instincts, which, like Nature in general, have, on the whole, guided us rightly. Even now there is not much scientific knowledge on the subject; still there is a little, and something is gained when we begin seriously to reflect on anything, for knowledge is sure then to increase. All that man has ever aspired to and attained has always existed much earlier in idea than in reality. Ideas are never fully realized, as we all know, and it is only very gradually that they are realized at all.

It is generally asserted that vegetation purifies the air, and chiefly by three functions: firstly, because plants absorb carbonic acid; secondly, because under the influence of sunlight they exhale an equivalent in oxygen; and, lastly, because they produce ozone. These facts I need not demonstrate, as they have been placed beyond doubt by vegetable physiologists, chemists, and meteorologists. My task is to show what the direct sanitary effect of these three functions is.

I must at once state that none whatever can be proved to exist. And, as this assertion will contradict the prepossessions of many readers, I feel bound to prove my proposition.

As to carbonic acid, the first question is: What is the proper and normal proportion of this gas in the air, next how much more carbonic acid is contained in air which is notoriously bad; and, lastly, whether the air on a surface without vegetation contains essentially more carbonic acid than one having vegetation upon it?

The amount of carbonic acid in the open air has been often determined, and is confined within very narrow limits. It may be said—leaving severe storms or very thick fogs out of the question—to vary between three and four parts in each 10,000 of the volume of the air.

Experiments have also been made on the quantity of carbonic acid in apartments occupied by man, and it is generally taken as the criterion of the quality of the air, ventilation being regulated by it. In very bad air which is undoubtedly deleterious, it has been found to amount to from three to five per mille. One per mille marks the boundary-line between good and bad air in a room.

We next inquire whether the atmosphere over a vast tract of country destitute of vegetation contains more carbonic acid than one abounding in vegetation, whether in the former case the amount of carbonic acid approaches one per mille. In 1830 De Saussure began to make researches into the variations in the quantity of carbonic acid in Geneva, and they were continued about ten years later by Verver in Holland, and Boussingault in Paris; in more recent, and very recent times, a great number of experiments have been made on the subject by Roscoe in Manchester, Schulze at Rostock, and myself and my pupils, particularly Dr. Wolffhügel, at Munich. The result is, in the main, that the variations—very small from the first—have been found to be still smaller as the methods of determining carbonic acid have been perfected.

Saussure, who worked by a method liable to give an excess, found from 3.7 to 6.2 parts in 10,000. He considered that there were also slight variations between summer and winter, day and night, town and country, land and sea, mountains and valleys, which might be ascribed to vegetation. Boussingault, however, found the carbonic acid in the air to be rather less, and the same on an average in Paris and St.-Cloud; in Paris 4.13 and at St.-Cloud 4.14 in 10,000, which surprised him the more as he had reckoned that in Paris at least 2,944,000,000 litres of carbonic acid were exhaled by men, animals, and fuel.

Roscoe made experiments on the air at a station in the middle of Manchester, and at two stations in the country. He was originally of opinion that the vast manufactures of Manchester, chiefly dependent on the consumption of coal, must produce a perceptible effect on the carbonic acid in the air; but he also discovered that the air in the space in front of Owens College contained no more than the air at the country stations. He also observed occasional variations: but, when the carbonic acid increased or diminished in the city, it was generally just the same in the country. Roscoe found the greatest amount of carbonic acid in the air during one of the thick fogs prevalent in England.

Schulze found the amount of carbonic acid in the air at Rostock to be between two and half and four parts in 10,000. On an average it was somewhat higher when the wind blew off-shore than off the sea.

In Munich, Wolffhügel found the carbonic acid to be between three and four parts in 10,000. Now and then, but very seldom, he observed variations, the maximum being 6.9 parts in 10,000 in a very thick fog, the minimum 1.5 part in 10,000 in a heavy snow-storm, when the mercury was very low in the barometer.

It may be asked how the immense production of carbonic acid in a city like Paris or Manchester can thus vanish in the air. The answer is very simple: by rarefaction in the currents of the atmosphere. We are apt not to take this factor into account, but think rather of the air as stagnant. The average velocity of the air with us is three metres per second, and even in apparently absolute calm it is more than half a metre. If we therefore assume a column of air 100 feet high and of average velocity, it may be reckoned that the carbonic acid from all the lungs and chimneys of Paris or Manchester is not sufficient to increase its amount so as to be detected by our methods.

From this fact it may be logically concluded that, if no increase in the carbonic acid in the air is observable, no diminution will be observable from vegetation.

It is a universally recognized and incontrovertible fact that the carbonic acid contained in all the vegetable life on earth is derived from the carbonic acid in the air, in water, and the soil. Many conclude, therefore, that the air in a green wood must contain less carbonic acid than that in a city or that of an extensive tract of waste land. But I can assure them that the air in the Sahara, so called, of Munich, formerly called the Dultplatz, contains no more carbonic acid than the neighboring Eschen-grounds. Of this I can give incontestable proof, an argument *ad hominem*. Dr. Zittel brought me several specimens of air in hermetically-sealed glass tubes, from his travels in the Libyan Desert, from sandy wastes and from oases, on which I could conveniently make experiments at Munich. The amount of carbonic acid does not differ in the least in the air from the barren waste and the greenest oases. The case is just the same with the amount of oxygen in the air. It was formerly thought, when imperfect methods were employed, that perceptible variations could be proved. Thus, for example, the outbreak of cholera in 1831 was attributed to a diminution of oxygen in the air, and here and there experiments were made which seemed to confirm the opinion. The hypothesis did not seem improbable, for it was concluded with certainty that in tropical swamps, which are the home of cholera, the oxygen in the air might have been in course of time diminished by the vast masses of decaying matter. But, since the method of gas analysis has been arranged by Von Bunsen, the amount of oxygen in the air on the summit of Mont Blanc has not been found to differ from that in a city or in the swamps of Bengal. Neither is it greater in forest or sea air than in the air of the desert.

This absence of demonstrable variation, in spite of the production of oxygen by living plants and the absorption of it by the processes of combustion and decay, becomes intelligible when we consider first the mobility, and then the mass of the air encompassing our earth. The weight of this mass is, as the barometer tells us, equal to that of a layer of mercury which would cover the surface of the earth to the depth of 760 millimetres (more than three-quarters of a metre). From the weight of this, several billion kilometres, some idea can be formed of the volume of the air, when we consider that air, even beneath a pressure of 760 millimetres of mercury, is yet 10,395 times lighter than mercury. In masses like these, variations such as those we speak of go for nothing. The amount of carbonic acid and oxygen might perhaps be essentially changed in Paris or Manchester if all organic matter on and in the earth were burning at once.

Even if it is granted, however, in face of these incontrovertible facts, that vegetation exercises no perceptible influence upon the composition of the atmosphere in the open air, many persons will not be disposed to give up the idea that the air in rooms can be improved by plants, because, as is well known, every green leaf absorbs carbonic acid and gives out oxygen under the influence of light. This idea may seem the more justifiable, because, although the production of carbonic acid is not perceptible in the greatest assemblages of human beings in the open air, it is always observed in confined spaces, although the actual production is but small. In the air of a closed apartment, every person and every light burning makes a perceptible difference in the increase of carbonic acid in the air. Must not, therefore, every plant in a pot, every spray, any plant with leaves, make a perceptible difference in a room? Every lover of flowers may be pardoned for wishing to see this question answered in the affirmative. Have not even medical men proposed to adorn school-rooms with plants in pots instead of ventilating them better, in order that their leaves and stems might absorb carbonic acid from the mouths of the children, and give out oxygen in its stead? But hygiene cannot agree even to this. Hygiene is a science of economics, and every such science has to ask not only what exists and whether it exists, but how much there is and whether enough. The power of twenty pots of plants would not be nearly sufficient to neutralize the carbonic acid exhaled by a single child in a given time. If children were dependent on the oxygen given off by flowers, they would soon be suffocated. It must not be forgotten what a slow process the production of matter by plants is—matter which the animal organism absorbs and again decomposes in a very short time, whereby as much oxygen is used up as has been set free in the production of it. It is for this reason that such great extents of vegetation are required for the sustenance of animals and man. The grass or hay consumed by a cow in a cow-house grows upon a space of ground on which a thousand head of cattle could stand. How slow is the process of the growth of wheat before it can be eaten as bread, which a man will eat, digest, and decompose, in twenty-four hours! The animal and human organism consumes and decomposes food as quickly as a stove burns the wood which took so many thousand times longer to grow in the forest.

It would scarcely be intelligible if I were to calculate how much carbonic acid and oxygen a rose, a geranium, or a bignonia, would absorb and give out in a room in a day, and to what extent the air might be changed by it, taking into account the inevitable change of air always going on. I will draw attention to a concrete case which every one can understand:

When the Royal Winter Garden in Munich was completed and in use, it occurred to me to make experiments on the effect of the whole garden on the air within it. There could not be a more favorable opportunity for experimenting on the air in a space full of vegetation. This green and blooming space was not exposed to the free currents of air which at once immensely rarefy all gaseous exhalations, but was kept warm under a dome of glass, through which only the light of heaven penetrated. Although not hermetically sealed, the circulation of air in such a building, compared with that in the open air, is reduced over a hundred-thousandfold.

I asked permission to make experiments for several days at various hours of the day and night, which was readily granted. Now, what was the result? The proportion of carbonic acid in the air in the winter garden was almost as high as in the open air. This greatly surprised me, but I hoped at any rate to have one of my traditional ideas confirmed: I hoped to find less carbonic acid in the day than in the night, supported by the fact that the green portions of plants under the influence of light decompose carbonic acid and develop oxygen. But even here I was disappointed. I generally found carbonic acid increasing from morning till evening, and decreasing from night till morning. As this seemed really paradoxical, I doubled my tests and care, but the result remained the same. At that time I knew nothing of the large amount of carbonic acid of the air, in the soil, the air of the ground, or I should probably have been less surprised.

One day it suddenly became clear to me why there was always more carbonic acid by day than by night. I had been thinking only of the turf, the shrubs, and trees, which consume carbonic acid and produce oxygen, and not of the men and birds in the winter garden. One day, when there were considerably more men at work there than usual, the carbonic acid rose to the highest point, and sank again to the average during the night. The production of carbonic acid by the working and breathing of human beings was so much greater than that consumed by the plants in the same time.

The oxygen in the winter garden was rather higher than in the open air; there it was about twenty-one per cent., and in the winter garden twenty-two to twenty-three per cent.

I did not make any experiments on ozone, for reasons which I will give by-and-by.

The amount of carbonic acid in the air in the winter garden cannot be reckoned as telling for or against the hygienic value of vegetation in an inclosed space. Let us inquire, then, into the value of the slight increase of oxygen.

There is a wide-spread opinion that the breathing of air rich in oxygen effects a more rapid transformation of matter, a more rapid combustion, as we say, in the body. Even great inquirers and thinkers have considered that we only eat and imbibe nourishment to satiate the oxygen streaming through us, which would otherwise consume us. We know now well enough that the quantity of oxygen which we imbibe does not depend on the quantity in the air we breathe, but far more on previous changes in and the amount of transformation of matter in the body, which are regulated by the requirements of breathing. The inhalation of oxygen is not a primary but a secondary thing. When we inhale air at every breath richer than usual in oxygen—for example, when breathing highly-compressed air, as divers do, or laborers on the pneumatic foundations of bridge-piers—the result is not a larger comsumption of matter and an increased production of carbonic acid, but merely a decrease in the number of inhalations. If in air of ordinary density we make about sixteen respirations in a minute, in air of greater density we should involuntarily make only twelve, ten, or eight, according to the density and our need of oxygen; all else remains the same.

Lavoisier, and, half a century later, Regnault and Reiset, placed animals for twenty-four hours in air very rich in oxygen, but they did not consume more of it than in the ordinary air. An increase of oxygen in the air, therefore, or pure oxygen gas, only produces an effect in certain morbid conditions, in cases of difficulty of breathing, or where breathing has been for some time suspended, because an inspiration communicates more oxygen to the blood than breathing ordinary air. A healthy person can, however, without difficulty or injury, compensate for considerable differences, and an increase or decrease of one or two per cent. of oxygen does no harm, for under ordinary circumstances we only inhale one-fourth of the oxygen in the air we breathe; we inhale it with twenty-one per cent. and exhale it with sixteen per cent.

So far, therefore, as we feel ill or well in a winter garden, it does not depend on the quantity of oxygen in the air, and there is no greater appreciable quantity of oxygen in a wood of thick foliage than in a desert or on the open sea.

Let us also for a moment consider the ozone in the air, which may be looked upon as polarized or agitated oxygen. After its discovery, which has immortalized the name of Schönbein, was made known, it was thought for a time that the key had been found for the appearance and disappearance of various diseases, in the quantity of ozone in the air. But one fact, which was observed from the first, shows that it cannot be so; for the presence of ozone can never be detected in our dwellings, not even in the cleanest and best ventilated. Now, as it is a fact that we spend the greater part of our lives in our houses, and are better than if we lived in the open air, the hygienic value of ozone does not seem so very great. Added to this, the medical men of Königsberg long had several ozone-stations there, during which time various diseases came and went, without, as appears from the reports of Dr. Schiefferdecker, ozone having the slightest connection with the appearance or disappearance of any of them.

Dr. Wolfhügel, assistant at the Hygienic Institute at Munich, has lately been occupied with the question of the sanitary value of ozone, but has arrived at only negative results.

But in saying this I have no intention of denying that ozone is of great importance in the atmosphere, for I am of opinion that it is. It is the constant purifier of the atmosphere from all organic matter, which passes into it and might accumulate. The air would have been long ago filled with the vapors of decomposition if it were not for ozone, which oxidizes all that is oxidizable, if only time enough is allowed for it, and too much is not expected at once; for, generally, the amount of ozone in the air is so small that it is consumed in making its way into our houses, without disinfecting them, and we can no more dispense with the greatest cleanliness and best ventilation in our homes than we can essentially change the air in our rooms by means of plants in pots and foliage.

Some of my readers will perhaps ask in some disappointment, "In what, then, does the hygienic value of plants and plantations consist? Or do I mean to say that all the money spent by one and another on a parterre of flowers in his house or on a garden, or by a community for beautiful grounds, or by a state for the preservation of forests, with the idea of promoting health, is mere luxury, without any hygienic value?" These questions alter our standpoint, and I believe I shall be able to show that even hygiene does recognize a sanitary value in plants and flowers, in the laying out of grounds and plantations, only it offers a different explanation from the ordinary one.

I consider the impression which plants and plantations make upon our minds and senses to be of hygienic value; further, their influence on the conformation of the soil, with which health is in many respects connected; and, finally, their influence upon other qualities of the air, than carbonic acid, oxygen, and ozone: among these may be mentioned, in passing, shade in summer, and decrease of wind and dust.

It is an old observation, needing no demonstration, that the cheerful and happy man lives not only an easier, but, on the average, a more healthy life than the depressed and morose man. Medical men, and especially "mad doctors," could tell us much of the great value of a certain relative proportion of pleasurable and painful impressions upon health, and how frequently some unfortunate position, an absence of pleasure, or too much of painful impression, is the cause of serious illness. Man always tries, and has an irresistible need, to balance painful sensations by some kind of pleasure or other, so that often, in order to get himself into a tolerable frame of mind, or to deaden his feelings for a time, he will have recourse to wine, beer, or spirits, though he knows well enough that he will be worse afterward than before. A certain amount of change and recreation is indispensable, and, failing others, we seek them by injurious means. There are, doubtless, some unhappy and morbid natures who are always discontented, to whom everything comes amiss, and whom it is impossible to help; but the majority of men are easily pleased, find pleasure in little things, though it is but a sorry life they lead. It is something the same with the pleasures of life as with the pleasures of the table; we must relish our food if it is to do us good. What good will the most nourishing diet do me if it creates disgust? Prof. C. Voit has clearly pointed out, in his experimental researches into diet, the great value of palatable food, as well as nourishment, and how indispensable a certain variety in our meals is. We think we are only tickling the palate, and that it is nothing to the stomach and intestines whether food is agreeable to the palate or not, since they will digest it, if it is digestible at all. But it is not so indifferent, after all; for the nerves of the tongue are connected with other nerves and with the nerve-centres, so that the pleasures of the palate, or some pleasure, at any rate, even if it is only imagination, which can only originate in the central organ, the brain, often has an active effect on other organs. This is a matter of daily experience. If you put your finger down your throat, you produce retching; many people have only to think of anything disgusting to produce the effect of an emetic, just as the thought of something nice makes the mouth water just as much as tasting the most dainty morsel. Voit showed me one of his dogs with a fistula in the stomach. So long as this dog is not thinking of food, his stomach secretes no gastric juice, but no sooner does he catch sight of a bit of meat, even at a distance, than the stomach prepares for digestion and secretes gastric juice in abundance. Without this secretion the assimilation of nourishment would be impossible. If, therefore, some provocatives induce and increase certain sensations and useful processes, they are of essential value to health, and it is no bad economy to spend something on them.

I consider flowers in a room, for all to whom they give pleasure, to be one of the enjoyments of life, like condiments in food. It is certainly one of the most harmless and refined. We cannot live on pleasure alone; but, to those who have something to put up with in life, their beloved flowers perform good service.

The same may be said of private gardens and public grounds, and of the artistic perfecting of them. The more tastefully laid out, the better the effect. Though tastes differ, there is a general standard of taste which lasts for several generations, though it varies from time to time, and is subject to fashion. As their object is to give pleasure, public grounds should accord with the taste of the age, or aim at cultivating it. This is a justification for going to some expense for æsthetic ends.

The influence of vegetation on the soil is much more easy to determine than on the mind of man. Space fails me to go into all the aspects of this subject, and I will confine myself to some of the most obvious. The difference is most apparent on comparing the soil of a tract of land covered with wood with the soil outside, in other respects alike. The Bavarian Forest Department deserves great credit for having established meteorological stations with special reference to forest-culture, under the superintendence of Prof. Ebermayer, of Aschaffenburg. He has published his first year's observations in a work on "The Influence of Forests on the Air and Soil, and their Climatic and Hygienic Importance,"[1] which may be recommended to every one who wishes to study the subject.

Modern hygiene has observed that certain variations in the moisture of the soil have a great influence on the origin and spread of certain epidemic diseases, as for instance cholera and typhoid fever—that these diseases do not become epidemic when the moisture in the soil is not above or below a certain level, and has remained so for a time. These variations can be measured with greater accuracy by the ground-water of the soil than by the rainfall, because in the latter case we have to determine how much water penetrates the ground, how much runs off the surface, and how much evaporates at once. The amount of moisture in the soil of a forest is subject to considerably less variation than that outside. Ebermayer has deduced the following result from his meteorological observations on forestry: "If from the soil of an open space 100 parts of water evaporate, then from the soil of a forest free from underwood 38 parts would evaporate, and from a soil covered with underwood only 15 parts would evaporate." This simple fact explains clearly why the cutting down of wood over tracts of country is always followed by the drying up of wells and springs.

In India, the home of cholera, much importance has been attached in recent times to plantations as preventives of it. It has been always observed that the villages in wooded districts suffer less than those in treeless plains. Many instances of this are given in the reports of Dr. Bryden, President of the Statistical Office in Calcutta, and Dr. Murray, Inspector of Hospitals. For instance, Bryden[2] compares the district of the Mahanadda, one of the northern tributaries of the Ganges, the almost treeless district of Rajpoor, with the forest district of Sambalpoor. It is stated that in the villages in the plain of Rajpoor, sixty or seventy per cent. of the inhabitants are sometimes swept away by cholera in three or four days, while the wooded district of Sambalpoor is often free from it, or it is much less severe. The district commissioner, who had to make a tour in the district on account of the occurrence of cholera, reports, among other things, as follows:

"The road to Sambalpoor runs for sixty or seventy miles through the forest, which round Petorah and Jenkfluss is very dense. Now, it is a remarkable fact, but it is a fact, nevertheless, that on this route, traversed daily by hundreds of travelers, vehicles, and baggage-trains, the cholera rarely appears in this extent of sixty miles, and when it does appear it is in a mild form; but when we come to the road from Arang, westward to Chicholee Bungalow, which runs for about

[1] "Die physikalischen Wirkungen des Waldes auf Luft und Boden und seine klimatologische und hygienische Bedeutung."

[2] "Epidemic Cholera in the Bengal Presidency," 1869, p. 225.

ninety miles through a barren, treeless plain, we find the cholera every year in its more severe form, the dead and dying lying by the wayside, and trains of vehicles half of whose conductors are dead."

In the same report Dr. Bryden continues:

"I will mention one other fact as a result of my observations, namely, that places surrounded by those vast and splendid groves which are occasionally seen, lying in low and probably marshy situations, surrounded by hills, and which, from the mass of decaying vegetation, are very subject to fever in September, October, and November, are seldom visited by cholera, and if it occurs there are but few deaths, while places on high ground, or in what are called fine, airy situations, free from trees and without hills near, so that they are thoroughly ventilated, suffer very much from cholera."

Murray gives a number of instances showing the influence of trees on the spread of cholera. One of these may find a place here:

"The fact is generally believed, and not long ago the medical officer of Jatisgar, in Central India, offered a striking proof of it. During the wide-spread epidemic of cholera in Allahabad, in 1859, those parts of the garrison whose barracks had the advantage of having trees near them enjoyed an indisputable exemption, and precisely in proportion to the thickness and nearness of the shelter. Thus the European Cavalry in the Wellington Barracks, which stand between four rows of mango trees, but are yet to a certain extent open, suffered much less than the Fourth European Regiment, whose quarters were on a hill exposed to the full force of the wind; while the Bengal Horse Artillery, who were in a thicket of mango-trees, had not a single case of sickness; and the exemption cannot be regarded as accidental, as the next year the comparative immunity was precisely the same." [1]

We need not, however, go to India to observe similiar instances of the influence of a certain degree of moisture in the soil favored by woods or other conditions; we can find them much nearer home. In the cholera epidemic of 1854, in Bavaria, it was generally observed that the places in the moors were spared, in spite of the otherwise bad condition of the inhabitants. The great plain of the Danube from Neuburg to Ingolstadt was surrounded by places where it was epidemic, while in the plain itself there were but a few scattered cases. The same thing has been demonstrated by Reinhard, President of the Saxon Medical College. Cholera has visited Saxony eight times since 1836, and every time it spared the northerly district between Pleisse and Spree, where ague is endemic.

In the English Garden at Munich there are several buildings, not sparsely tenanted—the Diana Baths, the Chinese Tower, with a tavern and out-buildings, the Gendarmerie Station, and the Kleinkessellohe. In the three outbreaks of cholera at Munich none of these places have been affected by it. This fact is the more surprising, as three of them comprise public taverns into which the disease germs must have been occasionally introduced by the public; yet there was

[1] "Report on the Treatment of Epidemic Cholera," 1869, p. 4.

no epidemic in these houses, although it prevailed largely immediately beyond the English Garden and close to the Diana Baths in 1854 and 1873. It must have been accidental that no isolated cases occurred, as the inmates of the Chinese Tower, or the Kleinkessellohe, might have caught it in Munich as others did who came from a distance, but, had there been single cases, probably no epidemic would have occurred in these houses.

Even if these deductions must be accepted with caution from an etiological point of view, still, on the whole, they indisputably tell in favor of trees and woods.

Surface vegetation has also other advantages, besides its use in regulating the moisture in the soil; it purifies it from the drainage of human habitations, whereby it is contaminated and impregnated. If this refuse matter remains in soil destitute of growing vegetation, further decomposition sets in, and other processes are induced, not always of a salubrious nature, but often deleterious, the products of which reach us by means of air or water, and may penetrate into our houses. But from this indisputable fact false conclusions are sometimes drawn. Many people imagine that if a few old trees are left standing in an open space their roots will absorb all the impurities from the houses around, and render the refuse which accumulates beneath them innocuous. This idea is not only false in a sanitary point of view, but very injurious, as it prevents people from taking the measures which alone can keep the ground under our houses pure.

We will now explain why the shade of gardens and woods is at certain seasons so beneficial. The human race during its pilgrimage on earth and wanderings over it has many difficult tasks to perform. One of the most difficult is involved in the necessity that all our internal organs, and the blood, whether at the equator or the north-pole, should retain an equable temperature of 37½° Centigrade (98° Fahr.). Deviations of but one degree are signs of serious illness. The blood of the negro and that of the Esquimaux is of the same temperature, while the one lives in a temperature of 40° above, and the other 40° below zero (Centigrade). A difference of 80° has therefore to be equalized.

Our organism, doubtless, possesses a special apparatus for the performance of this colossal task, self-acting sluices so to speak, by means of which more or less of the heat generated in the body passes off: these consist mainly in the increase or diminution of the peripheric circulation, and the action of the pores of the skin. But we soon come to the end of our natural regulating apparatus, and have to resort to artificial means. Against cold we have excellent methods in clothing, dwellings, and fires; but at present our precautions against heat are very limited. This is, doubtless, the reason why higher civilization has extended so much farther toward the polar regions than toward the equator. The Germanic races, particularly, inevitably degenerate after living for a few generations in the tropics, and must be continually renewed by immigration if they desire to retain supremacy, as is proved by the case of the English in India. They will not be able to settle there and maintain the characteristics which have made them dominant, until means have been found of diminishing the heat of the body at pleasure, as we are able to maintain it in the north. At present our remedies against heat are baths, fans, and shade.

We lose the heat of our bodies in three different ways: by the medium in which we are, generally the air, and which can be warmed; by the evaporation of perspiration; and by radiation from bodies of a lower temperature, not taking into account a small portion of heat which goes off in mechanical labor. Under ordinary circumstances in temperate climates, we lose half the heat generated by radiation, one-fourth by evaporation, and one-fourth by the conducting medium in which we are. In proportion as any of these methods is diminished, one or both the others must be increased. As long as possible, our organisms are so obliging as to open and close the sluices themselves without our cognizance, provided that our regulating apparatus is in order, that we are not ill. It is only when our good servant the skin, under certain conditions, has come to an end of its powers, that we begin to feel that we must lend our aid. And thus we have found by experience that, in hot weather, shade helps the body to keep cool to the needful extent. The chief effect of shelter is to prevent the sun's rays from striking us directly; but, if this were all, it would be as cool in the height of summer in-doors, or even under the leaden roofs of Venice, which have driven many to frenzy and desperation, as under the shade of a tree or in a wood. It also makes a great difference whether the sun's rays fall on thick foliage or on a roof of slate or metal. A great deal of heat is neutralized by evaporation from the leaves; another portion by the decomposition of carbonic acid, just so much as is set free when we burn the wood and other organic combinations into the composition of which it enters. The heat produced by burning wood in a stove is derived from the sun; it is but the captured rays of the sun again set free by combustion. We learn from Ebermayer's work that the temperature of the trees in a forest, and even in the tops of them, is always lower than the air in the forest.

Besides this, shade in the open air always causes a certain draught which acts as a kind of fan. All must have noticed when walking in oppressive heat, when the air seems still as death, that a refreshing breeze arises as soon as a cloud casts a shade. The same thing may often be observed in summer in walking through a street with close rows of houses, when the air is still, and one side is sunny, the other in shade. On the sunny side there is not a breath of air, while on the other there may be a light breeze. This is easily explained; so far as the shade extends the air is cooler than in the sun; layers of air of unequal warmth are of different gravity, and this difference of temperature is the cause of the motion in the air.

The shade of a single tree, therefore, cools not only by intercepting the sun's rays, but also by the effect of gentle fanning. The shelter of a thick wood, however, is much more agreeable than that of a single tree. The air in a wood is cooler than that of an open space exposed to the sun. The air from outside is drawn into the wood, is cooled by it, and cools us again. And it is not only the air that cools us, but the trees themselves. Observation has shown that the trunks of trees in a wood breast-high, even at the hottest time of day, are 5° Centigrade cooler than the air. We therefore lose considerable heat by radiation to these cooler objects, and can cool ourselves more easily at a temperature of 25° Centigrade in a wood than at a much lower temperature in an open space. When the objects around us are as warm as ourselves we lose nothing by radiation; what is radiated from us is radiated back by them. This is why we are so uncomfortable in heated and overcrowded rooms. It is generally set down to bad air, and this does certainly contribute to it, but it is chiefly the result of disturbed distribution of heat, as has been plainly shown by experiments on the composition of such air, which makes many people feel ill.—*Contemporary Review.*

COUNTING BY THE AID OF THE FINGERS.

By Prof. JOHN TROWBRIDGE.

ONE cannot with any reason contend that the universal possession of ten fingers argues a natural tendency of the human mind toward the decimal system; it is certainly true, however, that multitudes of men and women find their fingers of great assistance in arithmetical operations. The intelligent school-teacher is apt to discourage the pupil's use of the fingers in addition, and to encourage mental counting without their aid. I have been interested to discover the nature of this mental process which goes on apparently without the aid of the hands. From questioning a large number of persons, I find that five or six is the limit to the numbers of things which one can repeat, and also keep the count. Of course, this limit can be much exceeded by practice; one person who was interrogated could count up to fifty, but he was an astronomer. Most persons reply to the interrogatory, "How do you keep the count?" by saying, "I run up to five, and then again to five, and so on." In most cases it was found that a subdivision into ones and twos preceded this division into fives. The division into twos seemed to be the most common; by accenting every second number it is not difficult to run up to six or eight, and still keep the count. In reflecting upon the answers to my interrogatories, I was led to believe that the possession of ten fingers was not the only cause of our counting by fives and tens, but that a certain rhythm in a system of counting by twos enabled us to overcome a resistance to memory.

This point can be elucidated in the following manner: If we desire to keep the count of the letters of the alphabet while we repeat their names, we can arrange them advantageously in a system of squares separated by a clamp of two, as in Fig. 1. Here we have a system of twos counting up to ten. A system of mental squares, so to speak, is formed, which enables us to hold the numbers apart, and to form a distinct classification. This system is capable of much extension: for instance, we

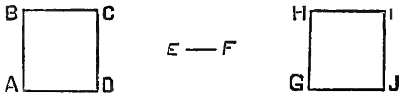

Fig. 1.

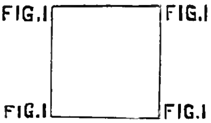

Fig. 2.

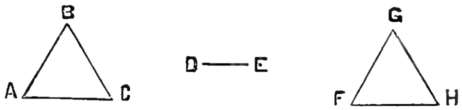

Fig. 3.

can readily form another square in which a mental diagram like Fig. 1 is placed again at the four corners of a square, giving us forty; and the system of squares is capable of much further extension before the mind becomes confused and loses its count. In repeating these diagrams in the mind, a certain rhythm will be perceived which is wanting when we use the system of triangles which is represented in Fig. 3, or a system of pentagons or hexagons. Indeed, with the last-named figures great mental confusion speedily arises; the mental resistance to holding a clear image of a square or triangle in the mind is much less than that which arises when we wish to behold mentally a pentagon or a hexagon.

It would not be difficult to prove a close relation between the forms of verse and the instruments by which a mathematician mounts to the expression of thought. The commonest forms of verse are written in four or five feet. In reading such lines the memory retains the rhythm and the words of each line without effort. When, however, we increase the number of feet in the verse, their length becomes cumbrous and the memory flags. No system of squares or triangles can obviate this difficulty. A system of geometrical mnemonics could undoubtedly be based upon the preceding exemplifications.

In the early dawn of human knowledge the arrangement of points in squares and triangles, and the further conception of areas by their subdivision into triangles, undoubtedly arose from the inability of the human mind to retain distinct images of figures more complicated than rectangles or squares. In the case of curved lines, the mind has a tendency to refer all arcs to circles, since a circle forms as definite a conception as a square. The fact that it is made up of an infinite number of straight lines has significance only to a geometer.

MODERN LIFE AND INSANITY.

By DANIEL HACK TUKE, M. D.

THE relation between modern civilized life and insanity cannot be regarded as finally determined while a marked difference of opinion exists in regard to it among those who have studied the subject; nor can this difference be wondered at by any one who has examined the data upon which a conclusion must be formed, and has found how difficult it is to decide in which direction some of the evidence points. Statistics alone may prove utterly fallacious. Mere speculation, on the other hand, is useless, and indeed is only misleading. It is a matter on which it is tempting to write dogmatically, but where the honest inquirer is quickly pulled up by the hard facts that force themselves on his attention. Nothing easier than to indulge in unqualified denunciations of modern society; nothing more difficult than a cautious attempt to connect the social evils of the present day with the statistics of lunacy. Nothing easier than to make sweeping statements without proof, nothing more difficult than to apportion the mental injury respectively caused by opposite modes of life; totally diverse social states of a nation often leading to the same termination—insanity. These are closely bound together in the complex condition of modern civilized society. No doubt if we care for truth, and avoid rash assertions, we do it at the expense of a certain loss of force and incisiveness. Dogmatic statements usually produce more effect than carefully-balanced and strictly logical positions. Honesty, however, compels us to speak cautiously, and to confess the difficulties to which we have referred.

We shall not enter at length into the question which is at once raised by an inquiry into the relation between modern life and insanity—whether lunacy is on the increase in England. Twenty years ago there was one lunatic or idiot officially reported to 577 of the population; the latest returns place it as high as one in 370. Were we to go further back, the contrast would be far greater. That the increase of known cases of insanity has been very great, no one, therefore, disputes. Further, that the attention paid to the disease; the provision made for the insane; the prolongation of their lives in asylums, and the consequent accumulation of cases, and other circumstances into which our limits forbid us to enter, account for the greater part of this alarming apparent increase, is certain. Whether, however, there is not also an actual increase, unaccounted for by population, or by accumulation, remains an open question, which statistics do not absolutely determine. At the same time we think that it is quite probable that there has been some real increase.

To what social class do the great mass of our lunatics belong, and to what grade of society does the striking apparent increase of the insane point? The large majority of lunatics under legal restraint undoubtedly belong to the pauper population. On the 1st of January, 1877, of the total number of patients in asylums and elsewhere (in round numbers 66,600), about 59,000 were pauper, and only 7,600 private patients. These figures, however, fail to convey a correct statement of the relative amount of insanity existing among the class of the originally poor and uneducated masses and the class above them, because in a considerable number of instances members of the middle and still higher classes have become paupers. Again, the wealthy insane remain very frequently at home, and do not appear in the official returns. We believe this class to be very large. Probably we get a glimpse of it from the census of 1871, which contained 69,000 lunatics, idiots, and imbeciles (and we have good reasons for knowing that this return was very far short of the truth), yet it exceeded the number given by the Lunacy Commissioners in the same year by 12,000! A large number no doubt lived with their families because these could well afford to keep them at home. None would be in receipt of relief, or they would have appeared in the Commissioners' Report. Another most important qualifying consideration remains—*the relative numbers of the classes of society from which the poor and the well-to-do lunatics are derived.* Several years ago the Scotch commissioners estimated the classes from which private patients are derived at only about an eighth of the entire population of Scotland; a proportion which would make them at least as relatively numerous as the pauper lunatics. No doubt in England the corresponding class of society is a larger one; but whatever it may be,[1] a calculation based upon the relative proportion of different social strata in this country would vastly reduce the apparent enormously different liability to insanity among the well-to-do and the poorer sections of the community, although, with this correction, the pauper lunatics would still be relatively in the majority.

The disparity between the absolute number of pauper and private

[1] We are informed by Dr. Farr that the proportion between the upper and middle classes on the one hand, and the lower classes on the other, is as 15 to 85. Calculated on this basis, the proportion of private and pauper lunatics to their respective populations would be one in 484 for the former, and one in 353 for the latter—a very different result from that obtained by the usual method of calculating the ratio of private and pauper lunatics to the whole population, viz., one in 3,231, and one in 415.

patients has greatly increased in recent years. In other words, the apparent increase of insanity is mainly marked among those who become pauper patients. This is certainly in great measure accounted for by the disproportionate accumulation of cases in pauper asylums, for reasons into which it is not now needful to enter. It assuredly does not prove that there has been anything like a corresponding growth of insanity among the poor as compared with the rich.

In any case, however, the illiterate population does yield a very serious amount of insanity, and the fact is so patent that it shows beyond a doubt that ignorance is no proof against the inroads of the disease. The absence of rational employment of the mental powers may lead to debasing habits and to the indulgence in vices especially favorable to insanity, less likely to attract a mind occupied with literary and scientific pursuits. No doubt mental stagnation is in itself bad, but the insanity arising out of it is more frequently an indirect than a direct result. If a Wiltshire laborer is more liable to insanity than other people, it may be not merely because his mind is in an uncultivated condition, but rather because his habits,[1] indirectly favored by his ignorance, and the brain he inherited from parents indulging in like habits, tend to cause mental derangement. It is conceivable that he might have had no more mental cultivation, and yet have been so circumstanced that there would have been very little liability to the disease. This distinction is extremely important if we are tracing causes, however true it would remain that ignorance is a great evil. A South-Sea islander might be much more ignorant than the Wiltshire laborer, and yet not be so circumstanced that he would be likely to transgress the laws of mental health. The ignorance of an African tribe and that of a village in Wilts may be associated, the one with very little, the other with very much lunacy. Mr. Bright's "residuum" of a civilized people and a tribe of North American Indians are alike uneducated, but, notwithstanding, present totally different conditions of life. We have no doubt that in a civilized community there will always be found by far the larger number of insane persons. There are three grand reasons for this. First, because those who do become insane, or are idiotic among savages, "go to the wall" as a general rule; the other reasons are to be discovered in the mixed character and influence of European civilization; its action on the one hand in evolving forms of mental life of requisite delicacy and sensibility, easily injured or altogether crushed by the rough blasts from which they cannot escape in life; and on the other hand in producing a state confounded, as we have said, with savagery, but which differs widely from it, and is, simply in relation to mental disorders, actually worse. Recklessness, drunkenness, poverty, misery, charac-

[1] Dr. Thurnam, the late superintendent of the Wilts County Asylum, found that the proportion of cases caused by drink in this county was very high—in one year (1872) amounting to thirty-four per cent.

terize the class; and no wonder that from such a source spring the hopelessly incurable lunatics who crowd our pauper asylums, to the horror of rate-payers, and the surprise of those who cannot understand why the natives of Madagascar, though numbering about 5,000,000, do not require a single lunatic asylum. We may add that they do not destroy the few insane and idiots which they have.

It is constantly forgotten that while there is nothing better than true civilization, there is something worse than the condition of certain savages, and that almost anything is better than that stratum of civilized society which is squalid, and drunken, and sensual; cursed with whatever of evil the ingenuity of civilized man has invented, but not blessed with the counteracting advantages of civilization. The conclusion, so far from damping the efforts of progress and modern developments of science, should stimulate us to improve the moral and physical condition of this class, and so lessen the dangers to mental disorder among them. The belief that savages are free from some of the insanity-producing causes prevalent in modern civilized England, is quite consistent with the position taken in this article, that education, ample mental occupation, knowledge, and the regularly trained exercise of the faculties, exert a highly-beneficial influence upon the mind, and thus fortify it against the action of some of the causes of insanity.

The relative liability of manufacturing and agricultural districts to mental disease has excited much discussion. This has partly arisen from the assumption that the latter may be taken as the representatives of savages. As we have shown this to be false, the comparison between these two districts does not, from this point of view, possess any value. On other grounds, however, it would be very interesting to determine whether urban or rural lunacy is most rife. Here, however, the worthlessness of mere statistics is singularly evidenced, and the difficulty of actually balancing the weight of various qualifying circumstances becomes more and more apparent. An agricultural county may be found here and there with less lunacy than a manufacturing county, but if a group of counties be taken in which the manufacturing element is greatly beyond the average, and another group in which the agricultural element greatly preponderates, we find one lunatic to 463 of the county population in the former, and one to 388 in the latter, showing an *accumulation* of more insane paupers in the agricultural districts. But it is very possible that, if we knew how many *become* insane, the result would be very different indeed. This, in fact, has been found to be the case in Scotland, where the Lunacy Commissioners have taken great pains to arrive at the real truth. In a recent report it is shown that while three Highland counties have, in proportion to the population, a decidedly heavier persistent burden of pauper lunacy than two manufacturing counties which are chosen for comparison, the number of lunatics receiving relief—that is, actually coming under treatment—is proportionally larger in the latter than in the former. In other words, the proportion of fresh cases of pauper lunacy appearing on the poor-roll is higher in urban than rural districts. The commissioners refer this result partly to the greater prevalence of the active and transitory forms of mental disorder—cases which before long are discharged—and partly to the greater facility of obtaining accommodation in an asylum free of charge in a city, from its being at hand; and the greater wealth of the urban districts offering no obstacle to admission. They attribute the above-mentioned persistent rural lunacy chiefly to the constant migration of the strong from the rural to the urban districts; the necessary exodus of the physically and mentally healthy leaving behind an altogether disproportionate number of congenital idiots, imbeciles, and chronic insane, in the agricultural counties. Hence, returning to England, it is quite clear that the mere ratio of accumulated pauper lunacy to the county population, which is constantly relied upon, proves little or nothing as to the relative liability to insanity of the agricultural and manufacturing districts. One conclusion only can be safely drawn from such figures, until minute investigations have been made into the circumstances attending rural and urban lunacy in England as has been done in Scotland—namely, that while theory is apt to say that a country life, passed, as it seems to be supposed, in pastoral simplicity, will not admit of the entrance of madness into the happy valley, fact says that, whatever may be the ultimate verdict as to the relative proportion of urban and rural lunacy, a large amount of insanity and idiocy does exist in the country districts, and that the dull swain, with clouted shoon, but too frequently finds his way into the asylum.

A glance at the annual reports of our lunatic asylums reveals the main occupations of the inmates and the apparent causes of their attacks. In a county asylum like Wilts the great majority of patients are farm-laborers, with their wives and daughters; and next in order, domestic servants and weavers. The number of farmers, or members of their families, is small. The character of the occupations in the population of an asylum like that for the borough of Birmingham of course differs. Here we find mechanics and artisans heading the lists, with their wives. Those engaged in domestic occupation form a large number. Shopkeepers and clerks come next in order. In both asylums are to be found a few governesses and teachers. Innkeepers, themselves the cause of so much insane misery in others, figure sparingly in these tables.

Among the causes, intemperance unmistakably takes the lead. This is one of those facts which, amid much that is open to difference of opinion, would seem to admit of no reasonable doubt. Secondly follows domestic trouble, and thirdly poverty. At the Birmingham Asylum, out of 470 admissions in three years, eleven cases were attributed to "over-application"—a proportion much lower than that observed in private asylums.

Recently, Mr. Whitcombe, assistant medical officer at the Birmingham Borough Asylum, has done good service by publishing the fact that, during the last twenty-five years, out of 3,800 pauper patients admitted into that asylum, 524, or fourteen per cent., had their malady induced by drink, and that the total expenditure thus caused by intemperance amounted, in maintenance and cost of building, etc., to no less than £50,373 during that period.

Some years ago we calculated the percentage of cases caused by intemperance in the asylums of England, and found it to be about twelve. This proportion would be immensely increased were we to add those in which domestic misery and pecuniary losses owed their origin to this vice. Although rate-payers grumble about the building of large lunatic asylums, it is amazing how meekly they bear with the great cause of their burden, and how suicidally they resent any attempt made to reduce by legislation the area of this wide-spread and costly mischief.

It is worthy of note that drink produces much less insanity in Warwickshire outside Birmingham than in Birmingham itself.

In connection with this aspect of the question, an interesting fact, recorded by Dr. Yellowlees, when superintendent of the Glamorgan County Asylum, may be mentioned: that during a "strike" of nine months the male admissions fell to half their former number, the female admissions being almost unaffected. "The decrease is doubtlessly mainly due to the fact that there is no money to spend in drink and debauchery." High wages, however, would be infinitely better than strikes, if the money were spent in good food, house-rent, and clothing.

The diet of the children of factory-operatives in Lancashire points to one source of mental degeneration among that class. Dr. Fergusson, of Bolton, gave important evidence not long ago which indicated the main cause of their debility and stunted development, whether or not they are worse now than they were. He does not consider that factory-labor in itself operates prejudicially, and reports the mills to be more healthy to work in now than they were in years past. The prime cause producing the bad physical condition of the factory-population is, in his opinion, the intemperate habits of the factory-workers. By free indulgence in stimulants and in smoking, the parents debilitate their own constitutions, and transmit feeble ones to their children. Instead of rearing them on milk after they are weaned, they give them tea or coffee in a morning, and in too many instances they feed them upon tea three times a day. In short, they get very little milk.

Mr. Redgrave, the Senior Inspector of Factories, does not consider that this miserable state of things has increased—we hope not—but he admits that more women are employed in the mills than formerly, and that this is most disastrous to the training of children. Some curious figures have been published, showing the weight of children at various years of age in the factory and agricultural districts, the comparison being greatly in favor of the latter.

Another cause of deterioration mentioned is that at least one-half of the boys in the mills from twelve to twenty years of age either smoke or chew tobacco, or do both—a habit most prejudicial to the healthy development of the nervous system. It was recently observed by Mr. Mundella that the lad who began at eight years of age in a mine without education, and who was associated with men whose whole ambition was a gallon of beer and a bull-dog, was not likely to grow up to be a Christian and a gentleman. We may add he would be very likely to end his days either in a prison or in a pauper asylum. It is observed in a recent report of the Royal Edinburgh Asylum that "such coal and iron mining counties as Durham and Glamorgan produce, in twice the proportion we do, the most marked and fatal of all the brain-diseases caused by excesses." It may be stated that the relation between crime and insanity, especially weak-mindedness, is one of the most intimate character, both in regard to the people who commit criminal acts and their descendants. Our examination of the mental condition of convicts, and of their physiognomy and cerebral development, has long convinced us that a large number of this class are mentally deficient: sometimes from birth; at other times their mental development being arrested by their wretched bringing up. From the reports of the English convict-prisons generally, it appears that one in every twenty-five of the males is of weak mind, insane, or epileptic, without including those sufficiently insane to be removed to an asylum. The resident surgeon to the general prison of Scotland at Perth (Mr. Thompson) gives a proportion of twelve per cent., founded upon a prison population of 6,000 prisoners.

Having referred to the bearing of the habits of one large portion of the population upon the manufacture of insanity, we pass on to the consideration of the relation between higher grades of modern society and mental disorder. It has been observed in institutions into which private and pauper patients are admitted, that the moral or psychical causes of lunacy are more frequently the occasion of the attack with the former than the latter class. This is not always accounted for—as might have been expected—by there having been less drink-produced insanity among the well-to-do patients; for in the Royal Edinburgh Asylum, where this disparity strongly comes out, there is even a higher percentage of insanity from this cause among the private than the pauper lunatics. The history of the daily mode of life of many members of the Stock Exchange would reveal, in the matter of diet, an amount of alcoholic imbibition in the form of morning "nips," wine at luncheon, and at dinner, difficult to realize by many of less porous constitutions, and easily explaining the disastrous results which in many instances follow, sooner or later, as respects disturbances of the nervous system, in one form or other. In fact, by the time dinner is due, the stomach is in despair, and its owner finds it necessary to goad a lost appetite by strong pickles and spirits, ending with black coffee and some liqueur. When either dyspepsia or over-business work is set down as the cause of the insanity of such individuals, it should be considered what influence the amount of alcohol imbibed has exerted upon the final catastrophe as well as the assigned cause. But whatever may be the relative amount of insanity produced among the affluent and the poor, of this there can be no doubt, that certain mental causes of lunacy, as over-study and business worry, produce more insanity among the upper than the lower classes. We have examined the statistics of six asylums in England for private patients only, and have found this to be the case. At one such institution, Ticehurst, Sussex, we find, from statistics kindly furnished us by Dr. Newington, that out of 266 admissions 29 were referred to over-study, and 18 to over-business work. Only 28 were referred to intemperance. Allowing a liberal margin for the tendency of friends to refer the disease to the former rather than the latter class, the figures remain striking, as pointing to the influence of so-called overwork. We say "so-called" because there is an apparent and fictitious as well as a real overwork. Both, however, may terminate in nervous disorder. Overwork is often confounded with the opposite condition—want of occupation. Civilization and mental strain are regarded by many as identical, and in consequence much confusion is caused in the discussion of the present question. It is forgotten that an idle life, leading to hysteria and to actual insanity, is much more likely to be the product of civilization than of savagery or barbarism. This is quite consistent with the other truth, that without civilization we do not see evolved a certain high pressure, also injurious to mental health. A London physician, Dr. Wilks, when speaking of a common class of cases, young women without either useful occupation or amusements, in whom the moral nature becomes perverted, in addition to the derangement of the bodily health, observes that the mother's sympathies too often only foster her daughter's morbid proclivities, by insisting on her delicacy and the necessity of various artificial methods for her restoration. It is obvious that such a case as this is the very child of a highly-organized society, that is, of a high state of civilization, and yet that such a young lady is not the victim of high pressure or mental strain in her own person, although it is certainly possible that she may inherit a susceptible brain from an overworked parent. However, the remedy is work, not rest; occupation, not idleness. We certainly do not want to make her more refined or artificial, but more natural, and to occupy herself with some really useful work. A luxurious, idle life is her curse. That insanity itself, as well as mere hysteria, is developed by such a mode of existence, we fully believe. The mind, although not uneducated, deteriorates for want of either healthy intellectual excitement, the occupation of business, or the necessary duties of a family. Life must have an aim, although to achieve it there ought not to be prolonged worry.

In the same way there is the lady instanced who eats no breakfast, takes a glass of sherry at eleven o'clock, and drinks tea all the afternoon, and who, "when night arrives, has been ready to engage in any performance to which she may have been invited." Clearly she is the product of a highly-artificial mode of life, found in the midst of modern civilization. She is certainly not suffering from mental strain; at the same time she is the outcome of the progress from barbarism and the hardy forms of early national life to our present complex social condition. We have particularly inquired into cases coming under our own observation in regard to the alleged influence of overwork, and have found it a most difficult thing to distinguish between it and other maleficent agents which, on close observation, were often found to be associated with it. We do not now refer to the circumstances which almost always attach themselves to mental fatigue, as sleeplessness, but to those which have no necessary relation to them, as vice. Here we have felt bound to attribute the attack to both causes, certainly as much to the latter as the former. In some cases, on the other hand, we could not doubt that long-continued severe mental labor was the efficient cause of derangement. In a large proportion of other cases we satisfied ourselves that overwork meant not only mental strain, but the anxiety and harass which arose out of the work in which a student or literary man was engaged. The overwork connected with business, also largely associated with anxiety, proved a very tangible factor of insanity. Indeed it is always sure to be a more tangible factor of mental disease than overwork from study, because of the much greater liability to its invasion during the business period of brain-life than the study period. At Bedlam Hospital, Dr. Savage finds that there are many cases in which overwork causes a breakdown, "especially if associated with worry and money troubles." Among the women, the cases are few in number. In one, where there was probably hereditary tendency, an examination, followed in two days by an attack of insanity, may be regarded as the exciting cause. Monotonous work long continued would seem to exert an unfavorable influence on the mind. Letter-sorting, short-hand writing, and continuous railway-traveling, are instanced. If diversified, hard work is much less likely to prove injurious. During a year and a half twenty men and eight women were admitted whose attacks were attributed to overwork. The employments of architect, surveyor, accountant, schoolmaster, policeman, and boot-maker, were here represented. Seven were clerks, two of whom were law-writers;

two were students, one being "an Oxford man who had exhausted himself in getting a double first, and the other a medical student preparing for his second college." Of the women, five were teachers, one a school-girl, and two dressmakers. Three of the teachers were in elementary schools, one a governess and the other a teacher of music and languages. If overwork alone did not, strictly speaking, cause the mental breakdown, still the concomitants must be blamed for these melancholy results.

A late medical officer to Rugby School (Dr. Farquharson), in defending that institution from a charge of injury in the direction of which we now speak, considers that instances of mental strain are more common at the universities, "for not only are the young men at a more sensitive period of life, but they naturally feel that to many of them this is the great opportunity—the great crisis of their existence—and that their success or failure will now effectually make or mar their career. Here the element of anxiety comes into play, sleep is disturbed, exercise neglected, digestion suffers, and the inevitable result follows of total collapse, from which recovery is slow and perhaps never complete."—(*Lancet*, January 1, 1876.) He thinks he has seen an increase of headaches and nervous complaints among poor children since compulsory attendance at board schools was adopted, and records a warning against too suddenly forcing the minds of wretchedly-feeble, ill-fed and ill-housed children, and against attempts to make bricks too rapidly out of the straw which is placed in our hands.

The psychological mischief done by excessive cramming both in some schools and at home is sufficiently serious to show that the reckless course pursued in many instances ought to be loudly protested against. As we write, four cases come to our knowledge of girls seriously injured by this folly and unintentional wickedness. In one, the brain is utterly unable to bear the burden put upon it, and the pupil is removed from school in a highly-excitable state; in another, epileptic fits have followed the host of subjects pressed upon the scholar; in the third, the symptoms of brain-fog have become so obvious that the amount of schooling has been greatly reduced; and, in a fourth, fits have been induced and complete prostration of brain has followed. These cases are merely illustrations of a class, coming to hand in one day, familiar to most physicians. The enormous number of subjects which are forced into the curriculum of some schools and are required by some professional examinations, confuse and distract the mind, and by lowering its healthy tone often unfit it for the world. While insanity may not directly result from this stuffing, and very likely will not, exciting causes of mental disorder occurring in later life may upset a brain which, had it been subjected to more moderate pressure, would have escaped unscathed. Training in its highest sense is forgotten in the multiplicity of subjects, originality is stunted and individual thirst for knowledge overlaid by a crowd of novel theories based upon yet unproved statements. Mr. Brudenell Carter, in his "Influence of Education and training in preventing Diseases of the Nervous System," speaks of a large public school in London, from which boys of ten to twelve years of age carry home tasks which would occupy them till near midnight, and of which the rules and laws of study are so arranged as to preclude the possibility of sufficient recreation. The teacher in a high-school says that the host of subjects on which parents insist upon instruction being given to their children is simply preposterous, and disastrous alike to health and to real steady progress in necessary branches of knowledge. The other day we met an examiner in the street with a roll of papers consisting of answers to questions. He deplored the fashion of the day; the number of subjects crammed within a few years of growing life; the character of the questions which were frequently asked; and the requiring a student to master, at the peril of being rejected, scientific theories, and crude speculations, which they would have to unlearn in a year or two. He sincerely pitied the unfortunate students. During the last year or two the public have been startled by the suicides which have occurred on the part of young men preparing for examination at the University of London; and the press has spoken out strongly on the subject. Notwithstanding this, the authorities appear to be disposed to increase instead of diminish the stringency of some of the examinations. The *Lancet* has recently protested against this course in regard to the preliminary scientific M. B. of the London University, and points out that the average of candidates who fail at this examination is already about forty per cent., and that these include many of the best students. This further raising of the standard will, it is maintained, make a serious addition to the labors of the industrious student who desires the M. D. degree. Whether this particular instance is or is not a fair example, we must say, judging from others, that it seems to be thought that the cubic capacity of the British skull undergoes an extraordinary increase every few years, and that therefore for our young students more subjects must be added to fill up the additional space.

The master of a private school informs us that he has proof of the ill effects of overwork in the fact of boys being withdrawn from the keen competition of a public-school career, which was proving injurious to their health, and sent to him, that they might in the less ambitious atmosphere of a private school pick up health and strength again. He refers to instances of boys who had been crammed and much pressed in order that they might enter a certain form or gain a desired exhibition, having reached the goal successfully, and then stagnated. He says that the too extensive curriculum now demanded ends in the impossibility of doing the work thoroughly and well. You must either force unduly or not advance as you would wish to do; the former does injury, and the latter causes dissatisfaction.

Of mental stagnation among the poor we have already spoken; an analogous condition among the well-to-do classes, not to be confounded with that of the young lady already described as seen in the London physician's consulting-room, deserves a passing observation. Excessive activity and excessive dullness may lead to the same dire result. Hence both conditions must be recognized as factors in the causation of mental disease. We have said that the indirect action of the latter it more powerful than its direct action, but there are no doubt cases of insanity which arise from the directly injurious influence of intellectual inactivity. The intelligence is inert; the range of ideas extremely limited; the mind broods upon some trivial circumstance until it becomes exaggerated into a delusion; the mind feeds upon itself, and is hyper-sensitive and suspicious, or it may become absorbed in some morbid religious notions which at last exert a paramount influence and induce religious depression or exaltation. From the immediate surroundings of the individual, whether in connection with parental training or from ecclesiastical or theological influences, or perhaps a solitary condition of life, there may be a dangerously restricted area of psychical activity. Prejudices of various kinds hamper the free play of thought; the buoyancy of the man's nature is destroyed; its elasticity broken; its strength weakened; and it is in fine reduced to a state in which it is a prey to almost any assertion however monstrous, if placed before it with the solemn sanctions which, from education, habit, or predilection, it is accustomed to reverence. Fantastic scruples and religious delusions frequently spring up in this soil. Such persons have been saved from the evils of drunkenness and vice; they have also been sheltered from worry and excitement, yet, to the astonishment of many, they become the inmates of a lunatic asylum. They have in truth escaped the Scylla of dissipation or drink, only to be shipwrecked on the Charybdis of a dreary monotony of existence. On this barren rock not a very few doubtless perish, and if parents they transmit, to a posterity deserving our sincerest pity, mediocre brains or irritably susceptible and unstable nerve-tissue.

On the dangers arising from waves of religious excitement, it would be easy to dilate, but we shall content ourselves with remarking that, if they have been exaggerated by some, they have been improperly ignored or denied by others. They are real; and frightful is the responsibility of those who, by excited utterances and hideous caricatures of religion, upset the mental equilibrium of their auditors, whether men, women, or children.

One remarkable feature of modern life—spiritualism—has been said to produce an alarming amount of insanity, especially in America. It has been recently stated by an English writer that nearly 10,000 persons have gone insane on the subject, and are confined in asylums in the United States; but careful inquiry, made in consequence, has happily disproved the statement, and we learn that the amount of insanity produced from this cause is almost insignificant—much less than that caused by religious excitement.

Looking broadly at the facts which force themselves upon our attention, we may say that a study of the relation between modern life and insanity shows that it is of a many-sided and complex character; that the rich and the poor, from different causes, though certainly in one respect the same cause, labor under a large amount of *preventable* lunacy; that beer and gin, mal-nutrition, a dreary monotony of toil, muscular exhaustion, domestic distress, misery and anxiety, account largely, not only for the number of the poor who become insane in adult life, but who, from hereditary predisposition, are born weak-minded or actually idiotic; that among the middle classes, stress of business, excessive competition, failures, and, also in many cases, reckless and intemperate living, occasion the attack; while in the upper classes intemperance still works woe—and under this head must be comprised lady and gentlemen dipsomaniacs who are not confined in asylums; that while multiplicity of subjects of study in youth and excessive brain-work in after-life exert a certain amount of injurious influence, under-work, luxurious habits, undisciplined wills, desultory life, produce a crop of nervous disorders, terminating not unfrequently in insanity. In a state of civilization like ours, it must also happen that many children of extremely feeble mental as well as bodily constitutions will be reared who otherwise would have died. These either prove to be imbeciles, or they grow up only to fall a prey to the upsetting influence of the cares and anxieties of the world. A considerable number of insane persons have never been really whole-minded people; there has, it will be found on careful inquiry, been always something a little peculiar about them, and when their past life is interpreted by the attack which has rendered restraint necessary, it is seen that there had been a smouldering fire in the constitution for a lifetime, though now, for the first time, bursting forth into actual conflagration.

Lastly, modern society comprises a numerous class of persons, well-meaning, excitable, and morbidly sensitive. Some of these are always on the border-land between sanity and insanity, and their friends are sometimes tempted to wish that they would actually cross the line, and save them from constant harass. When they do, it is easier to make allowance for them and their vagaries.

Whatever uncertainty there may attach to some aspects of this inquiry, unquestionable conclusions have been drawn; and, if these only accord with results arrived at from other considerations, they are valuable as confirming them. Had there appeared to be among the poor and ignorant a striking immunity from attacks of insanity, a strong argument would have been afforded, and would probably have been employed, against the extension of education at the present day to the working-classes. Nothing, however, in our facts or figures supports such an anti-progressive view; and, if the educated classes did not sin against their mental health in so many ways, they would doubtless compare more favorably than they do, in fact as well as in mere figures, with the uneducated poor. So again with regard to intemperance, and all that it involves, in spite of the difficulty of discriminating between the many factors which often go to make up the sum total of causes of an attack, we have no doubt of the large influence for mental evil exerted by drink—always admitting that where the constitution has no latent tendency to insanity, you may do almost what you like with it, in this or any other way, without causing this particular disease. A man will break down at his weak point, be it what it may.

Again, the lessons are taught of the importance, not of mere education, but a real training of the feelings; the evil of mental stagnation, not simply *per se*, but from the train of sensual degradation in one direction, and of gloomy fanaticism in the other, engendered, and the danger of dwelling too long and intently on agitating religious questions, especially when presented in narrow and exclusive forms, which drive people either to despair or to a perilous exaltation of the feelings. To true religious reformers, the physician best acquainted with the causation of mental disease will award his heartiest approval. Only as the high claims of duty, demanded from man by considerations of the dependence of his work in the world upon mental health, of what he owes to his fellow-men, and of what he owes to God, are fulfilled as well as acknowledged, will civilized man benefit by his civilization, as regards the prevention of insanity. Unpreventable lunacy will still exist, but a great saving will be effected for British rate-payers when that which is preventable shall have been reduced to a minimum by the widest extension of a thorough but not oppressive and too early commenced education, by the practical application of the ascertained truths of physiological and medical science, and by the influence of a Christianity, deep in proportion to its breadth, which shall really lay hold of life and conduct, and mould them in accordance with itself.—*Macmillan's Magazine.*

THE GROWTH OF THE STEAM-ENGINE.[1]

By Professor R. H. THURSTON,
OF THE STEVENS INSTITUTE OF TECHNOLOGY.

IV.

STEAM-NAVIGATION.

72. Among the most interesting of the applications of steam-power, to the political economist and to the historian, as well as to the engineer, is its use in ship-propulsion.

In the modern marine engine we find one of the most important adaptations of steam machinery and the greatest of all the triumphs of the mechanical engineer.

Although, as has been already stated in previous lectures, attempts had been made, before the beginning of the present century, to successfully effect this application of the power of steam, they did not succeed, in any instance, as commercial enterprises, until after that date.

Indeed, it is but a few years ago that the passage across the Atlantic was made by sailing-vessels almost exclusively, and that the dangers, the discomforts, and the irregularities of their trips were most serious.

Now, hardly a day passes that does not see several large and powerful steamers leaving the ports of New York and Liverpool to make the same voyages; and their passages are made with such regularity and safety that travelers can anticipate, with confidence, the time which will mark the termination of their voyage, predicting the day and almost the hour of their arrival, and can cross with safety and comparative comfort, even amid the storms of winter.

Yet, all that we to-day see of the extent and the efficiency of steam-navigation has been the work of the present century; and it may well excite both our wonder and our admiration.

73. The history of this development of the use of steam-power illustrates, more perfectly than any other, that process of the growth of this invention which has been already referred to. We can here trace it, step by step, from the earliest and rudest devices up to those most recent and most perfect designs, which represent the most successful existing types of the heat-engine—whether considered with reference to its design and construction, or as the highest application of known scientific principles—that have yet been found attainable in even the present advanced state of the mechanic arts.

74. This application of the force of steam was very possibly anti-

[1] An abstract of "A History of the Growth of the Steam-Engine," to be published by D. Appleton & Co.

cipated 800 years ago by Roger Bacon, that learned Franciscan monk who, in an age of ignorance and intellectual torpor, wrote:

"I will now mention some wonderful works of art and Nature, in which there is nothing of magic and which magic could not perform.

"Instruments may be made by which the largest ships, with only one man guiding them, will be carried with greater velocity than if they were full of sailors," etc.

For many years before even the first promising effort had been made, the minds of the more intelligent had been prepared to appreciate the invention when it should finally be brought forward, and were ready for even greater wonders than have yet been accomplished.

75. The earliest attempt to propel a vessel by steam is claimed, by Spanish authorities, as it has been stated, to have been made by Blasco de Garay in the harbor of Barcelona, Spain, in 1543.

The account seems somewhat apocryphal, and the experiment, if made, certainly led to no useful results.

76. In an anonymous English pamphlet, published in 1651,[1] which is supposed, by Stuart, to have been written by the Marquis of Worcester, an indefinite reference to what may probably have been the steam-engine is made, and it is there stated to be capable of successful application to propelling boats.

77. In 1690 Papin proposed to use his piston-engine to drive paddle-wheels to propel vessels; and in 1707 he applied the steam-engine, which he had proposed as a pumping-engine, to driving a model boat on the Fulda, at Cassel.

In this trial he probably used the arrangement of which a sketch

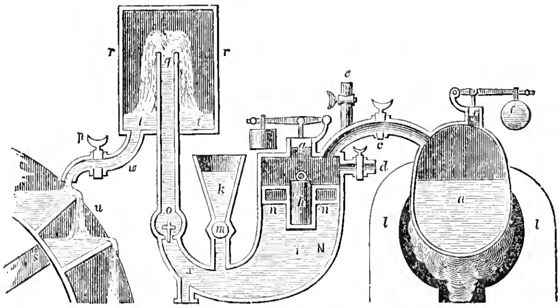

FIG. 44.—PAPIN'S MARINE ENGINE, 1707.

is here shown. His pumping-engine forced up water to turn a water-wheel, which, in turn, was made to drive the paddles, as in Fig. 44.

[1] "Inventions of Engines of Motion, recently brought to Perfection," London, 1651. A number of such treatises, vaguely hinting at new motors for propulsion of vessels, appeared during the sixteenth and seventeenth centuries.

An account of his experiment is to be found in manuscript in the correspondence between Leibnitz and Papin, preserved in the Royal Library at Hanover.

78. December 21, 1736, Jonathan Hulls took out an English patent for the use of a steam-engine for ship-propulsion, proposing to employ his steamboat in towing.

In 1737 he published a well-written pamphlet[1] describing this apparatus, an engraving of which is here shown in fac-simile.

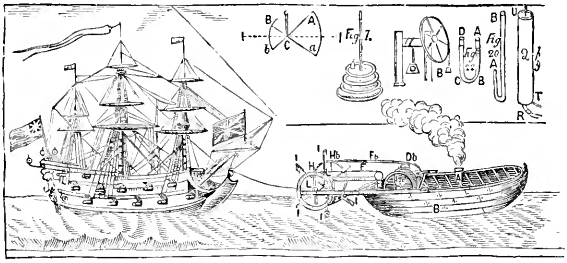

FIG. 45.—HULLS'S STEAM TOWBOAT, 1737.

He proposed using the Newcomen engine, fitted with a counterpoise weight, and a system of ropes and grooved wheels, which, by a peculiar ratchet-like action, gave a continuous rotary motion.

There is no positive evidence that Hulls ever put his scheme to the test of experiment, although tradition does say that he made a model, which he tried with such ill success as to prevent his further prosecution of the experiment. Doggerel rhymes are still extant which were, it is said, sung by his neighbors in derision of his *folly*, as they considered it.

79. William Henry, of Chester County, Pennsylvania, is said to have constructed a model steamboat in 1763. It was a failure, although not a discouraging one.

80. In 1774 the Comte d'Auxiron, a French nobleman, and a gentleman of some scientific attainments, constructed a steamboat, and tried it on the Seine, with the aid of M. Perier.

This experiment proving unsuccessful, M. Perier built another boat, which he tried independently in 1775, but was again unsuccessful, owing principally to the small power of his engine.

81. In 1778, and again in 1781 or 1782, the French Marquis de Jouffroy, who, in his later experiments, used quite a large vessel, succeeded in obtaining such good results as to encourage him to persevere, but, political disturbances driving him from his country, his labors terminated abruptly.

[1] "A Description and Draught of a Newly-invented Machine for carrying Vessels or Ships out of or into any Harbor, Port, or River, against Wind and Tide, and in a Calm," London, 1737.

82. About 1785 John Fitch and James Rumsey, two ingenious American mechanics, were engaged in experiments having in view the application of steam to navigation.

83. Rumsey's experiments began in 1774, and in 1786 he succeeded in driving a boat at the rate of four miles an hour against the current of the Potomac, at Shepardstown, Maryland.

Rumsey employed his engine to drive a great pump, which forced a stream of water aft, thus propelling the boat forward.

This same method has been recently tried again by the British Admiralty in the Water-witch, a gunboat of moderate size, using a centrifugal pump to set in motion the propelling stream, and with some other modifications which are decided improvements upon Rumsey's rude arrangements, but which have not done much more than did his toward the introduction of "hydraulic propulsion," as it is now called.

Rumsey died of apoplexy while explaining some of his schemes before a London society a short time later.

84. John Fitch was an unfortunate and eccentric, but very ingenious, Connecticut mechanic.

After roaming about until forty years of age, he finally settled on the banks of the Delaware, where he built his first steamboat.

In 1788 he obtained a patent for the application of steam to navigation.

His boat is shown in Fig. 46; it was sixty feet long and twenty

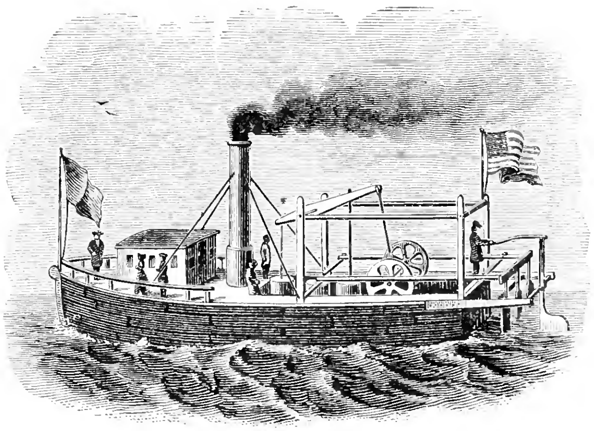

Fig. 46.—John Fitch, 1788.

feet wide. The propelling apparatus was a system of paddles, which were suspended by the upper ends of their shafts, and moved by a series of cranks, one to each, taking hold at the middle, and giving them almost exactly the motion which is imparted to his paddle by the Indian in his canoe.

Fig. 47 exhibits a sketch, reëngraved from a French work, which illustrates at once another of Fitch's steamboats and the Gallic artist's idea of the flora on the banks of the Delaware.

Fitch, while urging the importance and the advantages of his plan, confidently stated his belief that the ocean would soon be

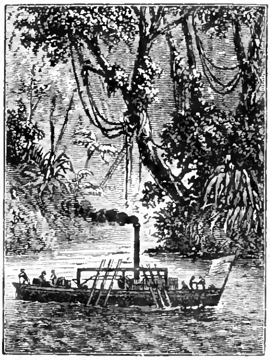

Fig. 47.—An Ideal Sketch of the Delaware.

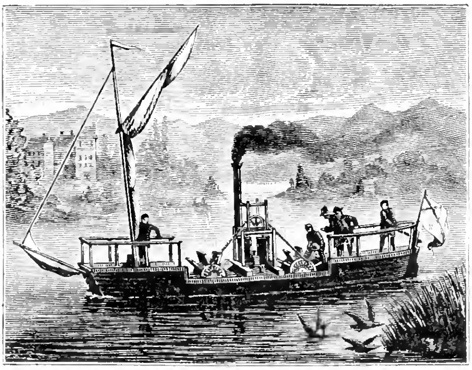

Fig. 48.—Steamboat on Dalswinton Lake, 1788.

crossed by steam-vessels, and that the navigation of the Mississippi would also become exclusively a steam-navigation.

Fitch's boat, when tried at Philadelphia, was found capable of making eight miles an hour. It was laid up in 1792.

85. In 1788 Patrick Miller, James Taylor, and William Symmington, attached a steam-engine to a boat with paddle-wheels, which had been built by the first-named, and tried it for the first time on Dalswinton Lake, in Dumfriesshire, Scotland.

This boat, having attained a speed of five miles an hour, another was constructed (Fig. 48), and was tried in 1789. This vessel was

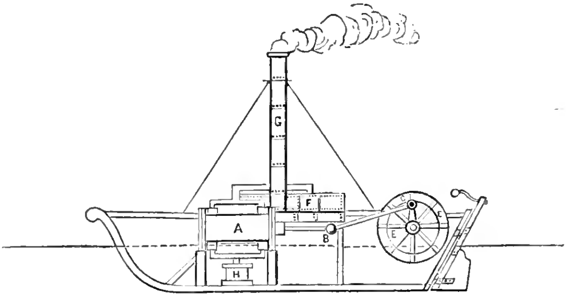

Fig. 49.—The Charlotte Dundas, 1801.

driven by an engine of twelve-horse power, and made seven miles an hour. This result, encouraging as it was, led to no further immediate action, the funds of the experimenters having failed.

86. In 1801, however, Symmington was employed by Lord Dundas to construct a steamboat, with the design of substituting steam for horse-power on canals.

After several trials, Symmington, whose experience, with Miller and Taylor, had been of much service in directing his experiments, completed a towboat, of which a sectional view is seen in Fig. 49, which he fitted with a stern-paddle wheel and a double-acting crank-engine of twenty-two inches diameter of cylinder and four feet stroke. This boat attained a speed of six miles an hour; but was laid aside, although perfectly successful, in consequence of a fear of injuring the banks of the canal by the waves produced by it.

ROBERT FULTON.

The Charlotte Dundas, as this boat was named, was so evidently a success that the Duke of Bridgewater ordered *eight* similar vessels for his canal; but his death, soon afterward, prevented the order being filled.

87. At this time, several American mechanics were also still working at this attractive problem.

In 1802–'3, Robert Fulton, with our other distinguished countryman, Mr. Joel Barlow, the patentee of the "Barlow boiler" (Fig. 50), in whose family he resided, and Chancellor Livingston, who had at that time taken up a temporary residence in Paris, commenced a small steamboat eighty-six feet long and of eight feet beam. The hull was altogether too slight to bear the weight of the machinery, and, when almost completed, the little craft literally broke in two, and sank at her moorings.

The wreck was promptly recovered and rebuilt, and in August, 1803, the trial-trip was made in presence of a large party of invited guests.

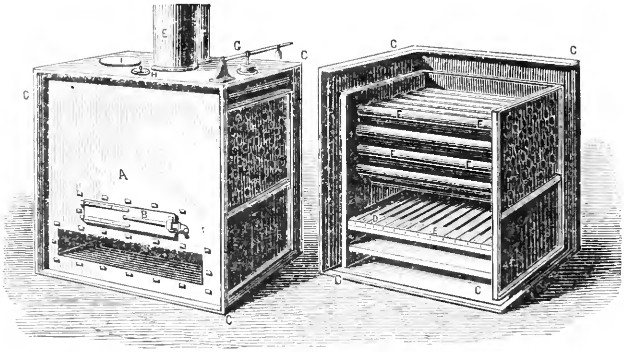

Fig. 50.—Water-tube Boiler of Fulton and Barlow, 1793.

88. The experiment was sufficiently successful to induce Fulton and Livingston to order an engine of Messrs. Boulton and Watt, directing it to be sent to America, where Livingston soon returned. In 1806 Fulton followed, reaching New York in December, and at once going to work on the vessel for which the English firm sent the engine, without being informed of its intended use.

In the spring of 1807 the Clermont (Fig. 51), as the new boat

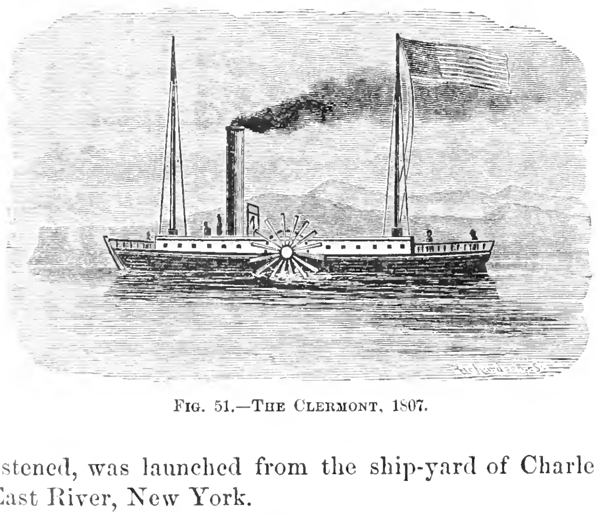

Fig. 51.—The Clermont, 1807.

was christened, was launched from the ship-yard of Charles Brown, on the East River, New York.

In August, the machinery was on board, and in successful operation. The hull of this boat was one hundred and thirty-three feet long, eighteen feet beam, and seven feet in depth.

The boat soon afterward made a trip to Albany, making the distance of one hundred and fifty miles in thirty-two hours running time, and returning in thirty hours. The sails were not used on either occasion.

This was the first voyage of considerable length ever made by a steam-vessel, and the Clermont was soon after regularly employed as a passenger-boat between the two cities.

Fulton, though not to be classed with James Watt as an inventor, is entitled to the great honor of having been the first to make steam-navigation an every-day commercial success, and of having thus made the first application of the steam-engine to ship-propulsion which was not followed by the retirement of the experimenter from the field of his labors before success was permanently insured.

89. The engine of the Clermont (Fig. 52), was of rather pecu-

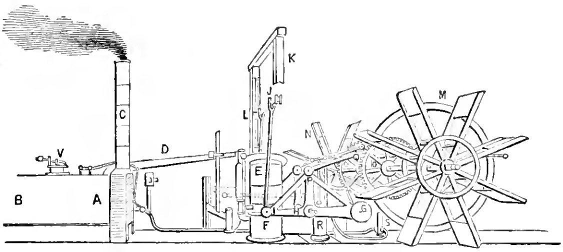

FIG. 52.—ENGINE OF THE CLERMONT, 1807.

liar form, the engine being coupled to the crank-shaft by a bell-crank, and the paddle-wheel shaft being separated from the crank-shaft, but connected with the latter by gearing. The cylinders were twenty-four inches in diameter and of four feet stroke. The paddle-wheels had buckets four feet long, with a dip of two feet.

An old drawing made by Fulton's own hand, showing this engine as it was improved in 1808, is in the relic-corner of the lecture-room of the author at the Stevens Institute of Technology.

The voyage of this steamer to Albany was attended with some ludicrous incidents, which found their counterparts whenever subsequently steamers were for the first time introduced.

90. Mr. Colden, the biographer of Fulton, says that she was described by persons who had seen her passing at night, "as a monster moving on the waters, defying wind and tide, and breathing flames and smoke."

This first steamboat used dry pine-wood for fuel, and the flame rose to a considerable distance above the smoke-pipe, and, when the fires were disturbed, mingled smoke and sparks rose high in the air.

"This uncommon light," says Colden, "first attracted the attention of the crews of other vessels. Notwithstanding the wind and tide were averse to its approach, they saw with astonishment that it was rapidly coming toward them, and, when it came so near that the noise of the machinery and paddles was heard, the crews (if what was said in the newspapers of the time be true), in some instances, shrunk beneath their decks from the terrific sight, and left their vessels to go on shore; while others prostrated themselves, and besought Providence to protect them from the approach of the horrible monster which was marching on the tides, and lighting its path by the fires which it vomited."

91. Subsequently, Fulton built several steamers and ferry-boats, to ply about the waters of the States of New York and of Connecticut.

The Clermont was a boat of but 160 tons burden; the Car of Neptune, built in 1807, was 295 tons; the Paragon, in 1811, measured 331; the Richmond, 1813, 370 tons; and the Fulton, the first built in 1814–'15, measured 2,475 tons. The latter vessel, whose size was simply enormous for that time, was what was then considered an exceedingly formidable steam-battery, and was built for the United States Navy.

Before the completion of this vessel, Fulton died of disease resulting from exposure, February 24, 1815, and his death was mourned as a national calamity.

92. But Fulton had some active and enterprising rivals.

OLIVER EVANS.

Oliver Evans had, in 1801 or 1802, sent one of his engines, of about 150 horse-power, to New Orleans, for the purpose of using it to propel a vessel, owned by Messrs. McKeever and Valcourt, which was there awaiting it.

The engine was actually set up in the boat, but at a low stage of the river, and no trial could be made until the river should again rise, some months later. Having no funds to carry them through so long a period, Evans's agents were induced to remove the engine again, and to set it up in a saw-mill, where it created great astonishment by its extraordinary performance in sawing lumber.

THE MAGNETIC OBSERVATORY AT MADISON, WISCONSIN.

By E. W. DAVIS.

A VISITOR to the grounds of the State University at Madison, Wisconsin, might perhaps wonder what could be the use of three small chimneys to be seen standing out of the south side of the university hill. On being told that under the ground is one of the two magnetic observatories of this country, he may be curious to see more. If so, he will go on down some distance past the chimneys, and, turning into a moderately deep cut, will enter the observatory through a tunnel in the hill-side.

Having divested himself of whatever iron he may have about him —his keys, his knife, and even his watch—two doors are successively thrown open, and he is ushered into a low, vaulted chamber measuring seventeen feet square. The darkness, which would be absolute but for the faint gleams of light escaping through the close coverings of three lamps; the silence, broken only by the ticking of two clocks, or the tread upon the paved floor; the strange character of the instruments, which he begins dimly to see—all unite to create a feeling of oppression, as though one breathed the air of some sorcerer's den.

Though the visitor may be interested in what there is to be seen, yet, in the short time he is allowed to stay, he can get but an imperfect idea of it all. He will learn, it may be, the names of the several instruments, and gain a slight knowledge of the manner in which the observations are recorded. He will be told that the observatory was established at Madison in the autumn of 1876 by the United States Coast Survey; and also, perhaps, that the instruments employed were in use at Key West, Florida, and then at Washington, D. C., being moved from the latter place in order not to be so nearly upon the meridian of a magnetic observatory at Quebec, Canada. If desired, the person in charge will show him some of the traces, one of these being nothing more than the crooked path which a moving spot of light, reflected from a mirror attached to either of the magnets, has left upon sensitive paper.

In order to really profit by his visit, he should have gained, beforehand, some idea of what is to be observed and the manner of observing. This information I shall try to give the readers of this article; and then proceed with a description of the observatory and its equipments.

The force called terrestrial magnetism is subject to variations both in intensity and in direction. There are three ways in which a varying force of this kind may be measured:

1. It may be resolved into components acting along three axes, and the intensity of these components measured. I am not aware that this method has ever been applied to the measurement of terrestrial magnetism; probably, because one of the components would be so small as not without great difficulty to be directly measured.

2. We may measure its intensity along some fixed axis, and its angular variation of direction from that axis, in each of two planes intersecting the same. This method is frequently employed. The fixed axis taken is the intersection of the plane of the magnetic meridian and the plane of the horizon, and the angular variations from the axis are measured in these planes, the variation in the horizontal plane being called the "declination," and that in the plane of the magnetic meridian the "dip."

3. We may measure the intensity of its components along two axes and its angular variation in direction from the plane of those two axes. This last is the method in use at the observatory. The axes assumed are horizontal and vertical, and their plane is that of the magnetic meridian. Angular variations from this plane may be measured in any plane at right angles to it, as the plane of the horizon, and are, therefore, changes of declination.

The instruments used for making the measurements are the declinometer, the bi-filar magnetometer, and the balance magnetometer.

The declinometer consists, essentially, of a bar magnet so suspended as to turn freely in the horizontal plane. Changes in the position assumed by the bar show changes in declination.

The magnet of the bi-filar magnetometer likewise turns in the vertical plane; but, while the magnet of the declinometer is free to assume any position in that plane, the magnet of this instrument is pulled by a constant force into a position at right angles to the magnetic meridian.

The magnet of the balance-magnetometer, like that of the last two instruments, is in a position at right angles to the magnetic meridian; but, unlike either of the other two, it turns in the vertical plane.

The only effect of the horizontal force is to press the magnet against its bearings, and were the magnet suspended at its centre of gravity, the north-seeking pole would point directly downward in obedience to the vertical force. In reality, the magnet is so suspended as to assume a position approximately horizontal. The force of gravity remaining constant, the magnet will not change its position, except with a variation in the intensity of the vertical component of terrestrial magnetism.

In making the observations, care must be taken that the temperature be kept as nearly constant as possible, a magnet losing about one ten-thousandth part of its power for each degree Fahrenheit of increase in temperature; also, that no magnetic bodies are present to influence the magnets; that the instruments be secured from all mechanical interference; and that all the adjustments be true.

Let us see how these requirements are met. The observatory has been built underground, and has double walls and roof, there being a space of two feet between the outside and inside walls. A differential thermometer placed within shows a daily variation in temperature of but 1° or 2° Fahr. In case of artificial heat being required, a brick stove has been built, with which it would be impossible to cause a sudden change in temperature.

The observatory has been placed without the influence of iron water or gas pipes, and in its construction and furnishing no iron has been employed, all metallic supports, mountings, etc., being of brass, copper, or zinc. The reservoirs of the lamps used have to be taken outside to be filled, since to bring a so-called *tin* oil-can within the observatory would seriously disturb the instrument. As before mentioned, visitors to the observatory leave outside whatever of iron they may have about them. An abnormal variation in the movements of the magnets at the Key West Observatory is thought to have been caused by the landing of some heavy guns in the vicinity, and their subsequent transportation past the observatory.

The mounting of the instruments upon heavy blocks of stone and their close incasement reduce the chance of mechanical interference to a minimum.

To still further guard against errors of observation, there are special adjustments in the several instruments.

The magnet of the declinometer is suspended by a skein of one hundred fibres of silk, the utmost pains being taken to reduce the torsion to a minimum. The length of skein is at least three feet, so that any residual torsion has the less effect. It seems impossible, however, to entirely get rid of this disturbing element. The records of the Key West observations show that the torsion of the suspension skein changed rapidly during the first five months after the suspension of the magnet, and did not become constant even after six years.

As variations in temperature do not affect the direction of the line of action of the magnetic force, no temperature adjustment is required for the declinometer.

The magnet of the bi-filar magnetometer is rigidly connected with a small glass rod of the same length as the magnet. Over the ends of this rod slip two zinc tubes, of such length as to reach within about five millimetres of its centre. At the inner end of each tube is attached one end of a suspension skein, that passes over a glass pulley three feet above the magnet. The diameter of the pulley is fourteen millimetres; it should, however, equal the distance between the ends of the suspension skein—ten millimetres. The present pulley is to be changed for one of that diameter.

The pulley is turned into such a position that the pull of the suspension skein brings the magnet approximately at right angles to the magnetic meridian. The magnet is in equilibrium under the action of three forces: gravity, the pull of the threads, and the horizontal component of the earth's magnetism. The first two forces being constant, the equilibrium is not destroyed save by a variation in the intensity of the third force. The changes in the direction of that force are never sufficiently great to appreciably alter the position of this magnet. The diameter of the pulley being greater than it should be, increases the leverage of the pull of the threads, and so lessens the ratio of the variation of the horizontal force to the sum of the opposing forces. The delicacy of the instrument is thus slightly impaired.

On each side of the point of suspension of the magnet is a place for a small weight. By weighting the magnet its angular position is slightly changed. A comparison of the effect thus produced with the changes due to variations in the horizontal force gives us a measure of that force. It is, in truth, weighing the magnetism.

Observe what takes place when the instrument is heated. Neither the glass pulley nor the glass rod would be sensibly affected. The magnet, however, would lose some of its power, and consequently be less strongly pulled by the horizontal force, which we wish to measure. To counterbalance this loss of magnetic power, the effect of one of the opposing forces must be diminished by an equal amount. This is effected by the zinc tubes, whose expansion brings the ends of the suspension skein nearer together, and thus lessens the pull of that skein.

I now come to the most delicate of all the instruments—the balance-magnetometer. Attached rigidly to the axis of this instrument, and at right angles to the same, is an axis, resting, through the interposition of agate knife-edges, upon an agate plate. By changing the position of small brass balls that screw upon vertical and horizontal arms of this axis, the centre of gravity of the instrument may be accurately adjusted to any desired position. None of these balls weigh over fifty grains, and the distance between two successive threads of the screw upon which they work is only the hundredth part of an inch; yet, if one of those for shifting the centre of gravity horizontally be turned through so much as the twentieth part of a revolution, thus advancing it the two-thousandth of an inch, the instrument will be so tilted as never to right itself. This extreme delicacy is attained by bringing the centre of gravity of the instrument close up under the axis of suspension. To prevent unnecessary wear of the agate knife-edges, there is an arrangement for lifting the instrument off of its bearings, when not in use.

The balance-magnetometer requires a delicate temperature adjustment. For this purpose there is attached to the side of the magnet a small tube containing mercury. Such is the position of the tube that the shifting of the centre of gravity of the magnetometer, due to the expansion or contraction of the mercury, shall just balance the tendency of the north-seeking pole of the magnet to rise or fall with the temperature. Adjusting the tube to its proper position occupied Mr. Suess for five days.

The variations of these several instruments are recorded by photography, each instrument, with its recording apparatus, constituting a magnetograph. A cylinder, turned by clock-work, carries the sensitive paper upon which the record is to be made. A single cylinder, with its sensitive paper, suffices for both the declinometer and the bi-filar magnetometer, the cylinder turning between the two instruments and receiving the two records at its opposite ends. A second and vertical cylinder is required for the balance magnetometer. The record of all the instruments is made in the same way. The light from a German student-lamp, after passing through a narrow slit, is received upon a concave mirror carried by the magnet. The mirror throws a thread-like image of the slit upon two cylindrical lenses fixed in the case of the recording instrument. By these lenses the line of light is shortened to a dot, to be received by the sensitive paper.

Were the spot of light stationary, a straight line would be traced upon the sensitive paper, since, by the revolution of the cylinder, the paper would be carried directly forward from in under the light. But, by the movement of the magnet, the image of the slit is made to travel back and forth along the lenses and a more or less eccentric trace left upon the sensitive paper.

In order that the trace may not go beyond the limits of the paper, the magnet must be kept from swinging through more than a small arc. This is effected, in the bi-filar magnetometer, by the pull of the suspension skein acting against the magnetic force. In fact, owing to the too great size of the glass pulley, the magnet does not swing quite freely enough.

In the other two instruments a special arrangement is adopted. Surrounding the magnet and forming a closed circuit, is a rectangle of four flat copper bars. Any movement of the magnet gives rise to a current in the circuit, which tends to pull the magnet back again. Thus, if the north-seeking pole of the magnet in the declinometer be deflected toward the east, a current will be generated, running from south to north along the upper bar of the rectangle, and back along the lower bar. The current, in turn, acts upon the magnet, checking it in its swing toward the east, so that the paper can receive the entire trace.

In addition to the concave mirror, each magnet carries a plane mirror to receive the reflection of a scale attached to the back of a small telescope. The telescopes are mounted upon the stands of the recording instruments, and for convenience of observation are provided with diagonal eye-pieces. On looking into either telescope one sees its scale reflected in the plane mirror carried by one of the magnets. When the mirror turns with the swing of the magnet, the scale appears to the observer to traverse the mirror's face. At the beginning and again at the end of each trace a record is made of the division of the scale then covered by the cross-wires of the telescope. Knowing the times at which each trace was started and stopped, and the readings of the scale at those times, it is easy to divide off the paper into spaces corresponding to the hours of the day and into other spaces at right angles to these corresponding to divisions of the scale. An exact record is thus made of all magnetic variations.

Particular interest attaches to magnetic observations on account of the way in which the magnetic state of the earth seems to be influenced by the position of the sun, and to a slight degree by the position of the moon; also from the connection between auroral displays and magnetic variations, curves representing the frequency of either agreeing quite closely with curves representing the area of the sun covered by spots. It is well to remark that the curves representing magnetic variations and auroras lag about six months behind those representing the sun-spot variations. The sun-spot area seems in some way to depend upon the position of the planets. Not only is the earth's magnetism thus, seemingly at least, influenced by the sun-spots, but also some of the phenomena of the weather. These last are, of course, in general, masked by local disturbances; but, lately, a very remarkable agreement has been shown to exist between certain magnetic and barometric traces. Investigations into the causes of magnetic variations and the laws under which these variations occur are made by officers of the United States Coast Survey; and to the headquarters of this survey, at Washington, are forwarded, each month, the traces obtained at Madison.

THE CHEMISTRY OF FRUIT-RIPENING.[1]

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TO form the seed seems to be the chief end of the plant. When in the vigor of its own maturity, and when receiving the sun's strongest rays and the earth's richest nourishment, the plant gathers

[1] From the forthcoming "Transactions of the Michigan Pomological Society" for 1877; furnished by the author for THE POPULAR SCIENCE MONTHLY.

all its resources, and devotes them to the building of the seed. When done, the seed itself, the embryo, commonly possesses little substance and serves little use beyond its primary purpose, the reproduction of the plant. But in *the coatings and coverings of the seed* we find a large and abundant supply of substances, in variety and quantity the rarest and richest stock in the vegetable commonwealth. Indeed, the wrappings of seed-germs constitute the especial provision for the nourishment of the human race. The seeds enveloped with starch and albuminoids, as in the cereal grains, make up "the staff of life" for man. Seeds with oily coatings, including the nuts, present a good supply of fats for food. The seeds with succulent coverings, the fruits, yield a great number of sharply-defined substances, most of which claim the approval of man, and some of which require for their due application the best efforts of the human intellect. Without the grains, the fruits, and the nuts, man would be left to browse with the ox and prey with the wolf.

In this abundant material gathered around the seed-germs, chemistry has achieved more success than elsewhere in the organic world. It is well understood that chemists have no reason to boast of what they can do with the products of living cells. In an analysis of vegetable or animal products, there is always a percentage, and often a large percentage, of unknown matter. It might be named "chemist's dirt;" not "matter out of place," but simply "matter unknown." It has weight, it may have color and consistence, but it responds to no inquiries and yields to no suggestions. Like an open polar sea, it baffles and invites and baffles again. But, with all due reservation for unknown bodies, the condition of organic analysis gives good ground for encouragement. Especially in this material about the seed, the analyst finds numerous compounds of clearly definite chemical character, many of them capable of sure identification and exact separation, even when taken in complex mixtures. Working with some of these compounds, an insight into their chemical structure has been obtained; so that the chemist can bring together the materials and conditions for their production. In the products of the peach, at every autumn's ripening, certain chemical changes occur in the kernel under your hand—changes as well known to science and capable of as exact quantitative statement as the local changes of the planets in the solar system. Forty-four years ago, Liebig and his fellow-workers discovered certain links in those chemical changes, in the products of the almond family, and the discovery was an era in chemical science.

The chemistry of the covered seed is of interest not only for the quality of the compounds found in it, but, quite as much, for the *history* of these compounds, *the chemical changes of seed and fruit-ripening* in the plant. These changes differ in their general character from other changes of plant chemistry, coinciding more nearly with the changes of animal chemistry. Taking for study the ripening of *seeds with succulent coverings*, the fruits—the proper subject of this article—we may undertake to compare fruit-ripening with vegetable nutrition on the one hand, and with animal nutrition on the other hand, as follows:

In Vegetable Nutrition.	In Fruit-Ripening.	In Animal Nutrition.
1. Oxygen is given to the air.	Oxygen is taken from the air.	Oxygen is taken from the air.
2. Carbonic acid is taken from the air.	Carbonic acid is given to the air.	Carbonic acid is given to the air.
3. The service of plant-green is required.	The service of plant-green is dismissed.	....
4. Simple compounds are changed to those more complex.	Complex compounds are changed to those more simple.	Complex compounds are changed to those more simple.
5. The expended power of the sun is stored.	The stored-up power of the sun is expended.	The stored-up power of the sun is expended.
6. Heat is absorbed.	Heat is liberated.	Heat is liberated.
7. The changes represent reductions and syntheses, difficult to the chemist, and hindered by atmospheric conditions.	The changes represent combustions and dissociations, and are mostly favored by atmospheric conditions.	The changes represent combustions and dissociations, such as are favored by atmospheric conditions.
8. Opposed to fermentations, and to other changes classed under the term organic decomposition.	The changes include a great number of distinct fermentations, some of which are spontaneous in the air, or occur in cooking food.	Some of the changes are allied to fermentations, but are mostly not liable to occur without the living body.
9. The important compounds of the vegetable kingdom—cellulose, starch, sugar, and many acids and other products—are common to the fruit and other parts of the plant.		Only a few animal products are found in the vegetable kingdom.

Fruit-ripening, then, coincides with vegetable nutrition in acting with the same substances, and coincides with animal nutrition in moving in the same direction.

To inquire, now, somewhat in detail, into the more obvious of the changes which constitute fruit-ripening, we may examine the proportion and formation of the following five classes of Fruit-Products:

1. Sugars (starches).
2. Pectous substances and gums.
3. Acids, tannin, and other glucosides.
4. Ethers.
5. Alkaloids.

The analyses of fruits hitherto reported have mostly been made by European chemists. The fullest reports of ripe fruits, upon which I am in good part dependent, were made by Fresenius, from analyses under his direction, nearly twenty years ago, and represent the fruits of the Rhine district, obtained at Wiesbaden.

1. Sugars.—The prevailing sugar in fruits is *glucose* (*dextrose*),

often termed grape-sugar. It is the same compound that is largely manufactured from starch, and called starch-sugar. It is much less sweet than cane-sugar, and less abundantly soluble in water, having an oily or "mealy" taste. As made from starch, it is now much used in certain candies. When in the uncrystallizable form, *glucose* (*lævulose*) is the same as "fruit-sugar," the uncrystallizable product obtained to some extent in manufacturing cane-sugar, and which forms a part of the sirups of the market. Many of the fruits contain *cane-sugar* (which is the same as beet-sugar and maple-sugar), and certain rare varieties of sugar are found in some fruits.

Buignet decided that the apple, peach, plum, raspberry, orange, and pineapple, contain cane-sugar, with *glucose* (mostly as *lævulose*). The sugar of the grape, cherry, gooseberry, and fig, consists wholly of *glucose.*

The average proportion of sugars in ripe fruits is given, by Fresenius, as follows (the smallest percentages being placed first):

Peaches, 1.6 per cent. (not varying very widely).
Apricots, 1.8 per cent. (from 1.1 to 2.7).
Plums, round red, 2.1 per cent. (from 2.0 to 3.5).
Greengages, 3.1 per cent.
Raspberries, 4.0 per cent. (from 3.0 to 5.0).
Blackberries, 4.4 per cent.
Strawberries, 5.7 per cent. (from 3.2 to 7.0).
Currants, 6.1 per cent. (from 4.8 to 6.6).
Gooseberries, 7.1 per cent. (from 6.0 to 8.2).
Pears, red, 7.4 per cent.
Apples, 8.4 per cent. (from 5.9 to 10.4).
Cherries, 9.8 per cent. (from 8.5 to 13.1).
[Summer peaches, 11.6 per cent. Berard's analysis.]
Grapes, 14.9 per cent. (from 13 to 19).

It is seen from this list that the *sweetness* of fruit has but slight correspondence with its proportion of sugar. Currants were found to have more sugar than raspberries, blackberries, or strawberries, and over three times as much as the peaches examined by Fresenius. All analysts agree in the predominance of grapes for their quantity of sugar. The sweetness of fruit is probably favored less by large proportions of sugar than by three other conditions, namely: 1. Small proportions of acids; 2. Large proportions of pectous substances; 3. Presence of cane-sugar instead of grape-sugar.

The sugar of fruits is chiefly formed or deposited in them during their ripening. Berard found that the pulp of cherries, unripe, contained only 1.1 per cent. of sugar; ripe, 18.1 per cent.; gooseberries, unripe, 0.5 per cent.; ripe, 6.02 per cent. In 1862 Hilger determined the *sugar of grapes*, at ten periods during their growth and ripening, as follows (*Landw. Versuchsstat*, xvii., 245; *Journal of the Chemical Society*, xxviii., 281):

		Austrian.	Riesling.
1.	June 27th	1.37 per cent.	1.01 per cent.
2.	August 16th	1.33 " "	1.23 " "
3.	August 22d	2.18 " "	1.81 " "
4.	August 28th	4.25 " "	2.39 " "
5.	September 1st	2.53 " "	2.58 " "
6.	September 12th	4.49 " "	2.89 " "
7.	September 17th	5.33 " "	3.87 " "
8.	September 23d	7.71 " "	7.70 " "
9.	October 10th	9.90 " "	8.64 " "
10.	November 10th	9.90 " "	8.21 " "

Whether the *sugar of fruits is formed* within them, or introduced through the stem, and, if formed in the fruits, from what substance formed, are questions which have been investigated, but not wholly settled. It has been pretty generally held that *starch* in the unripe fruits is converted into sugar in the ripe fruits; the fruit acids inducing the change, as we know they have power to do. But starch is not found in the unripe stage of all fruits, and, in the cases where found, its quantity is sometimes too small to serve as the source of all the sugar of the ripened fruit. In the investigation of Hilger, above quoted, the immature fruit was at no time found by microscopic examination to contain starch. It appeared in the fruit-stalks in June; after August it almost wholly disappeared from the fruit-stalks, and was found only in the wood of the vines. Payen (*Comptes Rendus*, liii., 313) reported that he had demonstrated the presence of starch in unripe fruits and its conversion to sugar during ripening; but did not ascertain how much of the sugar of fruits is formed in this way.

It has been advanced that sugar is formed *from malic and other acids*, during ripening, either in the fruit or in the parts of the plant supplying juices to the fruit. Six molecules of malic acid and six molecules of tartaric acid, with nine molecules (eighteen atoms) of oxygen, would furnish the atoms for formation of four molecules of glucose, twelve molecules of water, and twenty-four molecules of carbonic anhydride. Mercadante (*Gazetta Chimica Italiana*, cxxv.; *Journal of the Chemical Society*, xxviii. [1875], 904) made a series of determinations of the malic acid and sugar in plums, commencing May 20th. The quantities of both acid and sugar increased in the fruit so long as it was green and emitting oxygen in the daylight; the branches which bore the fruit containing acid and pectous substances but no sugar. During the same time, the pectous and gummy substances in the green fruit had decreased from six per cent. of the pulp to three per cent. of the pulp. The investigator believed the sugar of the green fruit to have been chiefly formed, in the fruit, from the pectous and gummy substances, under contact of the acids. As soon as the fruit, losing green color, began to emit carbonic acid in the daylight, the acid in it began steadily to decrease as the sugar increased. The increase of sugar at expense of the acid in the pulp of plums is shown as follows:

	Sugar.	Malic Acid.
June 20th	16.52	2.76 (per cent. in pulp).
June 24th	16.64	2.46 " "
June 30th	16.78	2.16 " "
July 4th	17.05	1.57 " "
July 12th	17.38	0.82 " "

The green plums contain *tannin*, which commenced to diminish as soon as the fruit began to emit carbonic acid in the daylight, wholly disappearing by June 20th, the date at which the malic acid began to diminish. It is well known to every one that many green fruits are very astringent, and that their tannin decreases and sometimes disappears during ripening. Also, it is a familiar fact in the chemistry of tannin that it readily undergoes changes producing sugar. This, then, is the source of a portion of the sugar of many fruits. The formation of sugar from tannin will be discussed under the head of the glucosides of fruits.

Several chemists have reported the presence of sugar-producing substances peculiar to fruits. Buignet describes a fruit constituent, astringent like tannin, and combining with iodine like starch, and serving as the source of sugar.

The proportion of *cane-sugar*, in most fruits, is generally believed to diminish by transformation into *glucose*, as fruits become fully ripe or overripe. But Berthelot and Buignet (*Comptes Rendus*, li., 1094) found that, in oranges, the proportion of cane-sugar increased during ripening, the quantity of *glucose* remaining unchanged.

The *increase of weight* of fruits, during ripening, is no doubt largely owing to deposition of sugar. Berard found that 100 parts of unripe summer peaches yielded 179 parts of ripe fruit, and 100 parts of unripe apricots increased in ripening to 200 parts.

The maturity of fruit is the period of its maximum quantity of sugar. Sooner or later, the quantity of *sugar begins to diminish*, and then the fruit is overripe. It is safe to say that the sugar often begins to decompose during the life of the fruit; that is to say, fruit becomes overripe during its life. It would be difficult, however, to fix on the termination of the life of fruit. We certainly cannot say that life ceases when the circulation with the plant is cut off; and we cannot say that life continues in the sarcocarp until it is wholly disintegrated. Now it is within the limits of our subject to inquire *by what changes the sugar begins to disappear.*

In general terms, sugar suffers *oxidation* in ripe fruits, small portions being oxidized away even during the production of larger portions, and before perfect maturity. We do not know what fruit constituents, if any, result in this oxidation. The *final* products of oxidation, carbonic acid and water, are exhaled during ripening, and with greater rapidity after maturity has been passed.

It seems to be established that sugar in fruits is liable to traces of the alcoholic *fermentation*, even before maturity is passed. H. Gutzeit (Zeitscher Oest. Ap. Ver., 1875, p. 337; Pro. Am. Phar. Asso., 1876, p. 287) reports finding alcohol, or other simple compound of ethyl, in the fruits of a number of plants. Some of the fruits were not quite ripe, and none were overripe. De Luca (*Comptes Rendus*, lxxxiii., 512; *Jour. Chem. Soc.*, 1876, ii., 649) reports obtaining products of the alcoholic and acetic fermentations from the fresh fruits, leaves, and flowers, of several plants. In all these cases the quantities of alcohol obtained were very minute. The investigator first above named found methyl-alcohol, in some cases, with the ethyl-alcohol. Pasteur states that the germs which excite alcoholic fermentation are very abundant on the bunches of ripe grapes, where very rare in the atmosphere. Also, that the fermentive germs are found on ripe strawberries, cherries, and currants, but not on the same fruits unripe. The formation of methyl-alcohol, above referred to, is closely allied to the formation of methyl-salicylate or wintergreen-oil. A number of the essential or volatile oils, with which plants and fruits are perfumed and flavored, contain alcohol radicals in union as compound ethers. It is probable, from every point of view, that the slight occurrence of the vinous fermentation in fruits belongs to an important class of chemical formations, by means of which a multitude of odor-giving substances are scattered throughout vegetation. We shall inquire more carefully into the fruit-flavor compounds and their formation further on.

2. The Pectous Substances.—These are, in general terms, the constituents of plant-jelly. As vegetable products, they correspond to the varieties of gelatine obtained from animal tissues. Unlike gelatine, however, they are non-nitrogenous. They are found in the soft parts of plants generally, as in the tuber of the potato and the root of the carrot; but it is in fruits that they have most importance for edible value. The immediate origin of the pectous substances is pretty well known, being due to a specific fermentation, a prominent feature in fruit-ripening. The material from which all the pectous substances proceed is the fermentable body called *pectose*, an insoluble, tasteless substance, found abundantly in unripe fruits, also to some extent in immature roots and tubers, and having no more value for food than cellulose. Now, there is formed along with this substance a "ferment," as it is called, a body which by contact induces a specific fermentation—a definite chemical change. Pectase is the name of the ferment. Just as, in the germinating seed, starch, by contact with diastase, suffers fermentation with production of sugar, and as, in bruised and wetted mustard-seeds, sinigrin, by contact with myrosin, splits up into pungent oil of mustard and sugar, etc., so the crude pectose of green fruits, by contact of their pectase at the time of ripening, changes to the edible plant-jellies or pectous substances. Long boiling with water alone effects the same change.

Why this fermentation occurs just at the ripening-time, and not earlier or later, we do not precisely know. It may be that the pectose has just then become capable of fermentation, or the pectase then acquires potency for its office, or then, and not before, are other conditions of the change established. We know only that the fermentation gives us the before-mentioned pectous substances, which, moreover, succeed each other, during ripening, by repeated changes. It must be confessed that these products have been but imperfectly defined, but as a class their chief properties are known. They are given by chemists as follows (distinctions having value only in analysis being omitted):

Pectine: readily soluble in hot or cold water, gelatinizing when concentrated, and more perfectly by addition of sugar; changed by very long boiling to parapectine.

Pectic acid: gelatinous, insoluable in cold water, and but slightly soluble in hot water; hardened in jelly by solution of sugar, slowly changed by boiling to parapeptic acid, and afterward to metapeptic acid. Pectine and pectic acid result from long boiling of the crude *pectose.*

Parapectine: soluble in water, capable of gelatinizing slightly, changed by boiling to metapectine.

Parapeptic acid: soluble in water, the solution changing into one of metapeptic acid. Not gelatinous.

Metapectine: soluble in water, not gelatinous. (Found in overripe fruits.)

Metapectic acid: soluble in water, incapable of gelatinizing. (Found in overripe fruits; produced by fermentation in overripening from all the other pectous substances. Also produced, from most of the other pectous substances, by long boiling, much more readily if acids are present.)

Alkalies change pectine and parapectine and metapectine to salts of pectic acid.

The properties of the separated pectous compounds represent certain well-known characteristics of fruits, as these are found in *cooking.* Moist heat, as in any mode of cooking, produces upon these substances the chief results of ripening, and, if continued long enough, the results of overripening. *Unripe fruits* are made more edible and wholesome by cooking, owing to its artificial (imperfect) ripening of pectose. *Fruit-jellies* owe their substance to pectic acid, pectine, and slightly to parapectine, the products of early maturity, with the coöperation of sugar. For jellies, it is well known, the use of overripe fruits must be avoided, and too long boiling in the preparation must be avoided. If the fruit be underripe, the juice should be boiled much longer than if the fruit be fully ripe, and if the fruit be overripe, boiling should be maintained no longer than necessary to clarify, and standing in hot solution should be avoided. Grapes bear full ripening for jellies.

The following statements of the *quantities of pectous substances and of pectose* are compiled from the reports of Fresenius. It should be mentioned that Fresenius found widely-different quantities in the different varieties of the same fruit, and the average here drawn from the varieties of each fruit would greatly vary from an average obtained from other varieties of the same. The percentage in the fresh fruit is first given, and then percentage of solids, or strictly dry fruit, as obtained by calculation from the percentage of water:

	Pectous Substances (soluble).		Pectose (insoluble).	
	Of Fresh Fr't.	Of Solids.	Fresh Fruit.	Solids.
	Per cent.	Per cent.	Per cent.	Per cent.
Peaches—mean of two varieties........	8.45	42.25	0 85	4.25
Apples—mean of four arieties........	5.85	34.41	1.23	6.59
Pears—mean of two varieties.........	3.84	22.58	0.97	5.70
Raspberries—mean of three varieties..	1.42	10.14	0.24	1.71
Gooseberries—mean of six varieties....	1.17	8.36	0.65	4.64
Cherries—mean of three varieties......	1.59	7.23	0.78	3.54
Grapes—mean of two varieties........	0.36	2.00	0.84	4.66
Currants—mean of six varieties.......	0.17	1.13	0.84	5.66
Strawberries—mean of three varieties..	0.10	0.79	0.50	3.85

As *food-materials*, the pectous substances seem to be wellnigh indispensable to the health of man. They are not very nutritious; it is not known that they are fully digested into material which can be appropriated; and, being non-nitrogenous, they could scarcely yield tissue-building matter. What service they perform is not clearly understood. They may supply liquids important in digestion or assimilation. We obtain them in acidulous fruits, and in starchy tubers, and it is not clear how much of the value of each of these sorts of food is due to their pectous constituents; but, when all food containing pectine is cut off, the scurvy is liable to ensue, and then any food supplying pectine will serve as a remedy. At the same time it is found that pectous food is needed only in small quantities; large proportions proving not only innutritious but injurious, causing derangements of digestion and excretion.

3. Acids.—The principal fruit-acids, not astringent, are the following, given in the order of their importance:

Malic acid: Very widely distributed; predominating in apples, pears, cherries, gooseberries, strawberries, raspberries, and mountain-ash berries. Not extracted for use.

Citric acid: Found in lemons, oranges, tomatoes, currants, gooseberries, raspberries, strawberries, and a large number of other fruits, generally with malic and tartaric acids. Obtained from lemons for use.

Tartaric acid: Also widely distributed in most fruits not forming the chief acid, but constituting the acid of the grape. Manufactured from the deposit of fermenting grape-juice; used in baking-powders and in its salts, cream-of-tartar, and Rochelle salt.

Oxalic acid is sometimes found in small proportions in a few fruits. Reports vary as to its existence in the tomato.

Fresenius's analyses give the following as the average proportions of total acid, reduced to equivalent of malic acid:

Currant	2.04 per cent.
Raspberry	1.48 " "
Strawberry	1.31 " "
Sour cherry	1.28 " "
Apple	0.75 " "
Grape	0.74 " "
Peach	0.67 " "
Red pear	0.07 " "

The quantity of acids in fruits usually *diminishes during ripening*. The diminution is not, however, nearly so great as it appears to the taste, because the acid of ripe fruits is masked to the taste by the larger proportions of sugar and the pectous substances then present. The removal of acids is chiefly due to oxidation. It is not found that acids are neutralized, to any considerable extent, during ripening, by alkalies conveyed through the stem. The diminution of the acid in plums was shown definitely by the series of analyses before given from Mercadante. It is stated that the acids continue to oxidize away, after the sugar has reached its maximum and before it begins to diminish. Hence, perfect ripeness in fruit has been defined as that period during the maximum quantity of sugar when the quantity of acid is least. This will be, of course, just before the sugar begins to diminish.

It has been stated that both citric and malic acids are often found in unripe grapes, and are substituted by tartaric acid during the ripening. Oxalic acid is more often found in unripe than in ripe fruits. It is to be desired that closer determinations should be made as to the presence and proportion of oxalic acid in tomatoes and some other fruits. Any article of food containing oxalic acid (as the garden pie-plant) should probably be eaten with moderation, if at all.

A misapprehension sometimes occurs, from lack of reflection, as to the effect of sugar on the acidity of fruits. Sugar has no chemical effect upon acids. Its very sweet taste masks or overpowers to the sense the sour taste of free acids; but the acids remain free, all the same. Whatever effect the sugar eaten with fruits has on digestion and nutrition is due to the sugar itself; not to any change of the acids by the sugar, for there is no such change. Indeed, sugar approaches to the nature of an acid, though properly classed as a neutral body.

The varieties of tannic acids classed together as TANNIN are quite unlike the fruit acids above mentioned, both in sensible properties and in chemical relations. Only a few of the ripe edible fruits contain astringent acids, though these are found in many unripe fruits and in numerous ripe fruits not used for food. Most varieties of colored grapes contain a little tannin, deposited mostly in the skins and seeds, and imparting a slight astringency to the juice, retained after fermentation. In the red wines from 0.08 to 0.2 per cent. of tannin is found. The decomposition of tannin, by a fermentation producing sugar, has been mentioned under the head of sugars. Tannin is also liable to oxidation with various products not including sugar.

The vegetable kingdom furnishes numerous compounds, known as GLUCOSIDES, which are capable of definite and distinctive fermentations, one of the fermentation-products in each instance being sugar. A number of these glucosides are found in fruits. One of the most important of these is *amygdalin*, a glucoside found in the fruits, leaves, etc., of plants of the almond family, especially in the kernels of the bitter-almond, peach, and cherry, the leaves of the cherry-laurel, and the bark of the wild-cherry.

Amygdalin, when obtained pure, is a white, odorless solid, with a taste both sweet and bitter. Taken alone it is not poisonous, even in considerable quantities. But if mixed with a substance named emulsin, and wetted, amygdalin begins at once to break up, with formation of three other compounds, as follows:

Amygdalin, 457 parts (by contact with emulsin and coöperation with water), produces:	1. Bitter-almond oil, 106 parts. 2. Hydrocyanic acid (or "prussic acid"), 27 parts. 3. Glucose, 360 parts.

In the plant, amygdalin is accompanied with the emulsin needful for its fermentation. During the ripening of the fruit, and in the maturity of the leaves and other parts, the amygdalin is constantly, though slowly, being transformed into the three products above named. The bitter-almond oil and hydrocyanic acid are volatile and odorous, and give the pleasant odor of peach-kernels, almonds, etc., familiar to every one. The rapidity of the chemical change is chiefly governed by the proportion of moisture, being greatly accelerated by wetting the bruised kernels or leaves, and stopped altogether by drying, while the moisture of the living plant permits only a gradual rate of the transformation. One of the products of this change is poisonous, the well-known hydrocyanic acid, or prussic acid, one-tenth of a grain of which is a full medicinal dose. The bitter-almond oil (known to chemists as benzoic aldehyde, and easily oxidized to benzoic acid) is not in the least poisonous (when separated from the hydrocyanic acid). It will be seen from the numbers of parts resulting from the change (as given above) that one part of hydrocyanic acid and four of bitter-almond oil are produced by sixteen parts of pure amygdalin. The amygdalin of the shops, in Europe, where it is somewhat used to generate hydrocyanic acid in medicine, yields from $\frac{1}{20}$ to $\frac{1}{25}$ of its weight of hydrocyanic acid. In exposure to the air, the hydrocyanic acid, being very volatile, is quickly dissipated, while the bitter-almond oil vaporizes more slowly. In most fruits of the almond family the amygdalin and its products are obtained chiefly or only from the kernel, hence the well-known flavoring effect of leaving in the stones, or a few cracked stones, in canned fruits. Some of these fruits, however, have the amygdalin deposited in the sarcocarp (or edible portion). This is stated to be the case with black cherries.

The almond-flavor is a very grateful accompaniment of fruits and flowers, and it is provided by Nature in safe and wholesome proportions, but it has been so tampered with by the art of man that its use is now beset with dangers of several sorts. In the first place, there is the danger in concentrating what the Creator has diluted. The oxygen of the air itself is poisonous when concentrated. Bungling art is almost sure to "o'erstep the modesty of Nature" by using good things in hurtful excess. The essential oil of bitter-almonds extracted from cherry-laurel leaves, or from bitter-almond kernels, is liable to retain a poisonous proportion of the hydrocyanic acid, and its use in flavoring extracts, for pastry, etc., has now and then produced illness and even fatal results, more frequently with children. If made free from hydrocyanic acid, as the manufacturers should do, the essential oil is harmless in any quantity, and the essences, extracts, waters, etc., made from it can be used with entire safety. If long exposed to the air, the oil deposits a slight sediment of benzoic acid, which is harmless. The danger in the use of bitter-almond oil from the amygdaline of plants lies in possible neglect of removing the hydrocyanic acid. Then, in the next place, there is another substance which has the same odor as bitter-almond oil, viz., a substance named *nitrobenzine* and sometimes designated "oil of mirbane," a body which is in itself very poisonous, either when taken into the stomach or inhaled into the lungs. It it is a very cheap substitute for actual bitter-almond oil, which it resembles only in the odor. It has been manufactured for twenty years, from coal-tar, great quantities of it being used in making aniline dyes. It is from this article that many cheap grades of soap have been saturated with the smell of almond, of late years, quite to the discredit of the flavor. Unscrupulous manufacturers have used it in confectionery, and the danger of its substitution in culinary extracts besets the public, who cannot employ analysts for the examination of every manufactured article purchased for the kitchen. But if chemical art furnished a temptation for the improper substitution of nitrobenzine, it has lately compensated for it by discovering the manufacture of actual bitter-almond oil itself, a pure article, at once real and artificial, and by means so cheap that they are likely to remove the temptation to use nitrobenzine. German samples of this new product were on exhibition at the Centennial last summer.

4. Flavoring Ethers.—Many other odor-giving constituents, besides that of the almond, are subjects of chemical manufacture. For example, oil of wintergreen (found in the berry and other parts) is

well known to be chiefly salicylate of methyl, readily prepared from salicylic acid and wood-alcohol; and the oil or essence of pineapple is precisely butyric ether, manufactured largely from waste materials. Acetate of amyl and valerate of amyl are supposed to represent the flavor of the apple and the pear, but how accurately they coincide with the actual flavor-substances of these fruits has not been demonstrated. Formate of ethyl, another compound ether, is used in so-called peach-essence. Numerous *fruit-flavors*, used for culinary extracts and largely for soda-fountain sirups, are manufactured as mixtures of ethers, by recipes varying with different manufacturers. Many of these, resting on no due authority, are unwholesome mixtures, often spurious imitations of the true fruit-flavors, and again hurtful by reason of excessive proportions. As to the chemistry of the production of flavoring ethers in plants, some guesses were presented under the head of sugar fermentation.

5. Alkaloids.—*Substances strongly affecting the nervous system*, as medicines or poisons, of course do not occur in the edible fruits, and we are not in the habit of placing potent compounds among the constituents of fruits as a class; nevertheless, when we think of it, no small proportion of the banes and antidotes of the vegetable kingdom is matured in seeds and their coverings. In the poppy-fruit, the capsule or pericarp furnishes at least sixteen distinct alkaloids, including morphine, while the seeds are harmless, and yield an oil much used for food. In the fruit of the nux-vomica, the seeds are deadly with strychnine and other poisonous alkaloids, while the juicy pulp is but very slightly impregnated with these bitter poisons (Fluckiger and Hanbury, "Pharmacographia," p. 384). The seeds of henbane, and stramonium, and the Calabar-bean, contain potent alkaloids. The unripe tomato often contains traces of solanine, a poisonous alkaloid, which disappears during ripening, probably by a glucosic fermentation. The same alkaloid is sometimes found in the green or exposed parts of potato-tubers.

Many of the vegetable alkaloids are stable compounds, having clearly-marked chemical characteristics. Some of the opium-alkaloids closely resemble others in their composition. Different species of the same family often yield the same alkaloids. The theobromine of the chocolate-nut can be changed by the chemist into caffeine, the alkaloid of the coffee-berry. Such an insight has been obtained of the structure of conine, the alkaloid of the classic poison-hemlock, that it has been formed from inorganic materials, through the processes of the laboratory. But no evidence has been obtained as to the steps through which alkaloids are formed in the living plants.

It is little enough we know of the productive chemistry of plants. As, at the beginning, we had need to plead ignorance of plant-constituents, still more, at the end of our brief survey, must we declare ignorance of the chemical genesis of those constituents. We can only obtain such glimpses of the progressive order of plant-chemistry, and we have only such a distant view of chemical action itself, as can give us some hints of the order, harmony, and grandeur, of the molecular changes going on in ripening fruits before us. None the less for our ignorance, the forces each season complete their work and drop their bountiful products into our hands.

ADDRESSES OF ELIOT AND MARSH,

AT THE OPENING OF THE AMERICAN MUSEUM OF NATURAL HISTORY.

Address of President C. W. Eliot.

IN whose honor are the chief personages of the nation, State, and city, here assembled? Whose palace is this? What divinity is worshiped in this place? We are assembled here to own with gratitude the beneficent power of natural science; to praise and thank its votaries, and to dedicate this splendid structure to its service. The power to which we here do homage is the accumulated intelligence of our race applied generation after generation to the study of Nature; and this palace is the storehouse of the elaborated materials which that intelligence has garnered, ordered, and illuminated. What has natural science done for mankind that it should be thus honored? In the brief moments allotted to me I can but mention three pregnant results of the scientific study of Nature.

In the first place, natural science has engendered a peculiar kind of human mind—the searching, open, humble mind, which, knowing that it cannot attain unto all truth, or even to much new truth, is yet patiently and enthusiastically devoted to the pursuit of such little new truth as is within its grasp, having no other end than to learn, prizing above all things accuracy, thoroughness, and candor, in research, proud and happy not in its own single strength, but in the might of that host of students, whose past conquests make up the wondrous sum of present knowledge, whose sure future triumphs each humblest worker in imagination shares. Within the last four hundred years this typical scientific mind has gradually come to be the kind of philosophic mind most admired by the educated class; indeed, it has come to be the only kind of mind, except the poetic, which commands the respect of scholars, whatever their department of learning. In every field of study, in history, philology, philosophy, and theology, as well as in natural history and physics, it is now the scientific spirit, the scientific method, which prevails. The substitution in the esteem of reasonable men of this receptive, fore-reaching mind for the dogmatic, overbearing, closed mind, which assumes that it already possesses all essential truth, and is entitled to the exclusive interpretation of it, is a most beneficent result of the study of natural history and physics. It is an achievement which has had much to do with the modern increase of liberty in human society, liberty individual, political and religious; it is an achievement of the highest promise for the future of the race.

The second result which I wish to specify is the stupendous doctrine of hereditary transmission, which during the past thirty years, or within the lifetime of most of those who hear me, natural science has developed and enforced by observations and comparisons covering the whole field of organized life. This conception is far from being a new one. Our race has long practised, though fitfully and empirically, upon some crude and fragmentary forms of this idea. Tribes, clans, castes, orders of nobility, and reigning families, are familiar illustrations of the sway of this idea; in killing, banishing, and confining criminals mankind has in all ages been defending itself, blindly, to be sure, but effectually, against evils which incidentally flow from hereditary transmission; but it has been reserved for natural science in this generation to demonstrate the universality of this principle, and its controlling influence upon the families, nations, and races of men, as well as upon all lower orders of animate beings. It is fitting that natural history should have given this demonstration to the world; for the basis of systematic natural history is the idea of species, and the idea of species is itself founded upon the sureness of hereditary transmission, upon the ultimate fact that individual characteristics are hereditable. As the knowledge of heredity, recently acquired by science, permeates society, it will profoundly affect social customs, public legislation, and governmental action. It will throw additional safeguards around the domestic relations; enhance the natural interest in vigorous family stocks; guide wisely the charitable action of the community; give a rational basis for penal legislation; and promote both the occasional production of illustrious men and the gradual improvement of the masses of mankind. These moral benefits will surely flow from our generation's study of heredity.

Finally, modern science has discovered and set forth the magnificent idea of the continuity of creation. It has proved that the development of the universe has been a progress from good to better, a progress not without reactions and catastrophes, but still a benign advance toward ever higher forms of life, with ever greater capacities for ever finer enjoyments. It has laid a firm foundation for man's instinctive faith in his own future. From the sight and touch of what the eternal past has wrought, it deduces a sure trust in what the eternal future has in store.

> "And present gratitude
> Insures the future's good;
> And for the things I see
> I trust the things to be."

It has thus exalted the idea of God—the greatest service which can be rendered to humanity. "Each age must worship its own thought of God," and each age may be judged by the worthiness of that thought. In displaying the uniform, continuous action of unrepenting Nature in its march from good to better, science has inevitably directed the attention of men to the most glorious attributes of that Divine intelligence which acts through Nature with the patience of eternity and the fixity of all-foreseeing wisdom. Verily, the infinite, present Creator is worshiped in this place. A hundred lifetimes ago a Hebrew seer gave utterance to one of the grandest thoughts that ever mind of man conceived, but applied it only to his own little nation, and coupled it with barbarous denunciation of that nation's enemies. This thought, tender and consoling toward human weakness and insignificance as a mother's embrace, but sublime also as the starry heights and majestic as the onward sweep of ages, science utters as the sum of all its teachings, as the supreme result of all its searching and its meditation, and applies alike to the whole universe and to its last atom—"the eternal God is thy refuge, and underneath are the everlasting arms."

Address of Professor O. C. Marsh.

The opening of this Museum to-day is an important event in the annals of American science, and one from which great results are sure to follow. We see around us here, already, treasures of Nature from every land, and representing all periods of the earth's history. Not merely a few typical specimens, as in most new museums, but rich series, illustrating the marvelous diversity of Nature, both in the present and in the past. Such treasures, arranged with system, and to the best advantage, as here, arrest the attention of every observer, and invite study. This alone is a grand work accomplished, and yet, we are told, this is but the beginning.

The great museums of the world are in the great cities; and it is fitting that New York, one of the few great centres of culture, should at last take her proper place in science, and found a museum, worthy of herself, for the diffusion of knowledge among her citizens. But there is something higher than the diffusion of knowledge to strive for here, and that is the increase of knowledge. The old idea of a museum was a show-room; the modern idea makes it a workshop as well. If this institution is to hold high rank in science, as we hope, it will not be in consequence of the spacious halls before us, crowded though they be with the rarest of Nature's products; but, rather, it will come through the small work-rooms in the attic, where the naturalist, with microscope or scalpel, has patiently worked out discoveries that add to the sum of human knowledge. This Museum will fail of its highest good, fail even to achieve more than a local influence, unless the work-rooms above are made the most important feature of the whole. These vast collections will spread the elements of natural science among the people of New York, and the surrounding region; but the quiet workers in the attic, who pursue science for its own sake, will bring the Museum renown throughout the world.

There is yet a more important reason for making this institution a centre for original research. The science of to-day stands face to face with great problems. The antiquity of man, the origin of the human race, and even the origin of life itself, are among the questions which the present age submits to science, and to which it demands an answer. If these problems are to be solved by science, America must do her full share of the work, for the materials are here. In all that pertains to ancient life, the Western Continent possesses countless treasures, unknown in other lands. These, as I believe, are to unlock many mysteries in biology, and render important aid toward the solution of the profounder questions I have named. American science can thus repay its debt to the Old World, where science began, and gathering new facts, from broader and richer fields within her own borders, carry forward, with the vigor and enthusiasm of youth, the never-ending search for truth.

If the American Museum of Natural History, opened to-day under such favorable auspices, does not take a prominent part in this great work, it will not do justice to its founders, or to its opportunities. But with such a foundation as we have here, and such resources as wait to unfold their secrets within walls yet to be reared on this commanding site, I venture to predict for natural science in America greater triumphs than have hitherto been won in any land.

SPONTANEOUS GENERATION.

By Prof. JOHN TYNDALL, F. R. S.

I.

WITHIN ten minutes' walk of a little cottage which I have recently built in the Alps, there is a small lake, fed by the melted snows of the upper mountains. During the early weeks of summer no trace of life is to be discerned in this water; but invariably toward the end of July, or the beginning of August, swarms of tailed organisms are seen enjoying the sun's warmth along the shallow margins of the lake, and rushing with audible patter into the deeper water at the approach of danger. The origin of this periodic crowd of living things is by no means obvious. For years I had never noticed in the lake either an adult frog, or the smallest fragment of frog spawn;

so that, were I not otherwise informed, I should have found the conclusion of Mathiole a natural one, namely, that tadpoles are generated in lake-mud by the vivifying action of the sun.

The checks which experience alone can furnish being absent, the spontaneous generation of creatures quite as high as the frog in the scale of being was assumed for ages to be a fact. Here, as elsewhere, the dominant mind of Aristotle stamped its notions on the world at large. For nearly twenty centuries after him men found no difficulty in believing in cases of spontaneous generation which would now be rejected as monstrous by the most fanatical supporter of the doctrine. Shell-fish of all kinds were considered to be without parental origin. Eels were supposed to spring spontaneously from the fat ooze of the Nile. Caterpillars were the spontaneous products of the leaves on which they fed, while winged insects, serpents, rats, and mice, were all thought capable of being generated without sexual intervention.

The most copious source of this life without an ancestry was putrefying flesh, and, lacking the checks imposed by fuller investigation, the conclusion that flesh possesses and exerts this generative power is a natural one. I well remember when a child of ten or twelve seeing a joint of imperfectly salted beef cut into, and coils of maggots laid bare within the mass. Without a moment's hesitation I jumped to the conclusion that these maggots had been spontaneously generated in the meat. I had no knowledge which could qualify or oppose this conclusion, and for the time it was irresistible. The childhood of the individual typifies that of the race, and the belief here enunciated was that of the world for nearly two thousand years.

To the examination of this very point the celebrated Francesco Redi, physician to the Grand-dukes Ferdinand II. and Cosmo III. of Tuscany, and a member of the Academy del Cimento, addressed himself in 1668. He had seen the maggots of putrefying flesh, and reflected on their possible origin. But he was not content with mere reflection, nor with the theoretic guess-work which his predecessors had founded upon their imperfect observations. Watching meat during its passage from freshness to decay, prior to the appearance of maggots he invariably observed flies buzzing round the meat and frequently alighting on it. The maggots, he thought, might be the half-developed progeny of these flies.

The inductive guess precedes experiment, by which, however, it must be finally tested. Redi knew this, and acted accordingly. Placing fresh meat in a jar and covering the mouth with paper, he found that though the meat putrefied in the ordinary way, it never bred maggots, while the same meat placed in open jars soon swarmed with these organisms. For the paper cover he then substituted fine gauze, through which the odor of the meat could rise. Over it the flies buzzed, and on it they laid their eggs, but, the meshes being too small to permit the eggs to fall through, no maggots were generated in the meat. They were, on the contrary, hatched upon the gauze. By a series of such experiments Redi destroyed the belief in the spontaneous generation of maggots in meat, and with it doubtless many related beliefs. The combat was continued by Vallisneri, Schwammerdam, and Réaumur, who succeeded in banishing the notion of spontaneous generation from the scientific minds of their day. Indeed, as regards such complex organisms as those which formed the subject of their researches, the notion was banished forever.

But the discovery and improvement of the microscope, though giving a death-blow to much that had been previously written and believed regarding spontaneous generation, brought also into view a world of life formed of individuals so minute—so close as it seemed to the ultimate particles of matter—as to suggest an easy passage from atoms to organisms. Animal and vegetable infusions exposed to the air were found clouded and crowded with creatures far beyond the reach of unaided vision, but perfectly visible to an eye strengthened by the microscope. With reference to their origin these organisms were called "infusoria." Stagnant pools were found full of them, and the obvious difficulty of assigning a germinal origin to existences so minute furnished the precise condition necessary to give new play to the notion of heterogenesis or spontaneous generation.

The scientific world was soon divided into two hostile camps, the leaders of which alone can here be briefly alluded to. On the one side we have Buffon and Needham, the former postulating his "organic molecules," and the latter assuming the existence of a special "vegetative force" which drew the molecules together so as to form living things. On the other side we have the celebrated Abbé Lazzaro Spallanzani, who in 1877 published results counter to those announced by Needham in 1748, and obtained by methods so precise as to completely overthrow the convictions based upon the labors of his predecessor. Charging his flasks with organic infusions, he sealed their necks with the blow-pipe, subjected them in this condition to the heat of boiling water, and subsequently exposed them to temperatures favorable to the development of life. The infusions continued unchanged for months, and when the flasks were subsequently opened no trace of life was found.

Here I may forestall matters so far as to say that the success of Spallanzani's experiments depended wholly on the locality in which he worked. The air around him must have been free from the more obdurate infusorial germs, for otherwise the process he followed would, as was long afterward proved by Wyman, have infallibly yielded life. But his refutation of the doctrine of spontaneous generation is not the less valid on this account. Nor is it in any way upset by the fact that others in repeating his experiments obtained life when he obtained none. Rather is the refutation strengthened by such differences. Given two experimenters equally skillful and equally careful, operating in different places on the same infusions, in the same way, and assuming the one to obtain life while the other fails to obtain it; then its well-established absence in the one case proves that some ingredient foreign to the infusion must be its cause in the other.

Spallanzani's sealed flasks contained but small quantities of air, and as oxygen was afterward shown to be generally essential to life, it was thought that the absence of life observed by Spallanzani might have been due to the lack of this vitalizing gas. To dissipate this doubt, Schulze in 1836 half-filled a flask with distilled water, to which animal and vegetable matters were added. First boiling his infusion to destroy whatever life it might contain, Schulze sucked daily into his flask air which had passed through a series of bulbs containing concentrated sulphuric acid, where all germs of life suspended in the air were supposed to be destroyed. From May to August this process was continued without any development of infusorial life.

Here, again, the success of Schulze was due to his working in comparatively pure air, but even in such air his experiment is a very risky one. Germs will pass, unwetted and unscathed, through sulphuric acid, unless the most special care is taken to detain them. I have repeatedly failed, by repeating Schulze's experiments, to obtain his results. Others have failed likewise. The air passes in bubbles through the bulbs, and, to render the method secure, the passage of the air must be so slow as to cause the whole of its floating matter, even to the core of each bubble, to touch the surrounding liquid. But, if this precaution be observed, water will be found quite as effectual as sulphuric acid. By the aid of an air pump, in a highly-infective atmosphere, I have thus drawn air for weeks without intermission, first through bulbs containing water, and afterward through vessels containing organic infusions, without any appearance of life. The germs were not killed, but they were effectually intercepted, while the objection that the air had been injured by being brought into contact with strongly corrosive substances was avoided.

The brief paper of Schulze, published in Poggendorf's *Annalen* for 1836, was followed in 1837 by another short and pregnant communication by Schwann. Redi, as we have seen, traced the maggots of putrefying flesh to the eggs of flies. But he did not and he could not know the meaning of putrefaction itself. He had not the instrumental means to inform him that *it* also is a phenomenon attendant on the development of life. This was first proved in the paper now alluded to. Schwann placed flesh in a flask filled to one-third of its capacity with water, sterilized the flask by boiling, and then supplied it for months with calcined air. Throughout this time "there appeared no mould, no infusoria, no putrefaction; the flesh remained unaltered, while the liquid continued as clear as it was immediately after boiling."

Schwann then varied his experimental argument, with no alteration in the result. His final conclusion was, that putrefaction is due to decompositions of organic matter attendant on the multiplication therein of minute organisms. These organisms were derived not from the air, but from something contained in the air, which was destroyed by a sufficiently high temperature. There never was a more determined opponent of the doctrine of spontaneous generation than Schwann, though a strange attempt was made a year and a half ago to enlist him and others equally opposed to it on the side of the doctrine.

The physical character of the agent which produces putrefaction was further revealed by Helmholtz in 1843. By means of a membrane he separated a sterilized putrescible liquid from a putrefying one. The sterilized infusion remained perfectly intact. Hence it was not the liquid of the putrefying mass—for it could freely diffuse through the membrane—but something contained in the liquid, and which was stopped by the membrane, that caused the putrefaction. In 1854 Schroeder and Von Dusch struck into this inquiry, which was subsequently followed up by Schroeder alone. These able experimenters employed plugs of cotton-wool to filter the air supplied to their infusions. Fed with such air, in the great majority of cases the putrescible liquids remained perfectly sweet after boiling. Milk formed a conspicuous exception to the general rule. It putrefied after boiling, though supplied with carefully-filtered air. The researches of Schroeder bring us up to the year 1859.

In that year a book was published which seemed to overturn some of the best-established facts of previous investigators. Its title was "Hétérogénie," and its author was F. A. Pouchet, Director of the Museum of Natural History at Rouen. Ardent, laborious, learned, full not only of scientific but of metaphysical fervor, he threw his whole energy into the inquiry. Never did a subject require the exercise of the cold, critical faculty more than this one—calm study in the unraveling of complex phenomena, care in the preparation of experiments, care in their execution, skillful variation of conditions, and incessant questioning of results, until repetition had placed them beyond doubt or question. To a man of Pouchet's temperament, the subject was full of danger—danger not lessened by the theoretic bias with which he approached it. This is revealed by the opening words of his preface: "Lorsque, par la méditation, il fut évident pour moi que la génération spontanée était encore l'un des moyens qu'emploie la nature pour la reproduction des êtres, je m'appliquai à découvrir par quels procédés on pouvait parvenir à en mettre les phénomènes en évidence." It is needless to say that such a prepossession required a strong curb. Pouchet repeated the experiments of Schulze and Schwann with results diametrically opposed to theirs. He heaped experiment upon experiment, and argument upon argument, spicing with the sarcasm of the advocate the logic of the man of science. In view of the multitudes required to produce the observed results, he ridiculed the assumption of atmospheric germs. This was one of his strongest points. "Si les Proto-organismes que nous voyons pulluler partout et dans tout, avaient leurs germes disséminés dans l'atmosphère, dans la proportion mathématiquement indispensable à cet effet, l'air en serait totalement obscurci, car ils devraient s'y trouver beaucoup plus serrés que les globules d'eau qui forment nos nuages épais. Il n'y a pas là la moindre exagération." Recurring to the subject, he exclaims, "L'air dans lequel nous vivons aurait presque la densité du fer." There is often a virulent contagion in a confident tone, and this hardihood of argumentative assertion was sure to influence minds swayed not by knowledge, but by authority. Had Pouchet known that "the blue ethereal sky" is formed of suspended particles, through which the sun freely shines, he would hardly have ventured upon this line of argument.

Pouchet's pursuit of this inquiry strengthened the conviction with which he began it, and landed him in downright credulity in the end. I do not question his ability as an observer, but the inquiry needed a disciplined experimenter. This latter implies not mere ability to look at things as Nature offers them to our inspection, but to force her to show herself under conditions prescribed by the experimenter himself. Here Pouchet lacked the necessary discipline. Yet the vigor of his onset raised clouds of doubt, which for a time obscured the whole field of inquiry. So difficult indeed did the subject seem, and so incapable of definite solution, that when Pasteur made known his intention to take it up, his friends Biot and Dumas expressed their regret, earnestly exhorting him to set a definite and rigid limit to the time he purposed spending in this apparently unprofitable field.[1]

Schooled by his education as a chemist, and by special researches on the closely related question of fermentation, Pasteur took up this subject under particularly favorable conditions. His work and his culture had given strength and finish to his natural aptitudes. In 1862, accordingly, he published a paper "On the Organized Corpuscles existing in the Atmosphere," which must forever remain classical. By the most ingenious devices he collected the floating particles of the air surrounding his laboratory in the Rue d'Ulm, and subjected them to microscopic examination. Many of them he found to be organized particles. Sowing them in sterilized infusions, he obtained abundant crops of microscopic organisms. By more refined methods he repeated and confirmed the experiments of Schwann, which had been contested by Pouchet, Montegazza, Joly, and Musset. He also confirmed the experiments of Schroeder and Von Dusch. He showed

[1] "Je ne conseillerais à personne," said Dumas to his already famous pupil, "de rester trop longtemps dans ce sujet."—("Annales de Chemie et de Physique," 1862, vol. lxiv., p. 22.) Since that time the illustrious Perpetual Secretary of the Academy of Sciences has had good reason to revise this "counsel."

that the cause which communicated life to his infusions was not uniformly diffused through the air; that there were aërial interspaces which possessed no power to generate life. Standing on the Mer de Glace, near the Montanvert, he snipped off the ends of a number of hermetically-sealed flasks containing organic infusions. One out of twenty of the flasks thus supplied with glacier air showed signs of life afterward, while eight out of twenty of the same infusions, supplied with the air of the plains, became crowded with life. He took his flasks into the caves under the Observatory of Paris, and found the still air in these caves devoid of generative power. These and other experiments, carried out with a severity perfectly obvious to the instructed scientific reader, and accompanied by a logic equally severe, restored the conviction that, even in these lower reaches of the scale of being, life does not appear without the operation of antecedent life.

The main position of Pasteur, though often assailed, has never yet been shaken. It has, on the contrary, been strengthened by practical researches of the most momentous kind. He has applied the knowledge won from his inquiries to the preservation of wine and beer, to the manufacture of vinegar, to the staying of the plague which threatened utter destruction to the silk-husbandry of France, and to the examination of other formidable diseases which assail the higher animals, including man. His relation to the improvements which Prof. Lister has introduced into surgery is shown by a letter quoted in his "Études sur la Bière."[1] Prof. Lister there expressly thanks Pasteur for having given him the only principle which could have conducted the antiseptic system to a successful issue. The strictures regarding Pasteur's defects of reasoning, to which we have been lately accustomed, delivered with a tone of supercilious contempt, where reverent teachableness would have been the fitting state of mind, throw abundant light upon their author, but none upon Pasteur.

Redi, as we have seen, proved the maggots of putrefying flesh to be derived from the eggs of flies; Schwann proved putrefaction itself to be the concomitant of far lower forms of life than those dealt with by Redi. Our knowledge here, as elsewhere in connection with this subject, has been vastly extended by Prof. Cohn, of Breslau. "No putrefaction," he says, "can occur in a nitrogenous substance if its bacteria be destroyed and new ones prevented from entering it. Putrefaction begins as soon as bacteria, even in the smallest numbers, are admitted either accidentally or purposely. It progresses in direct proportion to the multiplication of the bacteria, it is retarded when they exhibit low vitality, and is stopped by all influences which either hinder their development or kill them. All bactericidal media are therefore antiseptic and disinfecting."[2] It was these organisms act-

[1] P. 43.

[2] In his last excellent memoir, Cohn expresses himself thus: "Wer noch heut die Fäulniss von einer spontanen Dissociation der Proteinmolecule, oder von einem unorgani-

ing in wound and abscess which so frequently converted our hospitals into charnel-houses, and it is their destruction by the antiseptic system that now renders justifiable operations which no surgeon would have attempted a few years ago. The gain is immense—to the practising surgeon as well as to the patient practised upon. Contrast the anxiety of never feeling sure whether the most brilliant operation might not be rendered nugatory by the access of a few particles of unseen hospital-dust, with the comfort derived from the knowledge that all power of mischief on the part of such dust has been surely and certainly annihilated. But the action of living contagia extends beyond the domain of the surgeon. The power of reproduction and indefinite self-multiplication which is characteristic of living things, coupled with the undeviating fact of contagia "breeding true," has given strength and consistency to a belief long entertained by penetrating minds that epidemic diseases generally are the concomitants of parasitic life. "There begins to be faintly visible to us a vast and destructive laboratory of Nature wherein the diseases which are most fatal to animal life, and the changes to which dead organic matter is passively liable, appear bound together by what must at least be called a very close analogy of causation."[1] According to this view, which, as I have said, is daily gaining converts, a contagious disease may be defined as a conflict between the person smitten by it and a specific organism which multiplies at his expense, appropriating his air and moisture, disintegrating his tissues, or poisoning him by the decompositions incident to its growth.

During the ten years extending from 1859 to 1869, researches on radiant heat in its relations to the gaseous form of matter occupied my continual attention. When air was experimented on, I had to cleanse it effectually of floating matter, and, while doing so, I was surprised to notice that, at the ordinary rate of transfer, such matter passed freely through alkalies, acids, alcohols, and ethers. The eye being kept sensitive by darkness, a concentrated beam of light was found to be a most searching test for suspended matter both in water and in air—a test indeed indefinitely more searching and severe than that furnished by the most powerful microscope. With the aid of such a beam I examined air filtered by cotton-wool, air long kept free from agitation, so as to allow the floating matter to subside, calcined air, and air filtered by the deeper cells of the human lungs. In all cases the correspondence between my experiments and those of Schroeder, Pasteur, and Lister, in regard to spontaneous generation, was perfect. The air which they found inoperative was proved by

sirten Ferment ableitet, oder gar aus 'Stickstoffsplittern' die Balken zur Stütze seiner Fäulnisstheorie zu zimmern versucht, hat zuerst den Satz 'keine Fäulniss ohne Bacterium Termo' zu widerlegen."

[1] "Report of the Medical Officer of the Privy Council," 1874, p. 5.

the luminous beam to be optically pure and therefore germless. Having worked at the subject both by experiment and reflection, on Friday evening, the 21st of January, 1870, I brought it before the members of the Royal Institution. Two or three months subsequently, for sufficient practical reasons, I ventured to direct public attention to the subject in a letter to the *Times*. Such was my first contact with this important question.

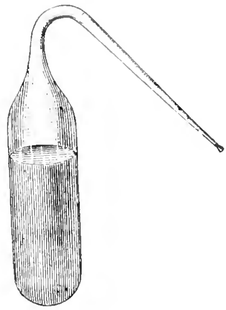
This letter, I believe, gave occasion for the first public utterance of Dr. Bastian in relation to this question. He did me the honor to inform me, as others had informed Pasteur, that the subject "pertains to the biologist and physician." He expressed "amazement" at my reasoning, and warned me that before what I had done could be undone "much irreparable mischief might be occasioned." With far less preliminary experience to guide and warn him, Dr. Bastian was far bolder than Pouchet in his experiments, and far more adventurous in his conclusions. With organic infusions he obtained the results of his celebrated predecessor, but he did far more—the atoms and molecules of inorganic liquids passing under his manipulation into those more "complex chemical compounds" which we dignify by calling them "living organisms." [1] For five years, or thereabouts, Dr. Bastian ploughed the field without impediment from me, and, now that one can overlook the work, I am bound in truth to say that very wonderful ploughing it has been. As regards the public who take an interest in such things, and apparently also as regards a large portion of the medical profession, he certainly succeeded in restoring the subject to a state of uncertainty similar to that which followed the publication of Pouchet's volume in 1859.

It is desirable that this uncertainty should be removed from the public mind, and doubly desirable on practical grounds that it should be removed from the minds of medical men. In the present article, therefore, I propose discussing this question face to face with some eminent and fair-minded member of the medical profession who, as regards spontaneous generation, entertains views adverse to mine. Such a one it would be easy to name; but it is perhaps better to rest in the impersonal. I shall therefore simply call my proposed co-inquirer my friend. With him at my side I shall endeavor, to the best of my ability, so to conduct this discussion that he who runs may read, and that he who reads may understand.

Let us begin at the beginning. I ask my friend to step into the laboratory of the Royal Institution, where I place before him a basin of thin turnip-slices barely covered with distilled water kept at a temperature of 120° Fahr. After digesting the turnip for four or

[1] "It is further held that bacteria or allied organisms are prone to be engendered as correlative products, coming into existence in the several fermentations, just as independently as other less complex chemical compounds."—(Bastian, "Transactions of the Pathological Society," vol. xxvi., p. 258.)

five hours we pour off the liquid, boil it, filter it, and obtain an infusion as clear as filtered drinking-water. We cool the infusion, test its specific gravity, and find it to be 1006 or higher—water being 1000. A number of small, clean, empty flasks, of the shape here shown, are before us. One of them is slightly warmed with a spirit-lamp, and its open end is then dipped into the turnip-infusion. The warmed glass is afterward chilled, the air within the flask cools, contracts, and is followed in its contraction by the infusion. Thus we get a small quantity of liquid into the flask. We now heat this liquid carefully. Steam is produced, which issues from the open neck, carrying the air of the flask along with it. After a few seconds' ebullition, the open neck is again plunged into the infusion. The steam within the flask condenses, the liquid enters to supply its place, and in this way we fill our little flask to about four-fifths of its volume. This description is typical; we may thus fill a thousand flasks with a thousand different infusions.



I now ask my friend to notice a trough made of sheet-copper, with two rows of handy little Bunsen burners underneath it. This trough, or bath, is nearly filled with oil; a piece of thin plank constitutes a kind of lid for the oil-bath. The wood is perforated with circular apertures wide enough to allow our small flask to pass through and plunge itself in the oil, which has been heated, say, to 250° Fahr. Clasped all round by the hot liquid, the infusion in the flask rises to its boiling-point, which is not sensibly over 212° Fahr. Steam issues from the open neck of the flask, and the boiling is continued for five minutes. With a pair of small brass tongs an assistant now seizes the neck near its junction with the flask, and partially lifts the latter out of the oil. The steam does not cease to issue, but its violence is abated. With a second pair of tongs held in one hand, the neck of the flask is seized close to its open end, while with the other hand a Bunsen's flame or an ordinary spirit-flame is brought under the middle of the neck. The glass reddens, whitens, softens, and as it is gently drawn out the neck diminishes in diameter, until the canal is completely blocked up. The tongs with the fragment of severed neck being withdrawn, the flask, with its contents diminished by evaporation, is lifted from the oil-bath perfectly sealed hermetically.

Sixty such flasks filled, boiled, and sealed, in the manner described, and containing strong infusions of beef, mutton, turnip, and cucumber, are carefully packed in saw-dust and transported to the Alps. Thither, to an elevation of about 7,000 feet above the sea, I invite my co-inquirer to accompany me. It is the month of July, and the weather is favorable to putrefaction. We open our box at the Bel-Alp, and count out fifty-four flasks, with their liquids as clear as filtered drinking-water. In six flasks, however, the infusion is found muddy. We closely examine these, and discover that every one of them has had its fragile end broken off in the transit from London. Air has entered the flasks, and the observed muddiness is the result. My colleague knows as well as I do what this means. Examined with a pocket-lens, or even with a microscope of insufficient power, nothing is seen in the muddy liquid; but regarded with a magnifying power of a thousand diameters or so, what an astonishing appearance does it present! Leeuwenhoek estimated the population of a single drop of stagnant water at 500,000,000: probably the population of a drop of our turbid infusion would be this many times multiplied. The field of the microscope is crowded with organisms, some wabbling slowly, others shooting rapidly across the microscopic field. They dart hither and thither like a rain of minute projectiles; they pirouette and spin so quickly round, that the retention of the retinal impression transforms the little living rod into a twirling wheel. And yet the most celebrated naturalists tell us that they are vegetables. From the rod-like shape which they so frequently assume, these organisms are called bacteria—a term, be it here remarked, which covers organisms of very diverse kinds.

Has this multitudinous life been spontaneously generated in these six flasks, or is it the progeny of living germinal matter carried into the flasks by the entering air? If the infusions have a self-generative power, how are the sterility and consequent clearness of the fifty-four uninjured flasks to be accounted for? My colleague may urge—and fairly urge—that the assumption of germinal matter is by no means necessary; that the air itself may be the one thing needed to wake up the dormant infusions. We will examine this point immediately. But I would meanwhile remind my friend that I am working on the exact lines laid down by our most conspicuous heterogenist. He distinctly affirms that the withdrawal of the atmospheric pressure above the infusion favors the production of organisms; and he accounts for their absence in tins of preserved meat, fruit, and vegetables, by the hypothesis that fermentation *has* begun in such tins, that gases *have* been generated, the pressure of which has stifled the incipient life and stopped its further development.[1] This is Dr. Bastian's theory of preserved meats. Its author has never, to my knowledge, pierced a tin of preserved meat, fruit, or vegetable, under water with a view of testing its truth. Had he done so, he would have found it erroneous. In well-preserved tins I have invariably found, not an outrush of gas, but an inrush of water, when the tin was perforated. I have noticed this recently in tins which have lain perfectly good for sixty-three years in the Royal Institution. Modern tins, subjected to

[1] "Beginnings of Life," vol. i., p. 418.

the same test, yielded the same result. From time to time, moreover, during the last two years, I have placed glass tubes, containing clear infusions of turnip, hay, beef, and mutton, in iron bottles, and subjected them to air-pressures varying from ten to twenty-seven atmospheres—pressures, it is needless to say, far more than sufficient to tear a preserved meat-tin to shreds. After ten days these infusions were taken from their bottles rotten with putrefaction and teeming with life. Thus collapses an hypothesis which had no rational foundation, and which could never have seen the light had the slightest attempt been made to verify it.

Our fifty-four vacuous and pellucid flasks also declare against this heterogenist. We expose them to a warm Alpine sun by day, and at night we suspend them in a warm kitchen. Four of them have been accidentally broken; but at the end of a month we find the fifty remaining ones as clear as at the commencement. There is no sign of putrefaction or of life in any of them. We divide these flasks into two groups of twenty-three and twenty-seven respectively (an accident of counting rendered the division uneven). The question now is whether the admission of air can liberate any generative energy in the infusions. Our next experiment will answer this question and something more. We carry the flasks to a hay-loft, and there, with a pair of steel pliers, snip off the sealed ends of the group of twenty-three. Each snipping-off is of course followed by an inrush of air. We now carry our twenty-seven flasks, our pliers, and a spirit-lamp, to a ledge overlooking the Aletsch glacier, about two hundred feet above the hay-loft, from which ledge the mountain falls almost precipitously to the northeast for about a thousand feet. A gentle wind blows toward us from the northeast—that is, across the crests and snow-fields of the Oberland mountains. We are, therefore, bathed by air which must have been for a good while out of practical contact with either animal or vegetable life. I stand carefully to leeward of the flasks, for no dust or particle from my clothes or body must be blown toward them. An assistant ignites the spirit-lamp, into the flame of which I plunge the pliers, thereby destroying all attached germs or organisms. Then I snip off the sealed end of the flask. Prior to every snipping the same process is gone through, no flask being opened without the previous cleansing of the pliers by the flame. In this way we charge our twenty-seven flasks with clean vivifying mountain-air.

We place the fifty flasks, with their necks open, over a kitchen-stove, in a temperature varying from 50° to 90° Fahr., and in three days find twenty-one out of the twenty-three flasks opened on the hay-loft invaded by organisms—two only of the group remaining free from them. After three weeks' exposure to precisely the same conditions, not one of the twenty-seven flasks opened in free air had given way. No germ from the kitchen-air had ascended the narrow necks, the flasks being shaped to produce this result. They are still in the Alps, as clear, I doubt not, and as free from life as they were when sent off from London.[1]

What is my colleague's conclusion from the experiment before us? Twenty-seven putrescible infusions, first *in vacuo*, and afterward supplied with the most invigorating air, have shown no sign of putrefaction or of life. And as to the others, I almost shrink from asking him whether the hay-loft has rendered them spontaneously generative. Is not the inference here imperative that it is not the air of the loft—which is connected through a constantly-open door with the general atmosphere—but something contained in the air, that has produced the effects observed? What is this something? A sunbeam glinting through a chink in the roof or wall, and traversing the air of the loft, would show it to be laden with suspended dust-particles. Indeed, the dust is distinctly visible in the diffused daylight. Can *it* have been the origin of the observed life? If so, are we not bound by all antecedent experience to regard these fruitful particles as the germs of the life observed?

The name of Baron Liebig has been constantly mixed up with these discussions. "We have," it is said, "his authority for assuming that dead decaying matter can produce fermentation." True, but with Liebig fermentation was by no means synonymous with *life*. It will be observed, by the careful reader of Dr. Bastian's works, that whenever their author refers to this alleged power of decaying matter, he invariably couples with it the vague term "fermentation," thus softening the shock of the hypothesis which he insinuates rather than asserts. But our present intention is to brush all vagueness aside. We therefore ask, "Does *the life* of our flasks proceed from dead particles?" If my co-inquirer should reply "Yes," then I would ask him: "What warrant does Nature offer for such an assumption? Where, amid the multitude of vital phenomena in which her operations have been clearly traced, is the slightest countenance given to the notion that the sowing of dead particles can produce a living crop?" With regard to Baron Liebig, had he studied the revelations of the microscope in relation to these questions, a mind so penetrating could never have missed the significance of the facts revealed. He, however, neglected the microscope, and fell into error—but not into error so gross as that in support of which his authority has been invoked. Were he now alive, he would, I doubt not, repudiate the use often made of his name—Liebig's view of fermentation was at least a scientific one, founded on profound conceptions of molecular instability. But this view by no means involves the notion that the planting of dead particles—"Stickstoffsplittern," as Cohn contemptuously calls them—is followed by the sprouting of infusorial life.

[1] An actual experiment made three months ago at the Bel-Alp is here described.

SKETCH OF WALTER BAGEHOT.

WALTER BAGEHOT was born February, 1826, in the west of England, where his father, who survives him, was a leading partner in an old-established bank. A student in the University of London, he took the mathematical scholarship with his Bachelor's degree in 1846, and the gold medal in intellectual and moral philosophy with his Master's degree in 1848. He then studied law at Lincoln's Inn, and was called to the bar; he thoroughly liked but never practised this profession, being induced to abandon it by considerations of his health. Always delicate, the excessive work by which alone the position of a successful barrister can be won and maintained would doubtless have shortened the already too-brief life.

He early developed remarkable talent, but in his youth philosophy, poetry, and theology, had a larger share of his attention than the narrower and more prosaic studies which occupied him later, and upon which his fame will rest. In deciding, as he wisely did, to join his father in business, he was conscious of defects which might hinder his career as a banker and merchant. He was absent-minded about minutiæ, inattentive to trifles—he used to declare that he could never "add up," and habitual inaccuracies marked his mathematical exercises in college. He proved, however, to be very successful in business, and was gratified with this success won in practical pursuits, in spite of the metaphysical and poetic tendency which at one time earned for him the reputation of a dreamer. He somewhere says: "The great pleasure in life is doing what people say you can't do. Why did Mr. Disraeli take the duties of Chancellor of the Exchequer with so much relish? Because people said he was a novelist—an *ad captandum* man—who could not add up. No doubt it pleased his inmost soul to do the work of red-tape people better than those who could do nothing else."

He was always busy with his pen. During the early part of his life he wrote for the *National Review*, the *Inquirer*, and other periodicals, and proved himself to be a brilliant and able critic in various departments—finance, politics, and literature. His first book, called "Estimates of Some Englishmen and Scotchmen," published twenty years ago, and now long out of print, was a very remarkable volume of essays, that for some reason, perhaps the unfortunate title, failed to receive the attention it deserved.

In 1858 Bagehot married the eldest daughter of James Wilson, proprietor of the *Economist*. The marriage was a happy one, and led to the production of his most popular and original books; it brought him into connection with the higher world of politics; and eventually, on the death of his father-in-law, to the ownership and editorial control of the *Economist*, which paper he carried to the position of great power which it now has.

His first political work, a new edition of which was recently reviewed in The Popular Science Monthly, is an analysis and explanation of that elaborate piece of mechanism—or rather, of that complex organism—"The English Constitution." He dispels many illusions and corrects many misconceptions concerning constitutions generally, and demonstrates the impossibility of framing a written document that will fulfill the functions discharged by the unwritten Constitution of England—the inevitable defects and weaknesses of made-to-order instruments being illustrated by examples drawn from the workings of our own much-vaunted ordinances, and the more recent instrument under which France is now governed.

In "Physics and Politics," Mr. Bagehot's first American book, the the growth of societies and states is treated according to the method of the evolution philosophy; it is a book which could only have been written by a man having a thorough knowledge of practical affairs, and a firm hold upon the theories of Spencer and Darwin. It is pronounced "clever" by the critics who do not accept those theories, but it is much more.

"Lombard Street," as its name indicates, deals with that abstruse and wayward subject, the "money-market," and is one of the best sources from which to learn the differences which exist between the realities of the "street" and the hypotheses of economists.

At the time of his death, March 24, 1877, he was engaged upon a book, some of the earlier chapters of which were published in the *Fortnightly Review* (February and May, 1876) under the title of "The Postulates of Political Economy;" they were able and timely, and it is to be hoped that the surmise that other of the chapters were so far forwarded as to warrant publication is correct.

Since his death his articles in the *Economist* upon the silver question have been reprinted, making a thin octavo volume; they lack completeness and finish, but are still the most valuable contribution to the subject, for he was the first to seek out and correctly correlate the causes that led to the decline and fluctuations in the price of silver.

This brief list comprises all that will be remembered as his "works," for, though a busy writer, his labor was mostly given to the leading articles in his paper. It is as a journalist that he will be chiefly missed. Though dealing with abstruse and technical topics, he never failed to make himself understood by men of ordinary cultivation and intelligence. His knowledge was so accurate and his grasp so strong as to command the respect of specialists, and yet his articles had the attention and interest of men whose only concern in or knowledge of the subjects was that obtained from Mr. Bagehot himself. In the abstract science with which he dealt he had the rare combination of a conversancy with the abstractions and a knowledge of the facts. He had the guessing faculty and the solid judgment of the man of business, and the trained reasoning power with which to test his guesses and value his conclusions.

CORRESPONDENCE.

"THE TIDES."

To the Editor of the Popular Science Monthly.

I MAKE the following comments on Prof. Schneider's second article about "The "Tides." All the objections to the statements in the first article remain in full force. The chief points of this second installment are two: 1. The disturbing action of the sun on the moon's motion; 2. The fall of the earth and the moon below their respective tangents, whereby it is sought to be proved that the moon approaches the earth at the time of opposition. If these two statements are shown to be wholly in error, the second article goes the way of the first.

On page 231, December number of this JOURNAL, we find this: "Thus our moon moves faster, and, by a radius drawn to the earth, describes an area greater for the time, and has its orbit less curved, and therefore approaches nearer to the earth in the syzygies than in the quadratures. . . . The moon's distance from the earth in the syzygies is to its distance in the quadratures, in round numbers, as 69 to 70."

This extract, which from its form would seem to be from a single paragraph, is in reality from two widely-separated parts of Newton's works, and is besides inaccurate. The phrase "in round numbers" is neither in the original nor in Motte's translation, but instead of it there is *cæteris paribus*, and it is hardly necessary to say that the phrases are not exactly equivalent. But let these slips pass. I give two other extracts from the "Principia," book iii., prop. xiv., cor. i.: "The fixed stars are immovable, seeing they keep the same positions to the aphelions and the nodes of the planets."

Herein is a double error:

Again, book iii., prop. xxxvii., cor. 3: "The density of the moon is to the density of the earth. . . . as 11 to 9."

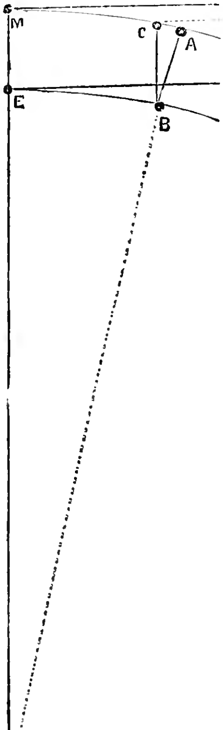
This is very far from the truth, and scores of other mistakes in the "Principia" are known to those who are familiar with that work. So "the best of authority" is sometimes at fault, and his conclusions are not always to be accepted blindly and without investigation. But if they are to be so accepted, as Mr. Schneider's way of parading his authority seems to imply, would it not be better to accept Newton's theory of the tides, which is the true theory, and so make an end of it. But that theory excludes Prof. Schneider's.

If Newton's statement concerning the distance of the earth and moon in the syzygies and quadratures is to be taken without qualification, then it is plainly wrong; and the *mathematical proof* that it is wrong can be found more or less fully developed in any of the following works on astronomy, viz., those of Woodhouse, Herschel, Lardner, Gummere, Loomis, Norton, Olmsted, Robinson, and others.

Further, there is the practical proof of the correctness of the other view in the *calculated* and the *observed* positions of the moon for *every hour of every day in every year*, these positions being carefully noted by a score of observers every day. There is no more possibility of universal error in these observations and calculations than there is that a person who says that two and two are four should be in error on that point.

Prof. Schneider's first statement, then, is all wrong; and, this failing, the second goes with it. But it is also easily shown by his own figures that his conclusion should be exactly the opposite to what he makes it. He says, "The distance the earth falls, in one second of time, toward the sun is about .12144 + of an inch," the moon toward the sun .12084 of an inch, and the moon toward the earth .05386 of an inch. The expression "falling toward the sun" evidently means "falling from the tangent;" any other meaning is false and absurd. With the correctness of these numbers I have nothing to do. Consider them correct; then at the end of a second the earth and moon will be farther apart than they were at the beginning. Here is the proof:

In the accompanying figure let M be the place of the moon at opposition, E, that of the earth, and S the sun; A, the place of the moon at the end of a second; B, that of the earth at the same instant. Then, since the moon at opposition moves in a second about two-thirds of a mile farther than the earth, the curve MA is longer than EB, and A is farther to the right than B, and the moon at A is below the point C by .0538 of an inch: the quantity being ascertained by supposing the earth to stand fast, while the moon moves forward with the difference of their motions. On this there can be no disagreement. The distance CA is about two-thirds of a mile. *But if A is below the tangent .12084 of an inch, and B .12144 of an inch below its tangent, then B is farther from A then when the bodies were at M and E respectively.* When the earth is at B it is at the same distance from the sun as it was at E—i. e., ES and BS are equal, and the earth must fall below the tangent .12144 in order to keep its proper distance. The same is true of the moon: in going from *C* to *A* it falls below the tangent at *C* .0538 of an inch, and then is at the same distance from *B* as it was at *C*—i. e., *B C* and *B A* are equal. Prof. Schnei-



der's way of combining these numbers is unique. It is as if the moon had dropped toward the sun first .12084 of an inch, then .05386, while the earth had dropped toward the sun only .12144 of an inch. But Nature does not proceed in that way. The .05386 is a part of .12084, as the figure plainly shows. The .05386 is the moon's distance at *A* below the dotted line drawn from *C*, and .12084 is the moon's distance at *A* below the tangent drawn from *M*. It is easy to see that the latter includes the former. In the interest of science allow me to protest against such theories and such mathematics.

It is eminently right that we all should be earnest seekers of the truth, and it may not be out of place to suggest that the search should be diligently prosecuted *till the truth is found*, after which there will be ample time for its publication.

R. W. McFarland,
Professor of Mathematics and Civil Engineering, Ohio Agricultural and Mechanical College.

Columbus, Ohio, *November* 24, 1877.

We can give no more space to this controversy.—Ed.

THE QUESTION OF REST FOR WOMAN.

To the Editor of the Popular Science Monthly.

Sir: May I be permitted to point out certain passages in the kind and careful review of my essay on the "Question of Rest," just published in your valuable journal, in which it seems to me that the reviewer has misunderstood the drift of the statements he criticises? Accepting entirely the general criticism on "the defects due to hasty preparation," I am yet loath that this haste should be made to appear to have had a wider influence than is really the case.

On page 242 the reviewer observes that the "author traced this result—painful menstruation—to a want of occupation; while we should explain the lack of occupation by the incapacity resulting from the periodical pain." I believe the essay is guiltless of such an absurdity in physiological reasoning as an attempt to trace pain *directly* to a negative circumstance, which could only have an influence through the medium of various physiological conditions more or less directly associated with it, and hence induced by it. The inference drawn by the reviewer from the statistics is certainly incorrect, for the "unoccupied persons" referred to were so because their fortune rendered paid labor unnecessary, and for this reason it had not been undertaken. The cases where work, once begun, had been forcibly interrupted by an acquired habit of menstrual suffering are contained in the tables of painful cases.

The reviewer, page 242, second column, says that the essay admits "that, in regard to rest, the above data do not suffice to inform us of its influence," and goes on to conclude therefore that, "so far as the main theme of the book is concerned, the author leaves the question of rest in just the condition in which she found it." The statement quoted from the essay loses its real meaning by its abbreviation. It is not asserted that the data from the tables throw *no* light on the "question of rest," but only that from them we can have no means of deciding how far those women who acquired the habit of menstrual pain might have escaped it, had they from the beginning "rested" during menstruation, since in no case was rest found to be taken until it had become unavoidable. But the fact that so large a percentage of women, even in the "upper" classes, are shown never to feel the need of rest at this period; the fact that in so large a proportion of those who suffer the suffering dates from the first menstruation, and hence precedes the habits of occupation sometimes supposed to induce it; the fact that in no case did rest alone succeed in averting pain or in curing its cause, and hence proved anything but the "panacea" the reviewer supposes it to be (page 244)—these facts appear plainly on the tables of the essay, and are certainly of importance in regard to the question at issue.

For the reason already surmised it may be that the reviewer has failed to see that the third section of the essay, which he describes as "containing a review of the various theories of menstruation," is devoted not to summarizing these, but to criticising them; and that an effort is made to replace one of the famous current doctrines of menstruation by another, substantially in agreement with those universally held prior to the writings of Bischoff and Pouchet and Raciborski, but claiming to contain some original details and suggestions for a new line of experiment. This effort is, to the intention of the author, the main subject-matter of the essay. That the reviewer has either overlooked this, or its bearing on the conclusions, or has not deemed it so worthy of notice as lesser details, is shown by his remark that the "experiments" were made "before, after, and during ovulation" (page 243), whereas the essay has ranged itself upon the side of those more modern thinkers whose researches are tending to reject the famous ovulation theory.

The reviewer further criticises the essay for a "strained meaning put upon the word rhythmic," and for confounding "reproduction with the conditions essential to reproduction" (page 243). It is true that a philosophical conception of causation compels us to regard every phenomenon as the result of a chain of sequences, and thus every intermittent phenomenon recurring at regular periods as the result of a rhythmic chain of sequences; and thus, in one sense, there can be no antagonism between "periodical" and "rhythmic." But the essay was compelled to consider not only facts in themselves, but certain popular preoccupations about those facts, and especially in regard to the intermittence of the menstrual hæmorrhage. The aim of the essay has been to show that this phenomenon is only one of a chain succeeding each other as continuously as do those involved in the processes of digestion, a detail of a rhythmic movement accomplished *in* the organism, and not—as much popular belief goes—a periodical accident happening *to* it. Again, it is true that in the essay the term "reproduction" is used as equivalent for the process by which material is accumulated in the parent organism for the function of reproduction. This restriction is justified by examples of the eminent biologists who, studying reproduction in its most general and abstract aspect, consider the whole process as a form of nutrition. (I may mention, as one example out of many, the lectures of Claude Bernard, published in the "Revue des Cours Scientifiques" for 1874.) For all those classes of animals in whom the conjugation of reproductive cells is effected externally to the parent organisms, it is evident that the influence of reproduction upon those organisms terminates with the formation of the reproductive cells and the accumulation of the material required for their nutrition. Hence, philosophically speaking, the most general view of reproduction coincides exclusively with this nutritive process—its type is discoverable in vegetable organisms, and the varying phenomena of animal life involved in the conjugation of reproductive cells may be considered apart. For its special purposes the essay was doubly justified in using the term "reproduction" in the sense thus defined.

It is because the essay was exclusively concerned with menstruation that "the derangements due to matrimony receive no attention," although the reviewer, in the preceding rather singularly-worded sentence, implies that they should.

In the same sentence the reviewer declares that the "motive of the book [is] to demonstrate woman's capacity for continuous work during certain periods." The only "motive" of the book was the desire to inquire *in what way* the relations of the female nutrition to the cost of reproduction might be theoretically expected to modify the capacity for exertion of the female nervo-muscular system. The reviewer is certainly in error in saying that the author "does not inform us whether ill-arrangement of work has reference to time or not;" for many pages of the essay are devoted to showing—at least in the opinion of the author—that the question of time *is* of great importance in regard to the nervo-muscular energies of women, but *not time in regard to the period of the menstrual hæmorrhages.* Morbid conditions, entailed with other diseases of civilization, may compel reference to such time; but the real necessity lies much deeper, and (theoretically) should compel more frequent intermittences in exertion, in order, roughly speaking, to allow of the accumulation in the blood of reproductive material. The essential danger of overwork in women, aside from the dangers common to both sexes, is that, if due provision be not made for "the needs of supplemental nutrition," this will be formed at the expense of the nutrition of the parent organism, which must, therefore, deteriorate. The question of rest has been entirely restated in the essay. And only by overlooking this can the reviewer be led to conclude that the "author is reasoning against her convictions;" because, having admitted that excessive work may become a cause of menstrual pain, it is nevertheless insisted upon that there is nothing in the nature of *menstruation* to imply the necessity for rest; but that the connection between overwork and menstruul suffering is more recondite than has generally been perceived.

The closing sentence of the essay, referring to the large percentage of women shown to be real sufferers at menstruation, observes that, wherever such women are engaged in industrial or other pursuits under an employer, humanity would dictate that as much rest be afforded as practicable during the period of suffering. It is difficult, therefore, to understand where the reviewer finds the recommendation for women to continue to work under the "lash of necessity or duty," if they can help it (page 244). Pain is certainly, as the reviewer says, "the ideal curse of humanity," but the world is much too far from an ideal condition to render avoidance of pain a very practicable matter in the immense majority of cases.

On page 243 the reviewer curiously misinterprets a technical statement made in the essay. It is there asserted that pain depends on an "imperfect power of resistance in the nerve-centres," an assertion which is merely the special application of a general truism in physiology. The torments suffered by dyspeptics offer a familiar illustration of the manner in which a normally painless process may become a constantly-recurring source of irritation. But no one would say, as does the reviewer, in regard to the sentence quoted from the essay, that "this presupposes an inherent tendency to pain in all human beings during this act, its expression depending on the power of repression" (page 243).

Finally, I would beg leave to say that the hope of "closing the discussion and furnishing an authoritative canon to measure the value of the question" was far beyond the ambition of the writer of the essay. The difficulty on the practical side is not "the innate delicacy of the sex in arms against the statistician" (page 241), but the difficulty common to all biological investigations upon organisms subjected to complex conditions. Every one knows that no pure experiment is possible unless all conditions are eliminated except the one whose influence is to be estimated. The difficulties in the way exactly resemble (for instance) those besetting Dr. Bowditch's recent important investigation concerning the influence of damp soils in the etiology of consumption. Although the statistics presented in the essay are, unfortunately, much smaller than is desirable, yet it is fair to add that they are the most extensive published up to this time on the subject, with the exception of those of Brierre de Boismont, and quoted in the essay. Since the addition of his results to those of the essay does not in any way conflict with the conclusions of the latter, I think it may be doubted whether more extensive *general* statistics would throw any further light on the subject. To be of value, further data must offer definite points of comparison in regard to the working and luxurious classes of society, since it is a matter of common observation, not yet submitted to strict analysis, that the liability to menstrual suffering increases in proportion as we recede from the former class (at least when it is composed of peasantry) and approach the latter. The conclusion (provisional to more exact investigation) is certainly that the menstrual disorder is not inherent in the process, or in habits of exertion during the menstrual period, being, on the whole, less in those who work than in those who do not work; but that this suffering is ultimately traceable to modifications of the entire female organism imposed by one or more of the influences of a complex civilization, many of which are confessedly pernicious. It has been the modest aim of the essay to trace out some of these modifications, and indicate in what way they might be counteracted.

MARY PUTNAM-JACOBI.

"OPEN AIR AND HEALTH."

To the Editor of the Popular Science Monthly.

I TRUST you will not think me too intrusive by a comment which I desire to make on the article in the December issue of THE POPULAR SCIENCE MONTHLY, on "Open Air and Health." I do this because I am *very solicitous* that your journal will only inculcate truth, such as we are able to know by the best heads and methods. I am of opinion that the article alluded to has a private end to boost, "a movement-cure institute," perhaps, and I am fortified in this by the false points of the essay. For instance, on page 221 it is said, "The lungs, like all mucous surfaces, secrete mucus," etc. It is needless to say that the lungs proper do not consist of mucous surface. This may, however, be a translator's stumble. But the same cannot be supposed of the following, page 223: "In the city night-air is always wholesomer than day-air, being both purer and stiller." How stillness makes it wholesome I am unable to conceive; indeed, with sewers, cesspools, and the filth of a thousand points, stillness is the most favorable for poisonous concentration, slowly diffused throughout the ambient air by the chemical law of gaseous diffusion. Does any one suppose that, amid sources of contamination, stagnant water would be purer than running? Had Dr. Niemeyer used his nose, or attended to its monitions in his midnight ramblings among the sick, he could never have penned such an erroneous sentence. Only solicitation that your journal shall occupy the highest grounds in all its selections animates this criticism from my pen.

J. R. Black.

Newark, Ohio, *December* 22, 1877.

"THE LAW OF CONTINUITY."

To the Editor of the Popular Science Monthly.

In the interest of scientific accuracy, I would call attention to one or two statements in the article on "The Law of Continuity," in your November number, which are either greatly strained or positively erroneous.

The author of the article in question says, speaking of sulphuric acid and water, "In all possible percentages do these liquids *chemically combine*, and this is at variance with the generally obeyed law of definite proportions" (page 32 — the italics are mine). This is a very loose use of language, as may be easily demonstrated by a comparison of this passage with the statement of the fact by any scientific authority. For example, Fownes ("Manual of Chemistry," eleventh edition, p. 203) says: "The most concentrated sulphuric acid, or *oil of vitriol*, as it is often called, is a definite combination of 40 parts sulphuric oxide and 9 parts water. . . . Oil of vitriol is not the only hydrate of sulphuric oxide; three others are known to exist. When the fuming oil of vitriol of Nordhausen is exposed to a low temperature, a white crystalline substance separates, which is a hydrate containing half as much water as the common liquid acid. Further, a mixture of 98 parts of strong liquid acid and 18 parts of water, $2H_2OSO_3$, or $H_2SO_4H_2O$, congeals and remains solid even at 7.2° C. (45° Fahr.)," etc. There is, then, in the case of sulphuric acid and water, at least, a clear enough distinction between mechanical mixture and chemical combination, although Mr. Iles quite loses sight of it.

Then, again, he says (p. 30), "Science is unable to give us any metal but gold in a translucent state." The inability does not lie with "science." It has long been known that silver may, by chemical means, be obtained in a translucent film. And likewise platinum, aluminum, bismuth, copper, lead, iron, nickel, cobalt, palladium, zinc, cadmium, magnesium, and other metals, have been procured in a layer so thin as to be transparent (Wright, *American Journal of Science and Arts*, No. 73, January, 1877).[1]

Launcelot W. Andrews.

Springfield, Mass., *November* 8, 1877.

EDITOR'S TABLE.

COOK AND HIS "BIOLOGY."

The Rev. Joseph Cook seems to have attained the position of an accepted champion of orthodoxy in its conflict with the science of the time, and as such must have a degree of attention to which he is not otherwise entitled. In the delivery of the lectures which compose his volume on biology, he was listened to, we are told, by large audiences of cultivated and scholarly men, who applauded him enthusiastically; while the book has been highly praised by eminent theologians and numerous newspapers, and has had a brisk and extensive sale. Yet we observe that the tide of encomium is perceptibly falling, and shrewd orthodox people are beginning to see that they cannot too quickly relieve themselves of responsibility in regard to his work. In an able review, in the January *New-Englander*, the scientific charlatanry of Mr. Cook's book is thoroughly exposed; its taste and rhetoric are pronounced "execrable," and the writer closes by saying that "this production is not one for orthodoxy to be proud of, and that it is best to declare this opinion plainly and promptly."

Nevertheless there is a startling significance in the fact that such a work could have received from an intelligent Christian community the measure of commendation that has been accorded

[1] It is but fair to say that the article in question was written and in the hands of the editor six months before Prof. Wright's researches were published.—Ed.

to it. Any infidel book that had gone as far toward extirpating the miraculous from Christianity would have been pitched into the flames as blasphemous by every devout believer. The grand central miracle of Christianity, among all orthodox people held as a belief too sacred to be approached in a rationalistic way, is the supernatural genesis of its divine founder. And yet this reverend biologist of Boston attacks the subject with the microscope, quotes Haeckel to prove that bees multiply without the intervention of the male, claims that this principle "extends to the higher forms of life," and, "in the presence of Almighty God," suggests that Christ may have originated in the same natural way. He even thinks that if this fact of parthenogenesis in natural history had been sufficiently known it would have been potent in saving men from skepticism by relieving their perplexities respecting the parentage of the Saviour, and he cites a conspicuous illustration, as follows: "When a great soul like the tender spirit of our sainted Lincoln, in his early days, with little knowledge, but with great thoughtfulness, was troubled with this difficulty, and almost thrown into infidelity by not knowing that the law that there must be two parents is not universal, I am willing to allude, even in such a presence as this, to the latest science concerning miraculous conception." "The latest science!" Perhaps Mr. Lincoln, after all, with his "little knowledge," was not so ignorant as our biological lecturer, who seems not to know that the Swiss naturalist, Bonnet, had established asexual multiplication, in the case of plant-lice, three-quarters of a century before Lincoln was born.

We must not, however, expect too much, and are glad of any earnest scientific discussion in theological quarters. A book from a clergyman, bearing the title of "Biology," has not only the commendable merit of novelty, but it is an encouraging sign of the times, and a promising precedent for the future. Nor should we be too exacting in regard to the quality of first efforts, as theology is certainly not the best preparation for biology. Yet when a Christian preacher takes up the science, and we allow for the imperfections of treatment to be naturally expected of an inquirer in an unfamiliar region, we are still entitled to demand candor, fairness, and conscientious painstaking honesty of statement. Though we may not get intelligence, we ought, at least, to have common morality. We propose briefly to test Mr. Cook's book by this very moderate standard, and will take his first position as a sample. We shall thus be enabled not only to get a good measure of the claims of his work, but to correct a popular misapprehension of some consequence.

It is generally known that Prof. Huxley, a few years ago, examined a substance brought up from the sea-bottom, and announced it as a newly-discovered form of protoplasm, to which he gave the name of *Bathybius*; and it is currently supposed that he afterward abandoned this view as erroneous. Mr. Cook begins his biology with an account of this matter. Its first sentence is as follows: "In 1868 Prof. Huxley, in an elaborate paper in the *Microscopical Journal*, announced his belief that the gelatinous substance found in the ooze of the beds of the deep seas is a sheet of living matter, extending around the globe." We have carefully read that article, and have found no such statement, and nothing equivalent to it, there. Dr. A. P. Peabody, of Harvard University, reviewing the book we are now considering, says that "Mr. Cook's reasonings are based in no instance on his own statement of physical or scientific truth or fact; but always on the expressly-quoted words of writers of universally admitted authority." This is contradicted by the very first utterance of Mr. Cook, in which

Prof. Huxley's words are neither "expressly quoted" nor quoted at all, and in which the substance is not to be found in the article cited.

The second paragraph of the book opens thus: "To this amazingly strategic and haughtily-trumpeted substance found at the lowest bottoms of the oceans, Huxley gave the scientific name *Bathybius*, from two Greek words meaning *deep* and *sea*, and assumed that it was in the past, and would be in the future, the progenitor of all the life on the planet." It is not true that, in the article cited by Mr. Cook, Prof. Huxley made any such assumption as is alleged, any more than it is true that the word Bathybius has the derivation here assigned to it. This characterization of the announcement of Bathybius is simply a slanderous misrepresentation. That Mr. Cook intended it to apply to Huxley is obvious from the connection, and is proved by the fact that on page 69 he again refers to it as "the haughty claim of Huxley." Nothing could be more false, as we shall presently show, than the impression conveyed by this language.

On the third page we are told that "Dr. Carpenter rejected Huxley's testimony on this matter of fact," but where, or in what form, he has done so is not mentioned. The statement is entirely improbable, as Dr. Carpenter had himself observed the living Bathybius dredged up on the expedition of the Porcupine, samples of which he furnished to Huxley; while so late as 1875 he speaks in his work on the microscope "of these indefinite expansions of protoplasmic substance, which there is much reason to regard as generally spread over the deep-sea bed."

Having introduced Bathybius to the attention of his auditors, in the manner here indicated, Mr. Cook announced to them, with due rhetorical flourish, that it is now nothing but an exploded myth. We shall be better able to judge of the truthfulness, both of his former statements and of this assertion, by briefly glancing at the history of the substance.

The paper of 1868 here referred to is entitled "On some Organisms living at Great Depths in the North Atlantic Ocean." In the first part of this article he referred to a report, which he had himself drawn up, concerning the sticky mud obtained by Captain Dayman in sounding the North Atlantic in 1857; the report of Prof. Huxley being published in 1858. In his observations upon this mud he discovered some curious little microscopic bodies, which at first suggested an organic origin, but which Prof. Huxley concluded were not of this character. The language in the original report is as follows: "I find in almost all these deposits a multitude of very curious rounded bodies, to all appearance consisting of several concentric layers surrounding a minute, clear centre, and looking, at first sight, somewhat like single cells of the plant *protococcus;* as these bodies, however, are rapidly and completely dissolved by dilute acids, they cannot be organic, and I will, for convenience' sake, simply call them coccoliths."

Some observations made by Dr. Wallich and Mr. Sorby led them to think that Prof. Huxley had been mistaken in the conclusion here given, and that the objects which he supposed to be of a mineral nature were really of organic origin. Prof. Huxley was then led to reconsider the subject, of which he made a prolonged study with higher microscopic powers, and the result was that he came to the same conclusion as the observers referred to, that the minute microscopic objects belonged to the lowest forms of the living world. Certain minute albuminous or protoplasmic bodies of the very lowest type had been discovered by Prof. Haeckel, and named moners, and it was Prof. Huxley's opinion that the minute objects he had been studying from the sea-slime belong to this class. We quote the passages from the article in the *Microscopical Journal* of 1868, in which his conclusions are stated: "Such, so far as I have been able to determine them, are the facts of structure to be observed in the gelatinous matter of the Atlantic mud, and in the coccoliths and coccospheres. I have hitherto said nothing about their meaning, as, in an inquiry so difficult and fraught with interest as this, it seems to be in the highest degree important to keep the questions of fact and the questions of interpretation well apart."

Again: "I conceive that the granule-heaps and the transparent gelatinous matter, in which they are imbedded, represent masses of protoplasm. Take away the cysts which characterize the *radiolaria*, and the dead *spherozoum* would very nearly resemble one of the masses of this deep-sea *Urschleim*, which must, I think, be regarded as a new form of those simple animated beings which have recently been so well described by Haeckel, in his 'Monographie der Moneren.' I propose to confer upon this new monera the generic name of *Bathybius*, and to call it after the eminent Professor of Zoölogy in the University of Jena, *B. Haeckelii*."

This modest and cautious statement is the whole of the announcement of Bathybius. It is made by a scientific man in the true spirit of science, and when the Rev. Mr. Cook charges Huxley with "haughtiness" in regard to it, his statement has no value except as an exemplification of the trustworthiness of his book. What the nature of the evidence was for the existence of this protoplasmic substance at the bottom of the sea will appear from the following statements:

Those eminent zoölogists, Sir Wyville Thomson and Dr. William B. Carpenter, while engaged in a deep-sea exploring expedition in the North Atlantic with the war-ship Porcupine, had abundant opportunity to examine the ooze of the ocean-bed, and they write in the *Magazine of Natural History* (1869), "This ooze was actually living; it collected in lumps, as though albumen had been mixed with it; and under the microscope the sticky mass was seen to be living sarcode." The protoplasmic character of this simplest-formed material of low animal life was still further attested by Sir Wyville Thomson in his "Depths of the Sea" (page 410, second edition, 1874): "If a little of the mud, in which this viscid condition is most marked, be placed in a drop of sea-water under the microscope, we can usually see, after a time, an irregular network of matter resembling white of egg, distinguishable by its maintaining its outline and not mixing with the water. This network may be seen gradually altering in form, and entangled granules and foreign bodies change their relative positions. The gelatinous matter is, therefore, capable of a certain amount of movement, and *there can be no doubt* that it manifests the phenomena of a very simple form of life."

Dr. Emil Bessels, who accompanied the expedition of the Polaris, writes to a German journal of natural history: "I found in Smith Sound, at the depth of ninety-two fathoms, great masses of free, undifferentiated homogeneous protoplasm," which he names Protobathybius. He adds: "I would simply say, in this place, that these masses consisted of pure protoplasm, in which calcareous particles occurred only by accident. They appeared to be very sticky, mesh-like structures, with perfect amœboid movements; they took up particles of carmine and other foreign substances, and there was active motion of the nuclei."

And now, to nullify the effect of such direct, positive, and concurrent observations made and verified, again and again, by experienced men, what have we? Only this: the ship Challenger started around the world to dredge the sea-bottom, and its observers sought Bathybius and did not find it. But this negative evidence is worth nothing, except to correct the error of those who supposed Bathybius to be universally distributed over the sea-bottom. It does not touch the question of its existence. Sir Wyville Thomson, in charge of the Challenger expedition, wrote to Huxley that they had not only failed to discover Bathybius, but that it was seriously suspected that the thing to which the name had been given is little more than sulphate of lime, precipitated in a flocculent state from sea-water by spirits of wine. Prof. Huxley immediately communicated this report of Sir Wyville Thomson to *Nature*,[1] and he adds: "Prof. Thomson speaks very guardedly, and does not consider the fate of Bathybius to be as yet absolutely decided. But, since I am mainly responsible for the mistake, if it be one, of introducing this singular substance into the list of living things, I think I shall err on the right side in attaching even greater weight than he does to the view which he suggests."

Let it be remembered that the sole question here is as to the interpretation to be given to observations on sea-slime. But such observations had been made elsewhere over and over again, in many places, and by numerous microscopists. The flocculent gypsum precipitate in sea-water had been, moreover, known to everybody who had preserved marine animals in alcohol. It was, of course, a proper question to raise, how far such an effect might not be mistaken for reactions of protoplasm; but to suppose that anything was here finally decided is simply preposterous—much more so, that all previous observations on sea-bottom protoplasm were proved worthless. The "suspicion" was quite legitimate, but it was only a suspicion, and was offered as nothing more. Huxley expressed himself simply in the terms of courtesy that were suitable to the occasion. Sir Wyville Thomson spoke cautiously; and Huxley accorded to his statement all possible weight. If he had been disposed to contest the matter, this would not have been the appropriate time, as his object was nothing more than to communicate to the public what had been sent to him for that purpose. Mr. Cook makes a great ado about Huxley's "recantation," but, so far from recanting, he does not even admit that he had been mistaken. He gave Sir Wyville Thomson the fullest benefit of his doubt, and there left the matter for further investigation. The Rev. Mr. Cook, however, returns to the subject in his third lecture, and edifies his intelligent Boston audience by closing with the following whoop: "That Bathybius has been discovered in 1875 by the ship Challenger, to be—hear O heavens! and give ear, O earth!—sulphate of lime. (Applause.)"

We may here note the contrast between the theological biology which so evoked the plaudits of Boston orthodoxy and biology of the common scientific kind. It was evidently a part of Mr. Cook's polemical tactics to open his course of lectures by a sensational dash that should make a breach in the scientific ranks which it was the object of the "Monday lectureship" to rout, and for this purpose nothing could be more telling than to discredit Prof. Huxley at the outset. So much had been said, and so little was really known, about "Huxley's Bathybius," that this seemed to offer the most vulnerable point of attack. But had Mr. Cook not been talking to people who know nothing about the difficulties of arriving at the truths of Nature—nothing of the inexorable disciplines of science—and who pride themselves on never giving up a dogma once professed; had he not, in short, been catering to the "closed, dogmatic" mind of a locality proverbial for pride of opinion, his effort would hardly have been greeted with the reported applause. Had Prof. Huxley been in error, would it not

[1] *See* Popular Science Monthly, October, 1877, p. 648.

have been to his credit to retract it? How else have the truths of science and the laws of Nature been established, except by righting wrong conclusions, committing mistakes and then correcting them, and escaping from erroneous opinions by showing them to be false? This is the essential method, and the constant work of science, and it is exactly here that it becomes the antagonist of that method which tacitly or openly affirms infallibility of belief, and holds it to be a reproach and a disgrace to acknowledge that one has ever been mistaken. If there had been no revolt against this spirit, we should never have had any such thing as science.

We dismiss this much-lauded book with one more illustration of its quality. Having got through the sixth lecture, still devoted to his main thesis—the deduction of immortality from protoplasm—Mr. Cook pointed the moral of the occasion in the following characteristic way. He said: "Here is the last white and mottled bird that flew to us out of the tall *Tribune* tower; and softly folded under its wing are these words concerning Darwin, from Thomas Carlyle, at his own fireside in London." He then read the sensational story that has for some time past been going the rounds of the newspapers about Carlyle's declaring the Darwins to be "atheists all," with some stupid rant about the gospel of dirt, and men coming from monkeys and frog-spawn, and winding up with his standing on the brink of eternity and reviving the lessons of his catechism. Mr. Cook then calls impressively upon "Boston, and the New England colleges, and all tender and thoughtful souls, to listen to Thomas Carlyle as he stands on the brink of eternity."

Now, we never doubted that this representation, so greedily caught by press and pulpit, was essentially a lie. Not that Mr. Carlyle may not have included Darwinism among the multitudinous modern things that he has been wont to rave about, but this circumstantial statement had all the internal evidence of fabrication and falsehood. Mr. Cook says it was an "extract from a letter from Carlyle, published in Scotland, and quoted in the London *Times*." Yet long before Mr. Cook published his book the story was contradicted in that journal "on the best authority." The "Monday lectureship" was, however, "abreast of the times" only for the purpose of *circulating* the scandal. The following note, printed in the London *Times* of January 20, 1877, neither appears in the "Biology," nor, so far as we have observed, has appeared in the American newspapers which gave such swift passport to the first statement:

MR. CARLYLE ON DARWINISM.

"L." writes: "Allow me to state on the best authority that the letter about Darwin and his doctrines, which was quoted in the *Times* on the 17th inst. from the *Ardrossan and Saltcoats Herald*, was not written by him."

This should have been quite sufficient to stop the story, but some people are incredulous when dirty gossip is to be checked, and demand responsible names. It may, therefore, be proper to say that we happen to have been informed by Herbert Spencer that the note to the *Times* was communicated by Mrs. Lecky, the wife of the historian, and that she stated to Mr. Spencer before its publication that, while Mr. Carlyle, in pursuance of his practice of never noticing misstatements, would not contradict it himself, he had authorized her to make the contradiction. It thus appears that a party in England forges a libelous letter, in the interest of orthodoxy, which is made to do duty in New England in the same interest, while the solemn adjuration to listen to the libelous forgery is responded to with the usual "applause."

It is the frequent custom of clergymen to characterize much of the work of modern scientific thinkers as "pseudoscience," "sham science," and "science falsely so called;" but truly does the Rev. Joseph Cook's "Biology" answer to their ideal of a genuine thing? And must we not conclude, from the way they praise it, that our orthodox friends are rather hard pressed for championship?

OPENING OF THE MUSEUM.

It is not often that we get so much momentous thought in so narrow a compass as was furnished by Professors Eliot and Marsh, in their addresses at the recent opening of the American Museum of Natural History in this city. President Eliot, of Harvard, summed up in a few weighty words the grandest characteristic of modern science, and pointed out two of its most profound and far-reaching results. The completion of a new Museum of Natural History seemed the fitting occasion to recognize that science has given a kind of new birth to the human mind—a new method and spirit of thought in essential contrast with the old dogmatic dispensation. This grand result, not yet very widely recognized, and where recognized not yet very courageously avowed, nevertheless many times outweighs in import all the material conquests of scientific research. The doctrine of heredity, in its comprehensive application to man and social institutions, and the doctrine of continuity in Nature, and the slow unfolding of higher and better conditions, are credited with an exalted place among the later achievements of the scientific mind. We cannot forbear expressing our gratification at so unqualified an indorsement from such a distinguished source, and on such a conspicuous occasion, of ideas which The Popular Science Monthly has earnestly sought to diffuse ever since it was started.

Prof. Marsh made a telling appeal for the encouragement of original scientific work. He called attention to the danger that such museums are liable to degenerate into mere shows, and pointed out that their higher service is to facilitate, encourage, and keep alive, that spirit of investigation by which alone knowledge is developed and perfected. His suggestions were pertinent and timely, and it is to be hoped they will be heeded, and that due provision will be made for students who wish to engage in the promotion of original work.

LITERARY NOTICES.

Elements of Geology: A Text-Book for Colleges and for the General Reader. By Joseph Le Conte, Professor of Geology in the University of California. 903 Illustrations. New York: D. Appleton & Co. Pp. 588. Price, $4.

Sir John Herschel has somewhere remarked that, in the vastness and sublimity of its leading ideas, geology is the rival of astronomy; for, as the latter has to deal with immeasurable space, the former opens the conception of immeasurable time. There is a splendor about the science of celestial phenomena that is, of course, unrivaled; but there is a deep fascination about the history of the development of our planet that comes from the immensity of the periods involved, the stupendous scale of the changes that have taken place, and the practical results derived from our knowledge of the constitution of the earth's crust.

These noble elements of the science must ever give geology a powerful claim upon the attention of cultivated people, and they have gained for it, and will secure to it, a leading place in all our higher courses of study. But scientific education is yet in its infancy, and its incorporation with the traditional culture has thus far been very much a matter of accident, caprice, or indifference. Geology has perhaps suffered more than any other science from the unsettled state of the relations between scientific and literary culture. Not that the subject has been neglected, but it has been treated without judicious and adequate preparation. We have had admirable elaborate works for the information of professional geologists and the training of students who design to become geologists; and we have had excellent rudimentary books for introducing beginners to the subject and for use in ordinary schools. But a good college text-book of geology has hitherto been wanting. There has been no American work for high-class institutions which treats the subject so as to meet the requirements of intelligent and scholarly people, who yet do not expect to become independent cultivators of geological science. This manifest gap has now been filled by the publication of the work before us, and a careful examination of the volume convinces us that it has been executed with great judgment with reference to the present needs of higher education. In his preface Prof. Le Conte thus states the purpose he had in view in writing the work: "I have attempted to realize what I conceive to be comprised in the word *elements* as contradistinguished from *manual*. I have attempted to give a really scientific presentation of all the departments of the wide field of geology, at the same time avoiding too great multiplication of detail. I have desired to make a work which shall be both interesting and profitable to the intelligent general reader, and at the same time a suitable text-book for the higher classes of our colleges. In the selection of material and mode of presentation, I have been guided by long experience as to what it is possible to make interesting to a class of young men, somewhat advanced in general culture and eager for knowledge, but not expecting to become special geologists. In a word, I have tried to give such knowledge as every thoroughly cultured man ought to have, and at the same time is a suitable foundation for the further prosecution of the subject to those who so desire. The work is the substance of a course of lectures to a senior class, organized, compacted, and disencumbered of too much detail by representation for many successive years, and now for the first time reduced to writing."

But, besides preparing a comprehensive text-book, suited to present demands, which was the author's main design, he has also given us a volume of great value as an exposition of the subject, thoroughly up to date. It is well known that geology is one of the most rapidly progressive of the sciences, but in recent years its advances have been very remarkable. Not only are its facts multiplying at an unprecedented rate, through the labors of the increasing multitude of geological observers in all lands, but its progress is to a still greater degree signalized by the light thrown upon it by various other sciences, and by the working out of fundamental principles by which its multitudinous details are organized into more perfect method. The law of evolution is now the key to geology. A vague principle of progress has long been obscurely recognized in geological phenomena, but that principle has now been brought out, amplified, formulated, and established, as the all-interpreting law that has governed the unfolding of the globe. Much remains to be done, no doubt, in the elucidation of this grand principle, but its imperfection now becomes a measure of the imperfection of geology itself, and no presentation of that science is any longer possible which does not give prominence to the doctrine of evolution. Prof. Le Conte not only accepts it, but puts it to its proper scientific use, as his volume bears abundant witness, and as he explains in the following words from the preface: "In the historical part, I have found much more difficulty in being scientific without being tiresome, and in being interesting without being superficial and wordy. I have attempted to accomplish this difficult task by making *evolution* the central idea about which many of the facts are grouped. I have tried to keep this idea in view, as a thread running through the whole history, sometimes very slender—sometimes, indeed, invisible; but reappearing from time to time to give consistency and meaning to the history."

The examples and applications of Prof. Le Conte's work are almost entirely derived from this country, so that the treatise may be properly considered an American geology. This involves no narrowness or incompleteness; for, although science is as wide as Nature, yet the illustrations of geology are necessarily local, and an important point is gained when those are selected which will be most naturally observed by the great mass of students for whom the volume was designed. The region of the Rocky Mountains and the Western portions of the continent, as is well known, have recently yielded the most striking and important contributions to the subject, both in dynamical and structural geology, and in the department of ancient life. Prof. Le Conte's residence in California, for the last few years, has been favorable to the cultivation of this field, of which he has fully availed himself by excursions of observations, and vacation-rambles with parties of students and graduates, through regions especially rich in geological interest. His book contains the results of these personal inquiries, and those of other observers, including the revelations of remarkable fossils by Prof. Marsh and the naturalists who have devoted themselves to paleontological exploration.

The volume is written with great clearness and with admirable judgment in respect to the proportions of space allotted to its multifarious topics. A prime object with the author has been to interest his readers, and for this purpose he has given prominence to principles and subordinated details, so that his work will prove attractive to the general reader as well as to the class-room student. It is profusely and elegantly illustrated, in a style of which the reader will be enabled to judge by referring to the article on "Geysers," in the present number of the Monthly, which is borrowed from the volume. This treatise is by an eminent working geologist, one who knows the subject thoroughly in its latest aspects, and we can commend it without qualification to all who desire an intelligent acquaintance with the science, as fresh, lucid, full, authentic, the result of enthusiastic study and of long experience in the art of teaching mature classes.

Deterioration and Race Education, with Practical Application to the Condition of the People and Industry. By Samuel Royce. New York: Printed by Edward O. Jenkins, 20 North William Street. Pp. 504. Price, $4.50.

In this book education is considered from a broad, humanitarian point of view, and in connection with the great causes of decay and deterioration that are operating in society. The wealth of facts and materials of all kinds that the author has brought together seems to have proved somewhat embarrassing to him, as he has hardly succeeded in bringing them into close logical method. But he has collected a great deal of interesting material, interspersed with valuable observations and reflections, and the volume is pervaded by a reformatory and progressive spirit. Mr. Royce's chapter on "Classical and Scientific Education" contains much good sense, and his opinions are very decided, as the following passage illustrates: "Emerson says that he has not met in all his travels in America with half a dozen men who could read Plato profitably. This whole Greek and Latin scholarship is an imposture, the writing of miserable verses in these languages included. There is not one teacher in ten who has sufficient knowledge of these languages to derive from them a higher culture. The learned apparatus requisite for their thorough understanding requires the study of a lifetime. Must hundreds of thousands of students in the land throw away their years and opportunities for the sake of a few hundred Latin and Greek roots, which can be learned by any English student with the help of an etymological hand-book in a few weeks, if not days?"

Notes on Leather. By Lieutenant D. A. Lyle.

These "Notes," published by order of the Secretary of War for the use of the Ordnance Department of the U. S. Army, contain a large amount of useful and practical information concerning hides and the manufacture of leather. Sundry fraudulent practices used in tanning are pointed out, and their effects on the leather described. The author does not undertake to give judgment on the comparative merits of oak-tanned and hemlock-tanned leather; it would require an exhaustive series of experiments to decide this question ultimately.

Transactions of the Kansas Academy of Sciences. Topeka: Kansas Publishing-House. Vol. V. Pp. 75.

Among the papers published in this volume are several natural history catalogues relating to the botany and entomology of Kansas, a meteorological summary for 1876, essays on evidences of ancient forests in Kansas, on river-bluffs, the habits of prairie-dogs, the influence of food-selection upon animal life, etc.

The A, B, C, of Finance. By Simon Newcomb, LL. D. New York: Harper & Brothers. Pp. 115. Price, 25 cents.

Prof. Newcomb is an astronomer, and of course mostly interested in the stars, but he finds time to give a portion of his attention to the affairs of his country, and he, moreover, makes a contribution where it is most needed. It is in the field of finance that the nation now needs the greatest help, and we agree with Prof. Newcomb that the popular instruction at present most urgently demanded is in the A, B, C, of financial science. In the miniature form of "Harper's Half-Hour Series" the author has brought out a succession of chapters on "Labor," "Capital," "Wages," "Value," the "Different Kinds of Money," "Public Faith," and the "Lessons of History," which are written in a clear, simple, instructive, and most convincing manner. Such nimble little pocket-books, pointedly summing up these large subjects, are wanted by the people, and are capable of doing more efficient service than larger books.

Robinson Crusoe's Money: or, The Remarkable Financial Fortunes and Misfortunes of a Remote Island Community. By David A. Wells. New York: Harper & Brothers. Pp. 118. Price, 50 cents.

In this small volume Mr. Wells inculcates the lessons of political economy through a sort of allegorical artifice, in which commercial and financial truths and absurdities are brought out in a dramatic way that is both amusing and instructive. Many who would not like a dry, didactic treatise on economics would be pleasantly beguiled by Mr. Wells's imaginary narration, while the characteristic illustrations, by Nast, will serve to help on both the fun and the logic of the text.

A New Treatise on Steam-Engineering, Physical Properties of Permanent Gases, and of Different Kinds of Vapor. By John W. Nystrom, C. E. New York: G. P. Putnam's Sons. Pp. 188. Price, $1.50.

This book consists of numerous tables, data, and information, which appear to the author to be wanting in the profession, and which have not heretofore been published. Among the topics are horse-power of steam-boilers, chimneys, combustion, properties of fuel, smoke-burning, water-gauges, safety-valves, radiation, steam-boiler explosion, strength of steam-boilers, compression and expansion of air, properties of water and steam, and various other subjects of interest to engineers. The author rejects no less than thirty-eight terms or phrases that have grown up, and come into modern use in mechanical science.

Public Health Reports and Papers. Vol. III. Presented at the Meetings of the American Public Health Association in the Years 1875–1876. New York: Hurd & Houghton. Pp. 241. Price, $4.

Among the most important volumes issued from our press are the reports of the American Public Health Association. They comprise papers on a variety of important topics, connected with the health of the community, by our most eminent sanitarians; and they will be generally found valuable as summing up, and stating in a clear and readable form, the results of long study and well-directed investigation. Among so excellent an array of articles as the present volume furnishes, it seems invidious to discriminate, and in especially commending the papers of Dr. Austin Flint, on "Food in its Relations to Personal and Public Health;" of Prof. Washburn, on "Expert Testimony and the Public Service of Experts;" and of Mr. Charlton Lewis, on "The Influence of Civilization on the Duration of Life," we do not for a moment imply that the other discussions of the volume, all of them on important subjects, are not of equal interest and ability. This series of reports should be found in the libraries of all who take interest in the vital subject of personal and public hygiene.

From Prof. C. V. Riley we have received a reprint of five papers contributed by him to the "Transactions" of the St. Louis Academy of Sciences; their titles are as follows: "Larval Characters and Habits of the Blister Beetles belonging to the Genera *Macrobasis* and *Epicauta*;" "On a Remarkable New Genus in *Meloidæ*;" "Notes on *Megathymus yuccæ*;" "Remarks on *Pronuba yuccasella*;" "Differences between *Anisopteryx pometaria* (Harr.) and *Anisopteryx æscularia* (W.-V.)."

Annual Report of the Board of Regents of the Smithsonian Institution for the Year 1876. Government Printing-Office, Washington. Pp. 488.

In addition to the report of the secretary, on the operations, expenditures, and conditions of the Institution, this volume contains the following elaborate and important papers. "Eulogy on Gay-Lussac," by M. Arago; "Biographical Sketch of Dom Pedro II., Emperor of Brazil," by Anpriso Fialho; "Kinetic Theories of Gravitation," by Wm. B. Taylor; "The Revolutions of the Crust of the Earth," by Prof. George Pilar; "Ethnology," by Otis T. Mason.

The Religious Feeling, a Study for Faith. By Newman Smyth. New York: Scribner, Armstrong & Co. Pp. 171. Price, $1.25.

This is an earnest, and intended to be a philosophic and liberal, discussion of the modern problems of religious thought in relation to science, positivism, and Darwinian and Spencerian doctrines. It is too brief to have finished up the inquiry; but its issue is thus stated by the author: "The problem of problems, upon which the thought of our time labors, may be reduced in the last analysis to the simple alternative: is man, through whatever intermediate forms he may have descended, the son of God, or is he the unintended product of molecular forces?" It is hardly necessary to say that the writer accepts the former alternative, and vigorously belabors the school of thinkers which he charges with holding the latter opinion.

Sanitary Condition of City and Country Houses. By G. E. Waring, Jr. Pp. 145. Magnetism of Iron Vessels. By F. Rogers. New York: Van Nostrand. Pp. 126. Price, 50 cents each.

The first of these little volumes contains two papers read by Mr. Waring at meetings of the American Health Association, together with the rather voluminous correspondence occasioned by their publication in the *American Architect*. In this correspondence some of the author's facts and conclusions are criticised by other sanitarians. Mr. Waring's replies to these strictures form a very valuable appendix to the original papers. Of the other volume named above, we need only say that it was originally prepared for a manual designed to be published by the Navy Department. The publication of the manual having been abandoned, the treatise was incorporated into Van Nostrand's "Science Series."

How to use the Microscope. By John Phin. New York: Industrial Publication Co. Pp. 181. Price, 75 cents.

Two years ago we noticed the first edition of this little manual for beginners with the microscope, and now we have to record the appearance of a second edition, fully illustrated and greatly enlarged. Its essential character as an *elementary* treatise is, however, still rigidly preserved.

Anales del Museo Nacional de México. México: Imprenta de C. Ramiro. Vol. I., Part I. Pp. 46. With Plate.

This initial number of the "Anales" is devoted mainly to Mexican archæology. The principal paper is a description, by Don Manual Orozco y Berra, of a curious cylindrical monument of stone, the Cuauhxicalli of Tizoc, supposed to be a sacrificial stone employed in human sacrifices. This monument is elaborately engraved with human figures. The second paper is by Dr. G. Mendoza, and describes an Aztec idol of Chinese type, found in a tumulus in the State of Puebla. The third and last paper is a general introduction to the "Paleontology of Mexico," by Mariano Bárcena.

PUBLICATIONS RECEIVED.

Why we Trade and How we Trade, pp. 67; The Silver Question, pp. 47, both by D. A. Wells; The Tariff Question by H. White, pp. 30. New York: Putnam's Sons. 26 cents each.

Rotation of the Earth. By W. L. Walker. New York: S. W. Green. Pp. 64.

The Kabbala, or True Science of Light. By Dr. S. Pancoast. Philadelphia: J. M. Stoddart & Co. Pp. 312. $2.

Transcendentalism. By J. Cook. Boston: J. R. Osgood & Co. Pp. 305. $1.50.

Manual of Heating and Ventilation. By F. Schumann, C. E. New York: Van Nostrand. Pp. 89. $1.50.

Daily Bulletin of the Signal Service, United States Army, for September, 1874.

What was He? or, Jesus in the Light of the Nineteenth Century. By W. Denton. Wellesley, Mass.: The author. Pp. 259. Paper, $1; cloth, $1.25.

The Spiritual Aspect Nature presents. By J. Wilmshurst. Boston: Colby & Rich. Pp. 151. 35 cents.

The Silver Country of the Southwest. By A.

D. Anderson. New York: Putnam's Sons. Pp. 221. $1.75.

Mechanics of Ventilation. By G. W. Rafter, C. E. New York: Van Nostrand. Pp. 96. 50 cents.

Golden Songs of Great Poets. New York: Sarah H. Leggett. Profusely illustrated. $5.

The Action of Medicines. By Dr. I. Ott. Philadelphia: Lindsay & Blakiston. Pp. 168. $2.

Notes from Chemical Laboratory of Johns Hopkins University. Nos. 4-8.

Mansill's Almanac of Planetary Meteorology. 1878. Rock Island, Ill.: R. Crampton. Pp. 60. 50 cents.

Ueber die als echt nachweisbaren Assonanzen der Chanson de Roland. Von A. Rambeau. Pp. 38.

Are the Indians dying out? Washington: Government Printing-Office. Pp. 42.

Mound-making Ants of the Alleghenies. By Rev. H. C. McCook. Philadelphia: Sold by J. A. Black. With Plates. Pp. 43. 75 cents.

Relation of Moisture in Air to Health. By R. Briggs. Philadelphia: W. P. Kildare print. Pp. 33.

Papers read before the Pi Eta Scientific Society. Troy: The Society. Pp. 40.

The Preliminary Arctic Expedition. Washington: Beresford print. Pp. 32.

Report of the Asylum at Walnut Hill, Hartford, Conn. Pp. 20.

The Heavenly Bodies; How they move. By D. McDonald. Montreal: *Gazette* print. Pp. 45.

Immortality. By W. Bross. Chicago: Jansen, McClurg & Co. Pp. 8.

Direct Process of making Iron and Steel. By C. M. Du Puy, C. E. Philadelphia: W. P. Kildare print. Pp. 12.

Medical Jurisprudence of Insanity. By Dr. H. Howard. Montreal: *Gazette* print. Pp. 13.

Every Saturday (weekly). Buffalo: D. Welch. Pp. 12.

A Decimal Gauge for Sheet-Metal and Wire. By R. Briggs, C. E. Philadelphia: W. P. Kildare print. Pp. 13.

POPULAR MISCELLANY.

Meyer's Electrical Apparatus for Beginners.—We some time ago noticed the admirable little work on electricity by Prof. Tyndall, which grew out of a course of holiday lectures to a juvenile audience at the Royal Institution. This book, "Lessons in Electricity," is designed as a guide for beginners to go through a course of electrical experimenting. The main purpose that he had in view, in preparing this little volume, is thus stated: "I had heard doubts expressed as to the value of science-teaching in schools, and I had heard objections urged on the score of expensiveness of apparatus. Both doubts and objections would, I considered, be most practically met by showing what could be done in the way of discipline and instruction by experimental lessons, involving the use of apparatus so simple and inexpensive as to be within everybody's reach."

Of course there can be no experimenting without the necessary instruments, and, if the work is to be pursued so as to yield its proper benefits, the apparatus must be sufficient to cover a definite field of study. Prof. Tyndall has marked this out in his little volume, and given figures of the various articles that will be required. An ingenious pupil can do something—after a time he can do much—in the way of widening his resources for making experiments, but he will at first require that the tools be ready at hand. A philosophical-instrument maker of New York, Mr. Curt W. Meyer, having been applied to for various articles suitable for rudimentary experiments in electricity, conceived the idea of meeting this demand by preparing the complete set of instruments needed for the illustration of Prof. Tyndall's book. These he has manufactured and put up in cases for transportation, so that those who wish to enter upon such a course of experiments will be spared all trouble in selecting or making the instruments necessary for the purpose. The price is such that many boys will probably be unable to procure it, but there are not many schools that by a little effort could not get the apparatus for the use of their pupils. Electricity is admirably adapted on many accounts for introducing the young to the scientific study of natural objects and agents, and in furnishing them with the facilities and equipments for the work Mr. Meyer has done them a very useful service.

Discovery of Mont Blanc.—Mont Blanc, the highest of the Alps, is, strange to say, a modern discovery. At least, no mention is made of this colossus of European peaks in any itinerary, or in any literary work whatever, till recent times. M. Charles Durier, in his work "Le Mont Blanc," says: "This mountain rises in the centre of the most populous and civilized states of Europe; it is, in fact, the axis around which European civilization has revolved and still does revolve; its height is considerable; it dominates everything in its vicinity, and, to make its appearance more striking on the background of the blue sky, its summit, though placed in a favored, temperate latitude, is ever covered with a mantle of snow. And yet during twenty centuries no historian, no traveler, no *savant*, no poet, names it, or so much as alludes to it. As the sun describes his daily track, that peak throws its shadow upon at least three countries possessing different languages, but still it was profoundly ignored." The same author informs us of a map of the region round about Mont Blanc, published in the second half of the sixteenth century, but which gives no hint as to the existence of the mountain, which, nevertheless, is visible from all sides at distances of sixty leagues.

Earthquakes in Japan.—It is a well-known fact that the number of earthquakes in any given region liable to such disturbances is greatest in that part of the month when the moon coöperates the most effectively with the sun in producing an attraction upon the earth.

Out of forty-eight earthquakes, observed in the years 1875 and 1876, I find that thirty-seven occurred on one of the five days immediately preceding, or on one of the five days immediately following, *full moon*: in other words, that in a period of twenty-eight days there were only eleven earthquakes falling within a limit of seventeen days, while on the remaining eleven there occurred thirty-seven—a disproportion too great not to be taken into account.

I may add that, thus far, the shocks observed in 1877 are even more noticeably in accordance with the above facts.

W. E. Parson.

Tokio, Japan, *November* 3, 1877.

An Agricultural Detective Agency.—We have received the "Bulletin" for October of the Connecticut Agricultural Experiment Station at New Haven, containing analyses of thirty-one specimens of fertilizers. This "station" is prepared to test all kinds of fertilizers, seeds, cattle-foods, etc., free of charge, for the use and advantage of citizens of Connecticut. The establishment, therefore, is clearly one of great public utility, and deserving of generous support. Farmers are too often the victims of charlatans, who palm off upon them their worthless fertilizers, insect-destroyers, seeds, etc., at prices enormously in excess of their real value. This agricultural station will in time put a stop to such fraud in Connecticut. As an instance of the sort of work to be expected from the very competent chemists who make the analyses, we may cite the first table given in the present circular. Here, two kinds of fertilizing compositions are analyzed, and shown to possess about the same value as harbor-mud, but the purchaser was made to pay a very high price, indeed, for this mud, when dubbed "composition for vegetables," or "composition for grass."

A New Species of Monkey.—There are now in the Alexandra Palace, London, six live specimens of a monkey new to science, the *Macacus gelada*, a native of the mountains of Abyssinia, where it lives at an elevation of from 7,000 to 8,500 feet above the sea-level. One of these monkeys is an adult male. It is hairy over the whole of the body, with the exception of a pink patch free from hair on the chest, and a space around the throat of the same color. When the animal becomes angry or excited, these pink patches turn bright-red. The nostrils are high up from the upper jaw, and the upper lip is so mobile that it is often turned up so as to show the whole of the upper teeth and gums. The tail is long and thick, and ends in a tuft resembling somewhat a lion's tail. The color of the hair is brown, except around the breast, where it is gray. The bare part of the chest shows two male indications of teats. The female has not such long hair as the male, and on the bare spot in front are two well-developed teats. The young monkey takes one in each hand, and sucks from both at once. While these animals have rejected all fruits, they have eaten Indian-corn and grass, taking the grass, pulling it apart, and making it into little balls. In their native habitat, these monkeys sleep in caves, and in London they sleep in a large box, the old male remaining on guard near the entrance.

Invention of the Torpedo.—Perhaps the earliest of all torpedoes was that invented by David Bushnell, of Connecticut, a little over one hundred years ago. Bushnell's idea was, to fix a small powder-magazine to the bottom of a vessel, and to explode it by a clock-work arrangement. In order to do this, he contrived a tortoise-shaped diving-boat of iron plate, which contained air enough to supply a man for half an hour. This boat was propelled by a sort of screw, and guided by means of a compass made visible by phosphorus. The torpedo was carried outside of the boat, but could be detached by the concealed operator within. It was connected by a line to a screw, which was to be driven into the bottom of the hostile ship. As soon as this was effected, the torpedo was to be cast off, when it floated against the vessel's side. The action of casting-off set the clock-work going and then the operator had time to retire to a safe distance before the catastrophe. This torpedo and submarine boat were actually tested against an English sixty-four-gun brig early in the War of Independence, but the attempt to blow up the vessel was unsuccessful. No further effort appears to have been made to turn this invention to account. Nevertheless, to Bushnell the honor belongs of having been the first to destroy a vessel by a torpedo. In an attack on the Cerberus frigate with a towed torpedo, he blew up a schooner astern of the frigate, and killed three or four men on board. This schooner was the first vessel ever so destroyed.

Human Stature.—Treating of "Human Stature," a writer in the *Revue d'Anthropologie* gives 1.585 metre (about 5.199 feet) as the lowest mean stature of males among the Esquimaux, while in some tribes of the same race the mean reaches the comparatively high figure of 1.708 metre (about 5.60225 feet). This flatly contradicts the belief that cold climates produce only men of low stature. Among the Lapps the mean stature of men is 1.535 metre, and of women 1.421 metre. The Fuegians, so far from being diminutive, are above the average stature of the human race. The Bushmen rank among the most diminutive, the average stature of both sexes being under 1.400 metre. The Akkas attain precisely the same average. The mean stature of six Obongo women, measured by Du Chaillu, was 1.428 metre. Neither the Negritos nor the Andaman-Islanders can compare for littleness with the Bushmen of South Africa. On the other hand, according to this author, the highest stature is attained by the Norwegians, in Europe, the Kaffirs in South Africa, some Indian tribes in North America, the Polynesians, and the Patagonians. The mean stature of the last-named people, according to the statements of the most trustworthy observers, is 1.781 metre (5.84169 feet); the mean of natives of the different Polynesian archipelagoes is 1.762 metre (5.77937 feet). The mean stature of the human race is about 1.600 metre (five feet three inches).

Artificial Ice.—We select from a report in the *Lancet*, on "Ice-making Machines," a description of a machine designed to produce ice on the large scale. A cistern, somewhat like a tubular boiler, contains some ether, which is the refrigerating agent. The vapor escaping from the ether is pumped, by a double-action air-pump, into a condenser surrounded by cold water; thence the ether, now once more liquid, flows back to the cistern. The evaporation of the ether causes the cistern to become intensely cold, and this cold is rapidly communicated to a strong solution of common salt, in which the cistern is immersed. The very cold brine so obtained is caused to circulate through flat, hollow, and vertical partitions of tinned copper, in a tank filled with pure water. Ice quickly forms in smooth slabs on the partitions, and is from time to time removed as the slabs acquire the requisite thickness. The ice so obtained is, of course, exceedingly pure, and is said to waste less and cost less than natural ice. In this machine the ether is condensed again and again with scarcely any loss, and the only expenses after the original outlay are, therefore, for rent, fuel, and labor.

Mineral Caoutchouc.—In presenting to the Academy of Natural Sciences of Philadelphia specimens of mineral caoutchouc from South Australia, Mr. Galloway C. Morris stated that the substance is found during the dry season in a limited area of country of a swampy nature in the Coorong district. It occurs in sheets from the thickness of writing-paper to about five-eighths of an inch. It is made into illuminating oil. Of the basin in which it is found the surface is sand, either white and barren or brown and loamy, with occasional ridges or distributions of limestone. Next below this is segregated limestone, hard and approaching crystallization, the interstices filled with light-brown tenacious clay, followed by compact light-red sandstone of various thickness, fading in color and consistence until it touches the water and merges into quicksand. On the lowest flats fissures occur in the limestone; the orifices are very small and irregular, but reach to the underlying quicksand. The following is the result of an analysis of this mineral caoutchouc:

Moisture	0.4682
Carbon	64.7300
Hydrogen	11.6300
Ash	1.7900
Fixed carbon	1.0050
Oxygen, and other unestimated matters	20.3768
	100.0000

Living Out-of-Doors.—A retreat for consumptives should possess above all things an equable temperature throughout the year, so as to favor living out-of-doors at all seasons. The advantages possessed in this respect by the Hawaiian or Sandwich Islands can hardly be surpassed. The climate there, says Dr. H. B. White, in the "Proceedings" of the Kings County Medical Society, in its average temperature and in equability, may be said to be perfect. These islands are situated between 19° and 22° north latitude, where the trade-winds blow with great regularity about ten months of the year. Though lying within the tropics, the temperature is modified by the constant fresh breezes. In the language of Hawaii, there is no word for *weather*. The most favorable situations for consumptives are, according to Dr. White, Honolulu, Lahaina, Ulepalekua, Kailua, and Ewa. The main temperature on and near the coasts is 75° to 79° for the warmest months, and 72° for the coldest. During Dr. White's four years' residence at Lahaina the maximum was 84°, and the minimum 61°, while the general average for the summer months was 82° for mid-day, and about 72° for the winter months. By ascending the mountains a few miles inland, almost any degree of temperature can be obtained.

"Farewell."

FAREWELL! I thought you loved me once—that dream is past forever!
Farewell! I must forget you now; that is, I must endeavor.
From all your vows of constancy I set you free henceforth,
And you needn't try them on again, I know now what they're worth.

You have quite ceased to care for me; with science you've been bitten,
Since you read that very stupid book that Mr. Darwin's written.
I can't think what it signifies; I'm sure I never wondered
Whether we all descended from one "type" or from a hundred.

If you remained unaltered, I shouldn't care the least
About the variability of any bird or beast;
But you carry out the principle of change and variation,
So I leave you to your science—may it prove a consolation!

I call it such a waste of time, bothering about these things,
Racking one's brains to find out why opossums haven't wings.
Of course, it's very curious spiders should live on flies,
And that the tails of peacocks should be so full of eyes.

Of course, it's all most interesting, there's not a doubt about it,
But I think that you and I, dear, were happier without it;
So I act on this idea of Natural Selection,
And beg you to accept of my definitive rejection.

Yet the light of all my life is quenched, my happiness gone by;
I sha'n't "struggle for existence;" I shall just lie down and die.
Each hour I live apart from you my misery increases,
And it's all through Mr. Darwin and his "Origin of Species."

Improvements in Photography.—Both the chemist and the practical photographer will be interested in a communication from Mr. M. Carey Lea, published in the *American Journal of Science* for July on certain new means of developing the latent photographic image. It has been supposed that only very few bodies possess this singular power of developing, but Mr. Lea's researches show—1. That, on the contrary, such bodies are very numerous; 2. That, contrary to what has been generally held, potash is a more powerful developing agent than ammonia; 3. That, so far from it being true that the most energetic form of development, when no soluble salt of silver is present, is that which depends on the use of free alkali, a most powerful development may be had *without free alkali;* 4. That ferrous salts do *not* act only in the presence of a soluble salt of silver. We have not space to describe the method followed by the author in his researches, but must content ourselves with simply stating the principal results, referring the reader who desires fuller information to the pages of our contemporary. Among the bodies found by Mr. Lea to possess the power of developing the latent image are *sugars*, manna being especially noteworthy as producing, under certain conditions, "an image as bold and strong as any substance hitherto known." Of the *glucosides* some give good images. Of several *organic acids* tried, only one, cevadic acid, exhibited tolerable developing power. The resins exhibit more or less developing power, guaiacum being nearly as energetic as pyrogallol itself. Among the *essential oils*, the oil of cloves yields a strong, clear image, and good results are also obtained from oil of Roman camomile and oil of peppermint. The *organic bases* exhibit little developing power. Concerning *pyrogallol* the author writes that with potassium formate it gives better results than with any other substance. A large number of vegetable substances were tried, with varying results. Finally, the author experimented with *cuprous oxide* and with *ferrous salts:* a colorless solution of the former in ammonia develops a strong image; but the salts of ferrous oxide "proved to be the most interesting and remarkable of all the bodies examined, in their action on the image."

Preservation of Wood by charring and tarring.—A writer in the *Industrie-Blätter*, in remarking on the methods of preserving wooden posts by charring and coating with tar, says that these methods are effectual only when both are applied. If the posts are only charred, the charcoal formed on the surface acts only as an absorber of moisture, and really hastens decay. By applying tar without previously charring, the tar only forms a casing about the wood. Timber that is exposed to the action of water or let into the ground should first be charred, and then while still warm should be treated with tar till it is fully impregnated. The acetic acid and oils contained in the tar are evaporated by the heat and only the resin left behind, which penetrates the pores of the wood and forms an air-tight and water-proof coating. It is important to impregnate the posts a little above the line of exposure, for here it is that the process of decay affects the wood first, and where the break always occurs when a post is removed from the earth or strained in testing.

Earthworms in Agriculture.—That the earthworm is of great service to the agriculturist is shown by the author of a paper, the substance of which we find in *Die Natur*. Not only does the earthworm not attack or injure the roots of plants; on the contrary, it aids them in their growth by excavating passages through which they can penetrate into strata otherwise inaccessible to them. And, as the overground portion of a plant is always proportioned to the length and number of its roots, it is plain that the earthworm is of great benefit to the plants in its neighborhood. The author placed an earthworm in a flower-pot containing a growing *Dracæna* two and a half feet in height. The worm was left undisturbed for some time, and soon it was found that it had passed through itself at least one-half of the earth in the flower-pot. The soil was in this way improved, many insoluble constituents being rendered soluble. The author's conclusion was that, inasmuch as he could discover no injury done to the roots of the *Dracæna*, the worm had fed on the remains of plants in the earth, utilizing and decomposing them thoroughly.

Drowning-Accidents.—The advantages of "paddling" and "treading water," as a means of escaping from drowning when one is suddenly precipitated into deep water, are set forth by a writer in the *Sanitary Record*. The motions performed in the acts of paddling and treading require no previous instruction, and in the great majority of cases would save life. In swimming, the mouth is on a level with the water in the intervals of the strokes; in paddling, the head is well elevated; the individual is able to look about, he can deliberate as to what is best to be done, and he is much less liable to take water into the larynx or glottis. Without prejudice to the art of swimming, children should be exercised from the tenderest age in the act of paddling and treading water, so as to impart confidence to them. Even without any preliminary practice whatever, there is nothing to hinder man, woman, or child, from beating the water with the hands and feet, just as the lower animals do, and so keeping themselves afloat for a protracted period—a period that in a multitude of instances would be sufficient to invite rescue, and preserve life. The action of the feet alone will sustain the body; *a fortiori*, the action of both feet and hands will prove yet more effectual. In this, as in many other things, man is too often unaware of his own immense capacities.

Peppermint-Culture.—We take from the *Polytechnic Review* the following notes on the cultivation of the peppermint-plant in the United States: Of the entire crop, fully two-thirds is produced in Michigan. The soils best suited for the cultivation of peppermint are the black-ash swamps of Western New York, and river-bottoms. The land must be drained to allow it being worked early in spring. The one-year roots are planted in ploughed land in rows, the space between the rows being from eighteen to thirty-six inches. During the first year the ground must be kept free from weeds. The plant contains most oil at the period of blossoming, or just afterward, and the crop must be gathered on a dry day. Within a day or two after cutting it is carried to the still and the oil extracted. There must be a good supply of water to make distilling successful. If dried too much, there is a loss in leaves falling off, and the yield of oil greatly diminished. The mint-straw, on being dried, is readily eaten by animals in winter. The annual product is about 70,000 pounds, the greater part of it being exported to Europe.

Uses of Castor-Oil in the Arts.—Castor-oil was formerly employed only as a medicinal agent; but now its uses in the arts are manifold, and its manufacture has come to be a considerable industry. St. Louis is the centre of this industry in the United States, and nearly all the castor-beans grown in this country are produced within a circle of about 200 miles south and southwest of that city. The chief uses of castor-oil in the arts are, according to the *Shoe and Leather Reporter*, as a lubricator for coach and carriage axles, in the manufacture of the best shoe-blacking, as a dressing for calf-skins, for treeing boots, as a substitute for neat's-foot oil, and keeping leather soft, mellow, and pliable. Crude castor-oil is used largely in the manufacture of morocco. It will not "fry" or "gum," and imparts softness and weight, and leather prepared with it remains mellow and pliable. The crop of castor-beans for the year 1875 was 303,498 bushels; in 1876 the crop was only about one-half as large. Last year a firm in St. Louis made, from 125,000 bushels of beans, 7,000 barrels (47 gallons each) of crude castor-oil.

NOTES.

There will be two solar eclipses this year, one on the 1st of February, the other on the 29th of July. The former will be central and annular as observed from high southern latitudes; the latter will be total in the western part of North America. It will be best observed at Denver, Colorado.

The "Copley Medal" for 1877 has been awarded by the London Royal Society to Prof. James Dwight Dana, of Yale College, for his biological, geological, and mineralogical investigations carried on through half a century, and for the valuable works in which his conclusions and discoveries have been published.

A prize of $20,000 is offered by the Council General of Guadeloupe for the best new process for extracting the juice from sugar-cane, the cost not to exceed 40 per cent. of the market value of the product. The prize is open to competition till June 1, 1880.

Numerous facts are cited by the Australian explorer, Landsborough, which go to prove that dense forests are on the increase in Australia, that the climate is growing moister, and that even the great central desert may, in course of time, become inhabitable. The frequency of fires, prior to the introduction of sheep-farming, when there was nothing to keep down the grass, was terribly destructive to trees and to all vegetation. Now these ravages are becoming limited in extent.

Karl Ludwig von Littrow, Professor of Astronomy, and Director of the Imperial Observatory at Vienna, died at Venice, November 16th, in the sixty-seventh year of his age.

The mean distance of the sun, as deduced by the British Astronomer Royal, Sir George Airy, from a comparison of the results obtained by the English telescopic observations of the transit of Venus in 1874, is equal to 93,300,000 miles. But, as the photographs of the transit are yet to be worked up, this estimate must be regarded as provisional only.

Dr. H. C. Yarrow, of the Army Medical Museum, Washington, is collecting materials for a memoir on the burial-customs of the North American Indians, both ancient and modern, and earnestly solicits information so as to enable him to treat the subject with all possible fullness. Correspondents are requested to state as exactly as may be the name of the tribe concerning which they give information, its locality, its manner of burial, ancient and modern, its funereal and other mortuary ceremonies, etc. Dr. Yarrow's address is 1,747 F Street, N. W., Washington.

Douglas A. Spalding, author of many suggestive papers on certain obscure questions in psychology which have appeared in the Monthly, died on the 31st of October, in the thirty-seventh year of his age. From a notice in *Nature* we learn that Mr. Spalding was in his early manhood a slater at Aberdeen; in 1862, through the kindness of Prof. Bain, he was allowed to attend free of charge the classes in literature and philosophy in the university. Later he went to London, and tried to earn a livelihood by teaching, at the same time studying law. His paper on the instinctive movements of young birds, read at the British-American meeting of 1872, first brought him to the notice of the world of science.

At a *conversazione* lately held in Guy's Hospital, London, a filter invented by a Major Crease was exhibited. It reduced strong tea and logwood infusion to clear, tasteless water. The nature of the filtering medium is at present a secret.

A prize of $25,000 is offered by the government of India for the best machine or process for preparing *rhea* or ramie-fibre; also a prize of $5,000 for the second best. The conditions of winning the prize are that the machine or process shall be capable of producing by animal, water, or steam power, one ton of dressed fibre at a total cost not exceeding $75 at any port in India, or $150 in England. The machines must be in readiness at Saharanpar by August 15, 1879.

A solution of bicarbonate of sodium applied to burns promptly and permanently relieves all pain. A laboratory assistant in Philadelphia having severely burned the inside of the last phalanx of the thumb while bending glass tubing, applied the solution of bicarbonate of soda, and not only was the pain allayed but the thumb could be at once freely used without inconvenience.

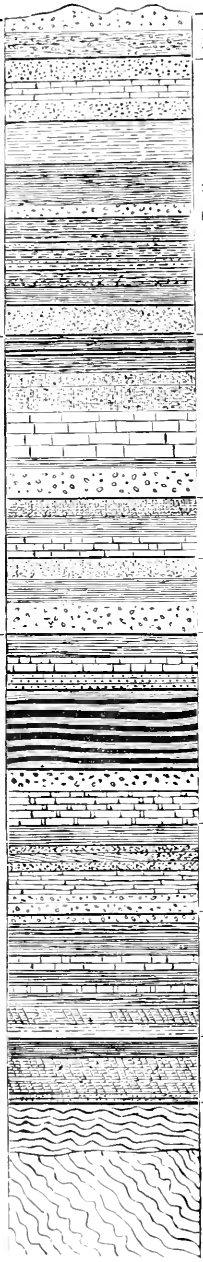
Munke quotes from the "Talmud" a passage in which mention is made of iron as a means of "protection from lightning and thunder;" and Wiedermann adds that the ancient Egyptians appear to have used gilded masts "for warding off the bad weather coming from heaven."

On board the British iron-clad ship Téméraire, besides the great engines for propulsion, there are no less than thirty-four small engines for the following purposes: two turning, two starting, four feed, two circulating, two fan, two bilge, one capstan, one steering, four pumping, four ash-lifters, two hydraulic gear-workers, one torpedo reservoir-charger, one to work the electric machine which lights the bridge, and four others.

Nearly all the salt used for domestic purposes passes out with the sewage, and is inseparable from it; the proportion of salt (chloride of sodium) found in water is therefore a pretty accurate measure of the degree of contamination by sewage. Hence, says Prof. Lattimore, of Rochester, "whenever the proportion of salt in well-water rises above a very few grains per gallon, contamination by sewage or house-drainage may be confidently asserted."

A singularly interesting discovery has been made by Reichenbach, with regard to the embryo of the crawfish. He finds that the "food-yelk" of the egg is not merely absorbed by the embryonic cells by a passive process of diffusion, but that these latter actually devour the yelk-globules in precisely the same manner as an amœba devours diatoms or desmids. The cells throw out pseudopod-like processes, and with these envelop the yelk-globules and drag them into their interior, where they undergo digestion.

The sermon of Henry Ward Beecher on the subject of future rewards and punishments, concerning which there has been such gross misrepresentation, is published in full in the *Christian Union* (New York) of December 26th. It is entitled "The Background of Mystery."



Era	Period	Epoch	Beds	Vertebrates
Cenozoic.	Recent. Post Tertiary.			Tapir, Peccary, Bison, Llama. *Equus*. *Megatherium*, *Mylodon*.
	Tertiary.	Pliocene.	Equus Beds.	*Equus*, *Tapirus*. *Elephas*.
			Pliohippus Beds.	*Pliohippus*, *Tapiravus*, *Mastodon*. *Protohippus*, *Aceratherium*, *Bos*.
		Miocene.	Miohippus Beds.	*Miohippus*, *Diceratherium*, *Thinohyus*.
			Oreodon Beds.	Edentates (*Moropus*), *Hyænodon*, *Eporeodon*, *Hyracodon*.
			Brontotherium B.	*Mesohippus*, *Menodus*, *Elotherium*.
		Eocene.	Diplacodon Beds.	*Epihippus*, *Amynodon*.
			Dinoceras Beds.	*Tinoceras*, *Uintatherium*, *Limnohyus*, *Orohippus*, *Helaletes*, *Colonoceras*.
			(Green River B.)	
			Coryphodon Beds.	*Eohippus*, Monkeys, Carnivores, Ungulates, Tillodonts, Rodents, Serpents.
Mesozoic.	Cretaceous.		Lignite Series.	*Hadrosaurus*, *Dryptosaurus*.
			Pterauodon Beds.	Birds with Teeth (*Odontornithes*), *Hesperornis*, *Ichthyornis*. Mosasaurs, *Edestosaurus*, *Lestosaurus*, *Tylosaurus*. Pterodactyls, Plesiosaurs.
			Dakota Group.	
	Jurassic.		Atlantosaurus B.	Dinosaurs, *Apatosaurus*, *Allosaurus*, *Nanosaurus*. Turtles, *Diplosaurus*.
	Triassic.		Conn. River Beds.	First Mammals (Marsupials), (*Dromatherium*). Dinosaur Footprints, *Amphisaurus*. Crocodiles (*Belodon*).
Paleozoic.	Carboniferous.		Permian.	
			Coal Measures.	First Reptiles (?)
			Subcarboniferous.	First known Amphibians (Labyrinthodonts).
	Devonian.		Corniferous.	
			Schoharie Grit.	First known Fishes.
	Silurian.		Upper Silurian.	No Vertebrates known.
			Lower Silurian.	
	Cambrian.		Primordial.	
	Archæan.		Huronian.	
			Laurentian.	

Section of the Earth's Crust.

TO ILLUSTRATE VERTEBRATE LIFE IN AMERICA.

THE

POPULAR SCIENCE MONTHLY.

MARCH, 1878.

INTRODUCTION AND SUCCESSION OF VERTEBRATE LIFE IN AMERICA.[1]

By Prof. O. C. MARSH.

THE origin of life and the order of succession in which its various forms have appeared upon the earth offer to science its most inviting and most difficult field of research. Although the primal origin of life is unknown, and may perhaps never be known, yet no one has a right to say how much of the mystery now surrounding it science cannot remove. It is certainly within the domain of science to determine when the earth was first fitted to receive life, and in what form the earliest life began. To trace that life in its manifold changes through past ages to the present is a more difficult task, but one from which modern science does not shrink. In this wide field, every earnest effort will meet some degree of success; every year will add new and important facts; and every generation will bring to light some law, in accordance with which ancient life has been changed into life as we see it around us to-day. That such a development has taken place, no one will doubt who has carefully traced any single group of animals through its past history, as recorded in the crust of the earth. The evidence will be especially conclusive, if the group selected belongs to the higher forms of life, which are sensitive to every change in their surroundings. But I am sure I need offer here no argument for evolution; since to doubt evolution to-day is to doubt science, and science is only another name for truth.

Taking, then, evolution as a key to the mysteries of past life on the earth, I invite your attention to the subject I have chosen: "The Introduction and Succession of Vertebrate Life in America."

In the brief hour allotted to me, I could hardly hope to give more than a very incomplete sketch of what is now known on this subject.

[1] An address delivered before the American Association for the Advancement of Science, at Nashville, Tenn., August 30, 1877, by Prof. O. C. Marsh, Vice-President.

I shall, therefore, pass rapidly over the lower groups, and speak more particularly of the higher vertebrates, which have an especial interest for us all, in so far as they approach man in structure, and thus indicate his probable origin. These higher vertebrates, moreover, are most important witnesses of the past, since their superior organization made them ready victims to slight climatic changes, which would otherwise have remained unrecorded.

In considering the ancient life of America, it is important to bear in mind that I can only offer you a brief record of a few of the countless forms that once occupied this continent. The review I can bring before you will not be like that of a great army, when regiment after regiment with full ranks moves by in orderly succession, until the entire host has passed. My review must be more like the roll-call after a battle, when only a few scarred and crippled veterans remain to answer to their names. Or, rather, it must resemble an array of relics, dug from the field of some old Trojan combat, long after the contest, when no survivor remains to tell the tale of the strife. From such an ancient battle-field, a Schliemann might unearth together the bronze shield, lance-head, and gilded helmet, of a prehistoric leader, and learn from them with certainty his race and rank. Perhaps the skull might still retain the barbaric stone weapon by which his northern foe had slain him. Near by, the explorer might bring to light the commingled coat-of-mail and trappings of a horse and rider, so strangely different from the equipment of the chief as to suggest a foreign ally. From these, and from the more common implements of war that fill the soil, the antiquary could determine, by patient study, what nations fought, and perhaps when and why.

By this same method of research the more ancient strata of the earth have been explored, and in our Western wilds veritable battle-fields, strewed with the fossil skeletons of the slain, and guarded faithfully by savage superstition, have been despoiled, yielding to science treasures more rare than bronze or gold. Without such spoils, from many fields, I could not have chosen the present theme for my address to-night.

According to present knowledge, no vertebrate life is known to have existed on this continent in the Archæan, Cambrian, or Silurian period; yet during this time more than half of the thickness of American stratified rocks was deposited. It by no means follows that vertebrate animals of some kind did not exist here in those remote ages. Fishes are known from the Upper Silurian of Europe, and there is every probability that they will yet be discovered in our strata of the same age, if not at a still lower horizon.

In the shore-deposits of the early Devonian sea, known as the Schoharie Grit, characteristic remains of fishes were preserved, and in the deeper sea that followed, in which the Corniferous limestone was laid down, this class was well represented. During the remainder of the Devonian, fishes continue abundant in the shallower seas, and, so far as now known, were the only type of vertebrate life. These fishes were mainly Ganoids, a group represented in our present waters by the gar-pike (*Lepidosteus*) and Sturgeon (*Acipenser*), but, in the Devonian sea, chiefly by the Placoderms, the exact affinities of which are somewhat in doubt. With these were Elasmobranchs, or the Shark tribe, and among them a few Chimæroids, a peculiar type, of which one or two members still survive. The Placoderms were the monarchs of the ocean. All were well protected by a massive coat of armor, and some of them attained huge dimensions. The American Devonian fishes now known are not so numerous as those of Europe, but they were larger in size, and mostly inhabitants of the open sea. Some twenty genera and forty species have been described.

The more important genera of Placoderms are—*Dinichthys*, *Aspidichthys*, and *Diplognathus*, our largest Palæozoic fishes. Others are —*Acanthaspis*, *Acantholepis*, *Coccosteus*, *Macropetalichthys*, and *Onychodus*. Among the Elasmobranchs were—*Cladodus*, *Ctenacanthus*, *Machæracanthus*, *Rhynchodus*, and *Ptyctodus*, the last two being regarded as Chimæroids. In the Chemung epoch, the great Dipterian family was introduced with *Dipterus*, *Heliodus*, and possibly *Ceratodus*. Species of the European genera, *Bothriolepis* and *Holoptychius*, have likewise been found in our Devonian deposits.

With the close of the Devonian, came the almost total extinction of the great group of Placoderms, while the Elasmobranchs, which had hitherto occupied a subordinate position, increase in numbers and size, and appear to be represented by Sharks, Rays, and Chimæras. Among the members of this group from the Carboniferous, were numerous Cestracionts,[1] species of *Cochliodus* of large size, with others of the genera *Deltodus*, *Helodus*, *Psammodus*, and *Sandalodus*. Of the Petalodonts there were *Antliodus*, *Chomatodus*, *Ctenoptychius*, *Petalodus*, and *Petalorhynchus*; and of the Hybodonts,[2] the genera *Cladodus*, *Carcharopsis*, and *Diplodus*. These Elasmobranchs were the rulers of the Carboniferous open sea, and more than one hundred species have been found in the lower part of this formation alone. The Ganoids, although still abundant, were of smaller size, and denizens of the more shallow and confined waters. The latter group of fishes was represented by true Lepidostidæ, of the genera *Palæoniscus*, *Amblypterus*, *Platysomus*, and *Eurylepis*. Other genera are —*Rhizodus*, *Megalichthys*, *Ctenodus*, *Edestus*, *Orodus*, *Ctenacanthus*, *Gyracanthus*, and *Cœlacanthus*. Most of these genera occur also in Europe.

From the Permian rocks of America no vertebrate remains are

[1] (*Cestracion* = sharp tool)—a group of sharks, so named from their denticulated dorsal spines.

[2] (*Hybodus* = hump-tooth)—a group of sharks.

known, although in the same formation of Europe Ganoids are abundant; and with them are remains of sharks, and some other fishes, the affinities of which are doubtful. The Palæozoic fishes at present known from this country are quite as numerous as those found in Europe.

In the Mesozoic age, the fishes of America begin to show a decided approach to those of our present waters. From the Triassic rocks, Ganoids only are known, and they are all more or less closely related to the modern gar-pike, or *Lepidosteus*. They are of small size, and the number of individuals preserved is very large. The characteristic genera are—*Catopterus*, *Ischypterus*, *Ptycholepis*, *Rhabdolepis*, and *Turseodus*. From the Jurassic deposit no remains of fishes are known,[1] but in the Cretaceous, ichthyic life assumed many and various forms; and the first representatives of the Teleosts, or bony fishes, the characteristic fishes of to-day, make their appearance. In the deep open sea of this age, Elasmobranchs were the prevailing forms, Sharks and Chimæroids being most numerous. In the great inland Cretaceous sea of North America, true osseous fishes were most abundant, and among them were some of carnivorous habits and immense size. The more sheltered bays and rivers were shared by the Ganoids and Teleosts, as their remains testify. The more common genera of Cretaceous Elasmobranchs were—*Otodus*, *Oxyrhina*, *Galeocerdo*, *Lamna*, and *Ptychodus*. Among the osseous fishes, *Beryx*, *Enchodus*, *Portheus*, and *Saurocephalus*, were especially common, while the most important genus of Ganoids was *Lepidotus*.

The Tertiary fishes are nearly all of modern types, and from the beginning of this period there was comparatively little change. In the marine beds, Sharks, Rays, and Chimæroids, maintained their supremacy, although Teleosts were abundant, and many of them of large size. The Ganoids were comparatively few in number. In the earliest Eocene fresh-water deposits, it is interesting to find that the modern Gar-pike, and *Amia*, the dogfish of our Western lakes, which by their structure are seen to be remnants of a very early type, are well represented by species so closely allied to them that only an anatomist could separate the ancient from the modern. In the succeeding beds, these fishes are still abundant, and with them are Siluroids nearly related to the modern catfish (*Pimelodus*). Many small fishes, allied apparently to the modern herring (*Clupea*), left their remains in great numbers in the same deposits, and, with them has been recently found a landlocked ray (*Heliobatis*).

The almost total absence of remains of fishes from the Miocene lake-basins of the West is a remarkable fact, and perhaps may best be explained by the theory that these inland waters, like many of the smaller lakes in the same region to-day, were so impregnated with mineral matters as to render the existence of vertebrate life in them

[1] A species of *Ceratodus* has recently been found in the upper Jurassic of Colorado, and named by the writer *C. Güntheri*.—O. C. M.

impossible. No one who has tasted such waters, or has attempted to ford one of the modern alkaline lakes which are often met with on the present surface of the same deposits, will doubt the efficiency of this cause, or the easy entombment of the higher vertebrates that ventured within their borders. In the Pliocene lake-basins of the same region, remains of fishes were not uncommon, and in some of them are very numerous. These are all of modern types, and most of them are Cyprinoids, related to the modern carp. The Post-pliocene fishes are essentially those of to-day.

In this brief synopsis of the past ichthyic life of this continent, I have mentioned only a few of the more important facts, but sufficient, I trust, to give an outline of its history. Of this history, it is evident that we have as yet only a very imperfect recond. We have seen that the earliest remains of fishes known in this country are from the lower Devonian; but these old fishes show so great a diversity of form and structure as to clearly indicate for the class a much earlier origin. In this connection, we must bear in mind that the two lowest groups of existing fishes are entirely without osseous skeletons, and hence, however abundant, would leave no permanent record in the deposits in which remains of fishes are usually preserved. It is safe to infer, from the knowledge which we now possess of the simpler forms of life, that even more of the early fishes were cartilaginous, or so destitute of hard parts as to leave no enduring traces of their existence. Without positive knowledge of such forms, and considering the great diversity of those we have, it would seem a hopeless task at present to attempt to trace successfully the genealogy of this class. One line, however, appears to be direct, from our modern gar-pike, through the lower Eocene *Lepidosteus* to the *Lepidotus* of the Cretaceous, and perhaps on through the Triassic *Ischypterus* and Carboniferous *Palæoniscus;* but beyond this, in our rocks, it is lost. The living Chimæra of our Pacific coast has nearly allied forms in the Tertiary and Cretaceous, more distant relatives in the Carboniferous, and a possible ancestor in the Devonian *Rhynchodus.* Our sharks likewise can be traced with some certainty back to the Palæozoic; and even the *Lepidosiren*, of South America, although its immediate predecessors are unknown, has some peculiar characters which strongly point to a Devonian ancestry. These suggestive lines indicate a rich field for investigation in the ancient life-history of American fishes.

The Amphibians, the next higher class of vertebrates, are so closely related to the fishes in structure that some peculiar forms of the latter have been considered by anatomists as belonging to this group. The earliest evidence of Amphibian existence, on this continent, is in the Sub-Carboniferous, where footprints have been found which were probably made by Labyrinthodonts, the most ancient representatives of the class. Well-preserved remains are abundant in the Coal-Measures, and show that the Labyrinthodonts differed in important particulars from all modern Amphibians, the group which includes our frogs and salamanders. Some of these ancient animals resemble a salamander in shape, while others were serpent-like in form. None of those yet discovered were frog-like, or without a tail, although the restored Labyrinthodont of the text-books is thus represented. All were protected by large pectoral bony plates, and an armor of small scutes on the ventral surface of the body. The walls of their teeth were more or less folded, whence the name Labyrinthodont. The American Amphibians known from osseous remains are all of moderate size, but the footprints attributed to this group indicate animals larger than any of the class yet found in the Old World. The Carboniferous Amphibians were abundant in the swampy tropical forests of that period, and their remains have been found imbedded in the coal then deposited, as well as in hollow stumps of the trees left standing.

The principal genera of this group from American Carboniferous rocks are—*Sauropus*, known only from footprints, *Baphetes*, *Dendrerpeton*, *Hylonomus*, *Hylerpeton*, *Raniceps*, *Pelion*, *Leptophractus*, *Molgophis*, *Ptyonius*, *Amphibamus*, *Cocytinus*, and *Ceraterpeton*. The last genus occurs also in Europe. Certain of these genera have been considered by some writers to be more nearly related to the lizards, among true reptiles. Some other genera known from fragmentary remains or footprints in this formation have likewise been referred to the true reptiles, but this question can perhaps be settled only by future discoveries.

No Amphibia are known from American Permian strata, but in the Triassic a few characteristic remains have been found. The three genera, *Dictyocephalus*, *Dispelor*, and *Pariostegus*, have been described, but, although apparently all Labyrinthodonts, the remains preserved are not sufficient to add much to our knowledge of the group. The Triassic footprints which have been attributed to Amphibians are still more unsatisfactory, and at present no important conclusions in regard to this class can be based upon them. From the Jurassic and Cretaceous beds of this continent no remains of Amphibians are known. A few only have been found in the Tertiary, and these are all of modern types.

The Amphibia are so nearly allied to the Ganoid fishes that we can hardly doubt their descent from some member of that group. With our present limited knowledge of the extinct forms, however, it would be unprofitable to attempt to trace in detail their probable genealogy.

The authors to whom especial credit is due for our knowledge of American fossil Fishes and Amphibians, are Newberry, Leidy, Cope, Dawson, Agassiz, St. John, Gibbes, Wyman, Redfield, and Emmons, and the principal literature of the subject will be found in their publications.

Reptiles and birds form the next great division of vertebrates, the *Sauropsida*, and of these the reptiles are the older type, and may be first considered. While it may be stated with certainty that there is at present no evidence of the existence of this group in American rocks older than the Carboniferous, there is some doubt in regard to their appearance even in this period. Various footprints which strongly resemble those made by lizards, a few well-preserved remains similar to the corresponding bones in that group, and a few characteristic specimens, nearly identical with those from another order of this class, are known from American Coal-Measures. These facts, and some others which point in the same direction, render it probable that we may soon have conclusive evidence of the presence of true reptiles in this formation, and in our overlying Permian, which is essentially a part of the same series. In the Permian rocks of Europe true reptiles have been found.

The Mesozoic period has been called the Age of Reptiles, and during its continuance some of the strangest forms of reptilian life made their appearance, and became extinct. Near its commencement, while the Triassic shales and sandstones were being deposited, true reptiles were abundant. Among the most characteristic remains discovered are those of the genus *Belodon*, which is well known also in the Trias of Europe. It belongs to the Thecodont division of reptiles, which have teeth in distinct sockets, and its nearest affinities are with the *Crocodilia*, of which order it may be considered the oldest known representative. In the same strata in which the Belodonts occur, remains of Dinosaurs are found, and it is a most interesting fact that these highest of reptiles should make their appearance, even in a generalized form, at this stage of the earth's history. The Dinosaurs, although true reptiles in all their more important characters, show certain well-marked points of resemblance to existing birds of the order *Ratitæ*, a group which includes the ostriches; and it is not improbable that they were the parent-stock from which birds originated.

During Triassic time, the Dinosaurs attained in America an enormous development both in variety of forms and in size. Although comparatively few of their bones have as yet been discovered in the rocks of this country, they have left unmistakable evidence of their presence in the footprints and other impressions upon the shores of the waters which they frequented. The Triassic sandstone of the Connecticut Valley has long been famous for its fossil footprints, especially the so-called "bird-tracks," which are generally supposed to have been made by birds, the tracks of which many of them closely resemble. A careful investigation, however, of nearly all the specimens yet discovered has convinced me that there is not a particle of evidence that any of these fossil impressions were made by birds. Most of these three-toed tracks were certainly not made by birds; but by quadrupeds, which usually walked upon their hind-feet alone, and only occasionally put to the ground their smaller anterior extremities. I have myself detected the impressions of these anterior limbs in connection with the posterior footprints of nearly all of the supposed "bird-tracks" described, and have little doubt that they will eventually be found with all. These double impressions are precisely the kind which Dinosaurian reptiles would make, and, as the only characteristic bones yet found in the same rocks belong to animals of this group, it is but fair to attribute all these footprints to Dinosaurs, even where no impressions of fore-feet have been detected, until some evidence appears that they were made by birds. I have no doubt that birds existed at this time, although at present the proof is wanting.

The principal genera of Triassic reptiles known from osseous remains in this country are—*Amphisaurus* (*Megadactylus*), from the Connecticut Valley; *Bathygnathus*, from Prince Edward's Island; *Belodon*, and *Clepsysaurus*. Other generic names which have been applied to footprints and to fragmentary remains need not here be enumerated. A few remains of reptiles have been found in undoubted Jurassic rocks of America, but they are not sufficiently well determined to be of service in this connection.[1] Others have been reported from supposed Jurassic strata, which are now known to be Cretaceous. It will thus be seen that, although reptilian life was especially abundant during the Triassic and Jurassic periods, but few bones have been found. This is owing in part to the character of most of the rocks then formed, which were not well fitted for preserving such remains, although admirably adapted to retain footprints.

During the Cretaceous period, reptilian life in America attained its greatest development, and the sediments laid down in the open seas and estuaries were usually most favorable for the preservation of a faithful record of its various phases. Without such a perfect matrix as some of these deposits afford, many of the most interesting vertebrates recently brought to light from this formation would probably have remained unknown. The vast extent of these beds insures, moreover, many future discoveries of interest.

In the lowest Cretaceous strata of the Rocky Mountain region, the Dakota group, part of which at least represents the Wealden of Europe, remains of *Chelonia*, or Turtles, Crocodiles, and Dinosaurs occur, the last being especially abundant. The *Chelonia*, although known from the Jurassic of Europe, here appear for the first time in American rocks. Some of the earliest forms are allied to the modern genus *Trionyx*. In the higher Cretaceous beds, some Chelonians of enormous size have been found. They belong to the genus *Atlantochelys*, which has the ribs separate, as in the existing *Sphargis*,[2]

[1] Since this address was delivered, I have determined the beds containing gigantic Dinosaurs, on the flanks of the Rocky Mountains, to be upper Jurassic, and called them Atlantosaurus Beds. (*See* frontispiece, section.) These strata were formerly referred to the Dakota group, or base of the Cretaceous.—O. C. M.

[2] *Sphargis*, a genus of turtles inhabiting the Atlantic and Mediterranean. They are

and presents other embryonic characters. A few genera appear to be related to the modern genus *Chelone.* The remaining Cretaceous species were mostly of the Emydoid[1] type; and others were related to *Chelydra.* The more important genera of Cretaceous Chelonians known from characteristic specimens are—*Atlantochelys* (*Protostega*), *Adocus*, *Bothremys*, *Compsemys*, *Plastomenus*, *Osteopygis*, *Propleura*, *Lytoloma*, and *Taphrosphys*. Most of these genera were represented by several species, and the individuals were numerous. No land-tortoises have as yet been found in this formation. In American Tertiary deposits, Chelonians are abundant, especially in the fresh-water beds. They all show near affinities with modern types, and most of them can be referred to existing genera. In the Tertiary lake-basins of the West, land-tortoises are very numerous, and with them are many fresh-water forms of *Trionyx* and allied genera.

A striking feature of the American Cretaceous fauna, as contrasted with that of Europe, is the almost entire absence in our strata of species of *Ichthyosaurus* and *Plesiosaurus*, which abound in many other regions, but here seem to be replaced by the Mosasaurs. A few fragmentary remains have indeed been referred to these genera, but the determination may fairly be questioned. This is more than true of the proposed new order *Streptosauria*, which was founded wholly on error. The order *Plesiosauria*, however, is well represented, but mainly by forms more nearly related to the genus *Pliosaurus* than to the type of the group. These were marine reptiles, all of large size, while some of them attained vast dimensions. So far as at present identified, they may be referred to the genera *Cimoliosaurus*, *Discosaurus* (*Elasmosaurus*), and *Pliosaurus*. The number of species is comparatively few, and none are known above the Cretaceous. The important suggestion of Gegenbaur, that the *Halisauria*, which include the Plesiosaurs, branched off from the fishes before the Amphibians, finds some support in American specimens recently discovered.

The Reptiles most characteristic of our American Cretaceous strata are the *Mosasauria*, a group with very few representatives in other parts of the world. In our Cretaceous seas, they ruled supreme, as their numbers, size, and carnivorous habits, enabled them to easily vanquish all rivals. Some were at least sixty feet in length, and the smallest ten or twelve. In the inland Cretaceous sea from which the Rocky Mountains were beginning to emerge, these ancient "sea-serpents" abounded; and many were entombed in its muddy bottom. On one occasion, as I rode through a valley washed out of this old ocean-bed, I saw no less than seven different skeletons of these mon-

the largest of all turtles, and have the body covered with a thick coriaceous skin instead of a hard shell.

[1] *Emys*, a genus of small land and fresh-water tortoises.

sters in sight at once. The Mosasaurs were essentially swimming lizards, with four well-developed paddles, and they had little affinity with modern serpents, to which they have been compared. The species are quite numerous, but they belong to comparatively few genera, of which *Mosasaurus*, *Tylosaurus*, *Lestosaurus*, and *Edestosaurus*, have alone been identified with certainty. The genus *Mosasaurus* was first found in Europe. All the known species of the group are Cretaceous.

The *Crocodilia* are abundant in rocks of Cretaceous age in America, and two distinct types are represented. The older type, which is foreshadowed by *Belodon* of the Trias, has biconcave vertebræ, and shows marked affinities with the genus *Teleosaurus*, from the Jura of Europe. The best-known genus is *Hyposaurus*, of which there are several species, all more or less resembling in form the modern gavial of the Ganges. A peculiar intermediate form is seen in *Diplosaurus*, from the Wealden of the Rocky Mountains. The second type, which now makes its appearance for the first time, has procœlian [1] vertebræ, and in other respects resembles existing crocodiles. The genera described are *Bottosaurus*, *Holops*, and *Thoracosaurus*, none of which, so far as known, pass above the Cretaceous. Of *Crocodilia* with opisthocœlous [1] vertebræ, America, so far as we know, has none. Specimens similar to those so termed in Europe are not uncommon here, but they pertain to Dinosaurs.

In the Eocene fresh-water beds of the West, Crocodilians are especially abundant, and all, with the exception of *Limnosaurus*, belong apparently to the genus *Crocodilus*, although some species show certain points of resemblance to existing alligators. The Miocene lake-basins of the same region contain no remains of crocodiles, so far as known, and the Pliocene deposits have afforded only a single species. The Tertiary marine beds of the Atlantic coast contain comparatively few Crocodilian remains, and all are of modern types; the genus *Gavialis* having one Eocene species, and the alligator being represented only in the latest deposits.

It is worthy of special mention, in this connection, that no true *Lacertilia*, or Lizards, and no *Ophidia*, or Serpents, have yet been detected in American Cretaceous beds; although their remains, if present, would hardly have escaped observation in the regions explored. The former will doubtless be found, as several species occur in the Mesozoic of Europe; and perhaps the latter, although the Ophidians are apparently a more modern type. In the Eocene lake-basins of Western America, remains of lizards are very numerous, and indicate species much larger than any existing to-day. Some of these,

[1] Vertebræ which have centra concave at each end have been conveniently termed *amphicœlous*; those with a cavity in front and a convexity behind, *procœlous*; where the position of the concavity and convexity is reversed, they are *opisthocœlous*.—(Huxley, "Anatomy of Vertebrated Animals.")

the *Glyptosauridæ*, were protected by a highly-ornamented bony coat-of-mail, and others were covered with scales, like recent lizards. A few resembled, in their more important characters, the modern iguana. The genera best represented in the Eocene are—*Glyptosaurus*, *Iguanavus*, *Oreosaurus*, *Thinosaurus*, *Tinosaurus*, and *Saniva*. Some of these genera appear to have continued into the Miocene, but here, as well as in the Pliocene, few remains of this group have been found. It is not improbable that some of our extinct Reptiles may prove to belong to *Rynchocephala*, but at present this is uncertain. The genus *Notosaurus*, from Brazil, has biconcave vertebræ, and some other characters which point to that group. No Dicynodonts[1] or Theriodonts[2] have as yet been found in this country.

The first American serpents, so far as now known, appear in the Eocene, which contains also the oldest European species. On the Atlantic border, the genus *Titanophis* (*Dinophis*) is represented by several species of large size, one at least thirty feet in length, and all doubtless inhabitants of the sea. In the fresh-water Western Eocene, remains of snakes are abundant, but all are of moderate size. The largest of these were related to the modern boa-constrictors. The genera described are *Boavus*, *Lithophis*, and *Limnophis*. The Miocene and Pliocene snakes from the same region are known only from a few fragmentary remains.

The *Pterosauria*, or flying-lizards, are among the most interesting reptiles of Mesozoic time, and many of them left their remains in the soft sediments of our inland Cretaceous sea. These were veritable dragons, having a spread of wings of from ten to twenty-five feet. They differed essentially from the smaller Pterodactyls found in the Old World, in the entire absence of teeth, showing in this respect a resemblance to modern birds; and they possess other distinctive characters. They have therefore been placed in a new order, *Pteranodontia*, from the typical genus *Pteranodon*, of which five species are known. The only other genus is *Nyctosaurus*, represented by a single species. All the specimens yet found are from essentially the same horizon, in the chalk of Kansas. The reported discovery of remains of this order from older formations in this country is without foundation.

The strange reptiles known as *Dinosauria*, which, as we have seen, were numerous during the deposition of our Triassic shales and sandstones, have not yet been found in American Jurassic,[3] but were well represented here throughout the Cretaceous, and at its close became extinct. These animals possess a peculiar interest to the anato-

[1] Dicynodonts (two canine teeth), a singular group of extinct reptiles from South Africa, India, and the Ural Mountains. The family name alludes to the two enormous canine teeth which grow from the upper jaw.

[2] Theriodonts (beast-tooth), a group of extinct reptiles, having, according to Owen, some characters which point toward the Mammalia.

[3] *See* note on page 520.

mist, since, although reptilian in all their main characters, they show clear affinities with the birds, and have some features which may point to mammals. The Cretaceous Dinosaurs were all of large size, and most of them walked on the hind-feet alone, like modern struthious birds. Two well-marked types may be distinguished among the remains discovered in deposits of this age: the herbivorous forms, represented mainly by *Hadrosaurus*, a near ally of the *Iguanodon* of Europe; and their carnivorous enemies, of which *Dryptosaurus* (*Lælaps*) may be considered typical in this country, and *Megalosaurus* in Europe. Near the base of our Cretaceous formation, in beds which I regard as the equivalent of the European Wealden, the most gigantic forms of this order yet discovered have recently been brought to light. One of these monsters (*Titanosaurus montanus*),[1] from Colorado, is by far the largest land-animal yet discovered; its dimensions being greater than was supposed possible in an animal that lived and moved upon the land. It was some fifty or sixty feet in length, and, when erect, at least thirty feet in height! It doubtless fed upon the foliage of the mountain forests, portions of which are preserved with its remains. With *Titanosaurus*, the bones of smaller Dinosaurs, one (*Nanosaurus*), not larger than a cat, as well as those of crocodiles and turtles, are not uncommon.[2] The recent discovery of these interesting remains, many and various, in strata that had long been pronounced by professional explorers barren of vertebrate fossils, should teach caution to those who decline to accept the imperfection of our knowledge to-day as a fair plea for the supposed absence of intermediate forms.

In the marine Cretaceous beds of the West, only a single Dinosaur (*Hadrosaurus agilis*) has been found, but in the higher fresh-water beds, which mark the close of this formation, their remains are numerous, and indicate several well-marked species if not genera. In the marine beds on the Atlantic coast, the bones of Dinosaurs are frequently met with, and in the Upper Cretaceous Greensand of New Jersey, the type specimens of *Hadrosaurus* and *Dryptosaurus* were found. In Cretaceous fresh-water deposits on the coast of Brazil, remains of this order occur, but the specimens hitherto discovered are not sufficiently characteristic for accurate determination. This is unfortunately true of many Dinosaurian fossils from North America, but the great number of these reptiles which lived here during the Cretaceous Period promises many future discoveries, and substantial additions to our present knowledge of the group.

[1] This generic name proved to be preoccupied, and I have substituted for it, *Atlantosaurus*.—O. C. M.

[2] A new order of huge reptiles (*Stegosauria*), apparently allied to the Dinosaurs and Chelonia, and two new genera of Dinosaurs (*Apatosaurus* and *Allosaurus*), have since been described by the writer from the same Upper Jurassic horizon.—(*American Journal of Science*, December, 1877.)

The first appearance of birds in America, according to our present knowledge, was during the Cretaceous Period, although many announcements have been made of their existence in preceding epochs. The evidence of their presence in the Trias, based on footprints and other impressions, is, at present, as we have seen, without value; although we may confidently await their discovery there, if not in older formations. *Archæopteryx*, from the European Jura, the oldest bird known, and now fortunately represented by more than a single specimen, clearly indicates a much higher antiquity for the class. The earliest American forms at present known are the *Odontornithes*, or birds with teeth, which have been exhumed, within the last few years, from the chalk of Kansas. The two genera *Hesperornis* and *Ichthyornis* are types of distinct orders, and differ from each other and from *Archæopteryx* much more than do any existing birds among themselves; thus showing that Birds are now a closed type, and that the key to the history of the class must be sought for in the distant past.

In *Hesperornis*, we have a large aquatic bird, nearly six feet in length, with a strange combination of characters. The jaws are provided with teeth, set in grooves; the wings were rudimentary and useless; while the legs were very similar to those of modern diving birds. This last feature was merely an adaptation, as the more important characters are struthious, showing that *Hesperornis* was essentially a carnivorous swimming ostrich. *Ichthyornis*, a small flying bird, was stranger still, as the teeth were in sockets, and the vertebræ biconcave, as in fishes and a few reptiles. *Apatornis* and other allied forms occur in the same beds, and probably all were provided with teeth. It is strange that the companions of these ancient toothed birds should have been Pterodactyls without teeth. In the later Cretaceous beds of the Atlantic coast various remains of aquatic birds have been found, but all are apparently distinct from those of the West. The known genera of American Cretaceous birds are—*Apatornis*, *Baptornis*, *Graculavus*, *Hesperornis*, *Ichthyornis*, *Laornis*, *Lestornis*, *Palæotringa*, and *Telmatornis*. These are represented by some twenty species. In Europe, but two species of Cretaceous birds are known, and both are based upon fragmentary specimens.

During the Tertiary period, birds were numerous in this country, and all yet discovered appear to have belonged to modern types. The Eocene species described are mostly wading birds, but here, and in the later Tertiary deposits, some characteristic American forms make their appearance, strongly foreshadowing our present avian fauna. The extinct genera are the Eocene *Uintornis*, related to the woodpeckers, and *Aletornis*, which includes several species of waders. Among the existing genera found in our Tertiary beds are—*Aquila*, *Bubo*, *Meleagris*, *Grus*, *Graculus*, *Puffinus*, and *Catarractes*. The great auk (*Alca impennis*), which was once very abundant on our northeast coast, has become extinct within a few years.

In this brief summary of the past life of reptiles and birds in America, I have endeavored to exclude doubtful forms, and those very imperfectly known, preferring to present the conclusions reached by careful study, incomplete though they be, rather than weary you with a descriptive catalogue of all the fossils to which names have been applied. Even this condensed review can hardly fail to give you some conception of the wealth of our continent in the extinct forms of these groups, and thus to suggest what its actual life must have been.

Although the Trias offers at present the first unquestioned evidence of true reptiles, we certainly should not be justified in supposing for a moment that older forms did not exist. So too in considering the different groups of reptiles, which seem to make their first appearance at certain horizons, flourish for a time, and then decline, or disappear, every day brings evidence to show that they are but fragments of the unraveled strands which converge in the past to form the mystic cord uniting all life. If the attempt is made to follow back any single thread, and thus trace the lineage of a group, we are met by difficulties which the science of to-day can only partially remove. And yet the anatomist constantly sees in the fragments which he studies hints of relationship which are to him sure prophecies of future discoveries.

The genealogy of the *Chelonia* is at present unknown, and our American extinct forms, so far as we now have them, throw little light on their ancestry. This is essentially true, also, of our *Plesiosauria*, *Lacertilia*, and *Ophidia*, although suggestive facts are not wanting to indicate possible lines of descent. With the *Crocodilia*, however, the case seems to be different, and Huxley has clearly pointed out the path for investigation. It is probable that material already exists in our museums for tracing the group through several important steps in its development. We have already seen that the modern procœlian type of this order goes back only to the Upper Cretaceous, while the *Belodonts*, of our Triassic rocks, with their biconcave vertebræ, are the oldest known Crocodilians. Our Jurassic, unfortunately, throws but little light on the intermediate forms, but we know that the line was continued, as it was in the Old World through *Teleosaurus*. The beds of the Rocky Mountain Wealden[1] have just furnished us with a genuine "missing link," a saurian (*Diplosaurus*) with essentially the skull and teeth of a modern crocodile, and the vertebræ of its predecessor from the Trias. This peculiar reptile clearly represents an important stage in the progressive series, and evidently one soon after the separation of the crocodile branch from the main stem. The modern Gavial type appears to have been developed about the same time, as the form was well established in the Upper Cretaceous genus, *Thoracosaurus*. The Teleosaurian group, with biconcave vertebræ,

[1] *See* note on page 520, also section.

evidently the parent stock of Crocodilians, became extinct with *Hyposaurus* of the same horizon, leaving the crocodile and gavial, with their more perfect procœlian vertebræ, to contend for the supremacy. In the early Eocene, both of these types were abundant, but some of the crocodiles possessed characters pointing toward the alligators, which do not appear to have been completely differentiated until later.

Nothing is really known to-day of the earlier genealogy of the *Pterosauria;* but our American forms, without teeth, are clearly the last stage in their development before this peculiar group became extinct. The oldest European form, *Dimorphodon*, from the Lower Lias, had the entire jaws armed with teeth, and was provided with a long tail. The later genus, *Pterodactylus*, retained the teeth, but had essentially lost the tail; while *Ramphorhynchus* had retained the elongated tail, but had lost the teeth from the fore-part of both jaws. In the genus *Pteranodon*, from the American Cretaceous, the teeth are entirely absent, and the tail is a mere rudiment. In the gradual loss of the teeth and tail, these reptiles followed the same path as birds, and might thus seem to approach them, as many have supposed. This resemblance, however, is only a superficial one, as a study of the more important characters of the Pterodactyls shows that they are an aberrant type of reptiles, totally off the line through which the birds were developed. The announcement made not long since in Europe, and accepted by some American authors, that the *Pterosauria*, in consequence of certain points in their structure, were essentially birds, is directly disproved by American specimens, far more perfect than those on which the conclusion was based.

It is now generally admitted, by biologists who have made a study of the vertebrates, that birds have come down to us through the Dinosaurs, and the close affinity of the latter with recent struthious birds will hardly be questioned. The case amounts almost to a demonstration, if we compare, with Dinosaurs, their contemporaries, the Mesozoic birds. The classes of Birds and Reptiles, as now living, are separated by a gulf so profound that a few years since it was cited by the opponents of evolution as the most important break in the animal series, and one which that doctrine could not bridge over. Since then, as Huxley has clearly shown, this gap has been virtually filled by the discovery of bird-like reptiles and reptilian birds. *Compsognathus* and *Archæopteryx* of the Old World, and *Ichthyornis* and *Hesperornis* of the New, are the stepping-stones by which the evolutionist of to-day leads the doubting brother across the shallow remnant of the gulf once thought impassable.

[*To be continued.*]

THE GROWTH OF THE STEAM-ENGINE.[1]

By Professor R. H. THURSTON,
OF THE STEVENS INSTITUTE OF TECHNOLOGY.

V.

STEAM-NAVIGATION (*continued*).

93. The prize gained by Fulton was, however, most closely contested by Colonel John Stevens, of Hoboken, who has been already mentioned in connection with the early history of railroads, and who had been, since 1791, engaged in similar experiments.

In 1789 he had petitioned the Legislature of the State of New York for an act similar to that granted Livingston, and stated that his plans were complete, and on paper.

In 1804, while Fulton was in Europe, Stevens had completed a steamboat (Fig. 53) sixty-eight feet long and fourteen feet beam, which combined novelties and merits of design in a manner that was

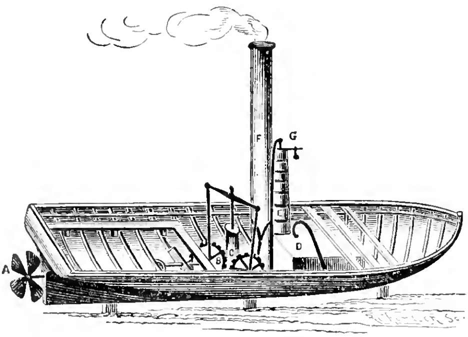


Fig. 53.—John Stevens's Screw-Steamer, 1804.

the best possible evidence of remarkable inventive talent, as well as of the most perfect appreciation of the nature of the problem which he had proposed to himself to solve.

The machinery of this interesting vessel is carefully preserved among the collections of the Stevens Institute of Technology. Its boiler, shown in section, in Fig. 54, is of what is now known as the water tubular variety. The inventor says in his specifications: "The principle of this invention consists of forming a boiler by means of a system or combination of small vessels, instead of using, as is the common mode, one large one; the relative strength of the materials

[1] An abstract of "A History of the Growth of the Steam-Engine," to be published by D. Appleton & Co.

of which these vessels are composed increasing in proportion to the diminution of capacity." The steamboat boiler of 1804 was built to bear a working pressure of over fifty pounds to the square inch, at a time when the usual pressures were from four to seven pounds. It consists of two sets of tubes, closed at one end by solid plugs, and at their opposite extremities screwed into a stayed water and steam reservoir, which was strengthened by hoops. The whole of the lower portion was inclosed in a jacket of iron lined with non-conducting material. The fire was built at one end, in a furnace inclosed in this jacket. The furnace-gases passed among the tubes, down under the body of the boiler, up among the opposite set of tubes, and thence to the smoke-pipe. In another form, as applied to a locomotive in 1825, the tubes were set vertically in a double circle surrounding the fire.

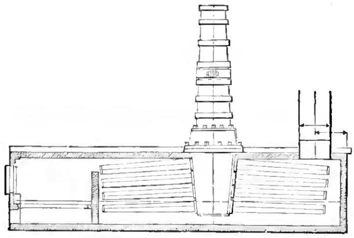


FIG. 54.—STEVENS'S "SECTIONAL" BOILER, 1804.

The engine (Fig. 55) was a direct-acting, high-pressure condensing engine of ten inches diameter of cylinder, two feet stroke of piston, and drove a *screw* of four blades, and of a form which, even to-day, appears quite good. The hub and one blade of this screw are still preserved. The whole is a most remarkable piece of early engineering. The use of such a boiler seventy years ago is even more remarkable than the adoption of the screw-propeller in such excellent proportions thirty years before the labors of Smith and of Ericsson brought the screw into general use. We have, in this strikingly original combination, as good evidence of the existence of unusual engineering talent, in this fellow-countryman of ours, as we found of his political and statesman-like ability in those efforts to forward the introduction of railways already described.

Colonel Stevens designed a peculiar form of iron-clad in the year 1812, which has been since reproduced by no less distinguished and successful an engineer than the late John Elder, of Glasgow, Scotland. It consisted of a saucer-shaped hull, carrying a heavy battery and plated with iron of ample thickness to resist the shot fired from the heaviest ordnance then known. This vessel was secured to a swivel, and was anchored in the channel to be defended. A set of screw-propellers driven by steam-engines and situated beneath the vessel, where they were safe against injury by shot, were so arranged as to permit the vessel to be rapidly revolved about its centre. As each gun was brought into line of fire it was discharged, and was then reloaded before coming around again. This was probably the earliest embodiment of the now well-established "Monitor" principle.

This great engineer and inventor was therefore far in advance of his time. The sectional steam-boiler only just becoming a standard type; high-pressure steam with condensation has just become generally adopted; the screw only came in use forty years later, when Ericsson, Smith, and Woodcroft, came forward with it, and twin-

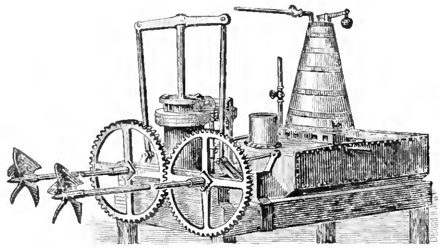


Fig. 55.—Machinery of Twin-Screw Steamer of 1804.

screws are hardly yet familiar to engineers. The revolving battery protected by iron plating is another of what are generally considered recent devices; and the peculiar Stevens revolving ship is reproduced by Elder sixty years later.

A model of the little steamer built in 1804 is preserved in the lecture-room of the department of mechanical engineering at the Stevens Institute of Technology, and the machinery itself (Fig. 55), the high-pressure "section" or "safety" tubular boiler as it would be called to-day, the high-pressure condensing engine with rotating valves, and with twin-screw propellers, is given a place of honor in the model-room or museum, where it contrasts singularly with the mechanism contributed to the collection by manufacturers and inventors of our own time.

94. The first of Stevens's boats performed so well that he immedi-

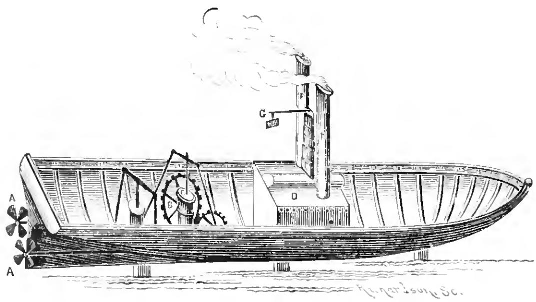


Fig. 56.—Stevens's Twin-Screws, 1805.

ately built another one, using the same engine as before, but employing a larger boiler, and propelling the vessel by *twin-screws* (Fig. 56 [1]), the latter being another instance of his use of a device brought forward long afterward as new, and since frequently adopted.

[1] These cuts are *fac-similes* of steel engravings made for Stevens.

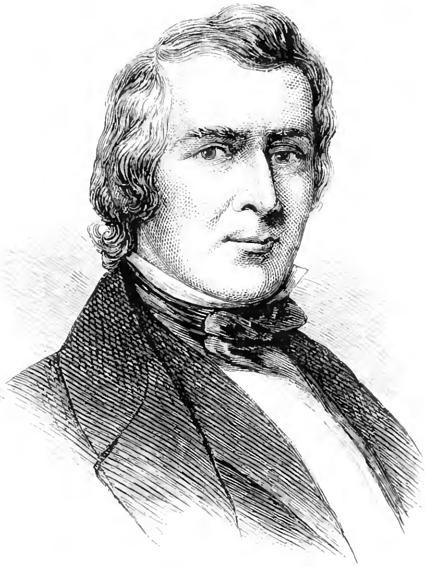
This boat was sufficiently successful to indicate the probability of making steam-navigation a commercial success, and Stevens, assisted by his sons, built a boat which he named the Phœnix, and made the first trial in 1807, just too late to anticipate Fulton. This boat was driven by paddle-wheels.

The Phœnix, shut out of the waters of the State of New York by the monopoly held by Fulton and Livingston, was placed for a time on a route between Hoboken and New Brunswick; and then, anticipating a better pecuniary return, it was concluded to send her to Philadelphia to ply on the Delaware.

At that time, no canal offered the opportunity to make an inland passage, and, in June, 1808, Robert L. Stevens, a son of John, started with Captain Bunker to make the passage by sea.

Although meeting a gale of wind, he arrived at Philadelphia safely, having been the first to trust himself on the open sea in a vessel relying entirely upon steam-power.

95. From this time forward the Messrs. Stevens, father and sons, continued to construct steam-vessels.



Robert L. Stevens.

After Fulton and Stevens had led the way, steam-navigation was introduced very rapidly on both sides the ocean, and on the Mississippi the number of boats set afloat was soon large enough to fulfill Evans's prediction that the navigation of that river would become a steam-navigation.

Except in Stevens's earlier boats, and in the boats plying on the

Western rivers, all steamers were then propelled, as they are still, by condensing engines. The instrument of propulsion was also, even in Stevens's own boats after his earlier experiments, the paddle-wheel. The use of the screw did not become general, even in deep water, until within the last twenty years.

96. The steam-engine in most general use for sea-going ships when the introduction of the screw compelled its withdrawal, with the paddle-wheel which it drove, was that shown in Fig. 57, which represents the side-lever engine of the steamer Pacific, as designed by Charles W. Copeland.

In the sketch, *A* is the steam-cylinder; *B C* the side-rods, or links, connecting the cross-head in the piston-rod with the end-centres

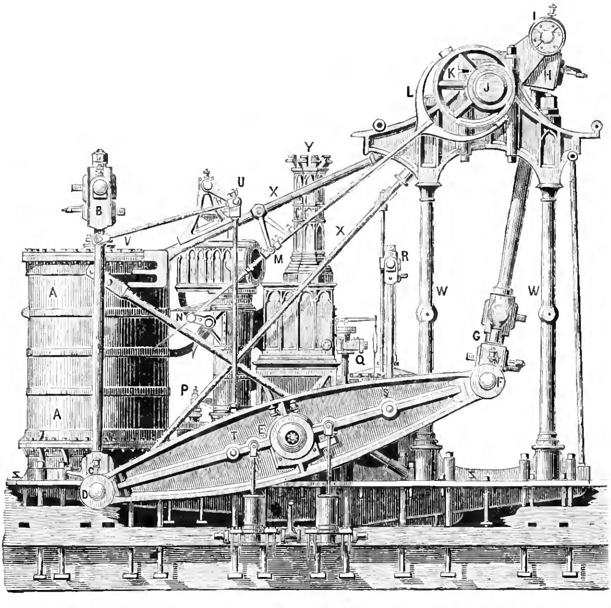


Fig. 57.—The Side-Lever Engine, 1849.

D, of the side-lever *D E F*, which vibrates about the main centre *E*, like the overhead beams. A cross-tail at *G* is connected with the side-lever and with the connecting-rod *G H*, which latter communicates motion to the crank *I J*, turning the main shaft *J*. The air-pump and condenser are seen at *O M*. This engine was one of the earliest and best examples of the type, and perhaps the first ever fitted with a framing of wrought-iron.

97. After the experiments of Stevens, we find no evidence of the use of the screw, although schemes were proposed and various forms were even patented, until about 1836.

In 1836 Francis P. Smith, an English farmer, who had become interested in the subject, experimented with a screw made of wood, and fitted in a boat built with funds furnished by a Mr. Wright, a London banker. He exhibited it on the Thames and on the Paddington Canal for several months. In February, 1837, by an accident, a part of the screw-blade was broken off, and the improved performance of the boat called attention to the advisability of determining its best proportions.

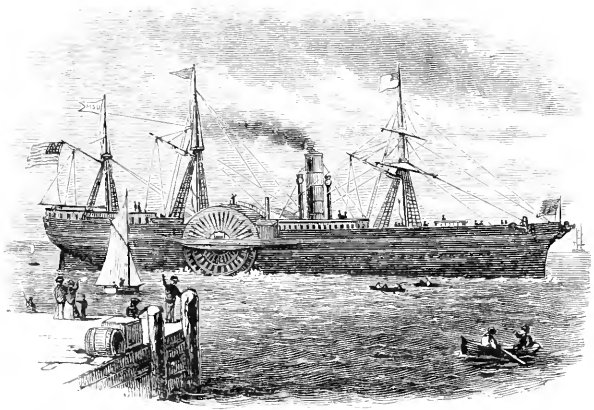


Fig. 58.—The Side-Wheel Ocean-Steamer, 1850.

In 1837 Smith exhibited his courage and his faith in the reliability of his little steamer by making a coasting-voyage in quite heavy weather, and the performance of his vessel was such as to fully justify the confidence felt in it by its designer.

The British Admiralty soon had its attention called to the performance of this vessel, and to the very excellent results attained by the Archimedes, a vessel of 237 tons burden, which was built by Smith and his coadjutors in 1838, and tried in 1839, attaining a speed of eight knots an hour. By the performance of the Archimedes, the advantages of screw-propulsion, especially for naval purposes, were rendered so evident that the British Government built its first screw-vessel, the Rattler, and Brunel adopted the screw in the iron steamer Great Britain, which had been designed originally as a paddle-steamer.

98. Simultaneously with Smith, Captain John Ericsson was engaged in the same project.

He patented, July, 1836, a propeller which was found at the first trial to be of such good form and proportions as to give excellent results.

His first vessel was the Francis B. Ogden, named after the United States consul at Liverpool, who had lent the inventor valuable aid in his work. The boat was forty-five feet long, eight feet beam, and drew three feet of water. It attained a speed of ten miles an hour, and towed an American packet-ship, the Toronto, four and a half miles an hour on the Thames. This was a splendid success.

Ericsson built several screw-boats, and finally, meeting Captain Robert F. Stockton, of the United States Navy, that gentleman was so fully convinced of the merits of Ericsson's plans that he ordered an iron vessel of seventy feet length and ten feet beam, with engines of fifty-horse power.

The trial of the Stockton, in 1839, was eminently satisfactory. The vessel was sent to America under sail, and the designer was soon induced to follow her to this country, where his later achievements are well known.

The engines of the Stockton were direct-acting, the first examples of engines coupled directly to the crank-shaft without intermediate gearing, that we meet with after that of John Stevens.

99. Soon after Ericsson arrived in the United States, he obtained an opportunity to design a screw-steamer for the United States Navy, the Princeton, and, at about the same time, the English and French Governments had screw-steamers built from his plans, or from those of his agent in England, the Count de Posen.

In these ships—the Amphion and the Pomone—the first horizontal, direct-acting engines ever built were used. They were fitted with double-acting air-pumps, having canvas valves and other novel features.

From 1840 the screw gained favor rapidly, and finally began to displace the paddle for deep-water navigation. Progress in this direction was at first somewhat slow.

In 1840, and during the following ten years, many experiments were instituted between the performance of screw and paddle steamers without definitely settling engineering practice.

100. The reason was, probably, that the introduction of the rapidly-revolving screw, in place of the slow-moving paddle-wheel, necessitated a complete revolution in the design of their steam-engines. And the unavoidable change from the heavy, long-stroked, low-speed engines, previously in use, to the light engines, with small cylinders and high piston-speed, called for by the new system of propulsion, was one that necessarily occurred slowly, and was accompanied by its share of those engineering blunders and accidents that invariably take place during such periods of transition.

Engineers had first to learn to design such engines as should be reliable under the then novel conditions of screw-propulsion, and their experience could only be gained through the occurrence of many mishaps and costly failures. The best proportions of engines and screws for a given ship were determined only by long experience, although great assistance was derived from the extensive series of experiments made on the French steamer Pelican. It also became necessary to train up a body of engine-drivers who should be capable of managing these new engines, for they required the exercise of a then unprecedented amount of care and skill. Finally, with the accomplishment of these two requisites to success, must simultaneously occur the enlightenment of the public, professional as well as non-professional, in regard to their advantages.

Thus it happens that it is only very recently that the screw has

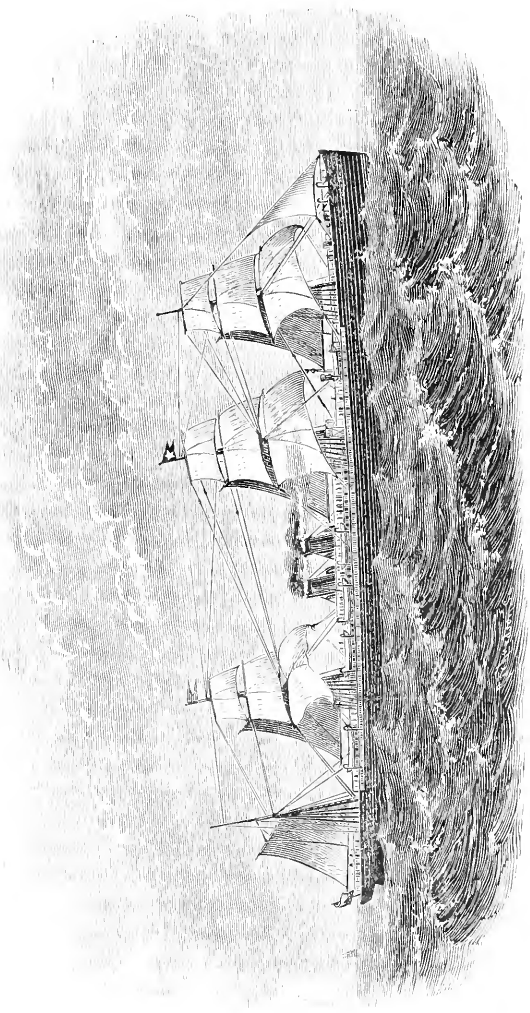


Fig. 59.—The Modern Steamship: The Germanic.

attained its proper place as an instrument of propulsion, and has only now driven the paddle-wheel almost out of use, except in shoal water.

Now our large screw-steamers are of higher speed than any paddle-steamers on the ocean, sometimes crossing the Atlantic from New

York to Queenstown in a week, making their passages with wonderful regularity, and developing their power at far less cost than the old side-wheel steamers. This increased economy is due, not only to the use of a more efficient propelling instrument, but, perhaps in even a higher degree, to the economy which has followed as a consequence of the accompanying changes in structure of the steam-engine driving it.

101. The earliest days of screw propulsion witnessed the use of steam of ten or fifteen pounds' pressure, in a geared engine using jet condensation, and giving a horse-power at an expense of, perhaps, seven or eight pounds of coal per hour.

A little later came direct-acting engines with jet condensation, and steam at twenty pounds' pressure, costing about five or six pounds per horse-power per hour. The steam-pressure rose a little higher with the use of greater expansion, and the economy of fuel was further increased. The introduction of the surface-condenser, which began to be generally adopted some ten or fifteen years ago, brought down the cost of power to between three and four pounds in the better class of engines.

At about the same time, this change to surface-condensation helping greatly to overcome the troubles arising from boiler-incrustation, which had checked the rise in steam-pressure above about twenty-five pounds, and, it being at the same time learned by engineers that the deposit of the scale and sulphate of lime in the marine boiler was determined by temperature rather than by the degree of concentration, and that all the lime entering the boiler was deposited at the pressure just mentioned, a sudden advance took place.

Careful design, good workmanship, and skillful management, made the surface-condenser an efficient apparatus, and, the dangers of incrustation being thus lessened, the movement toward higher pressures recommenced and progressed so rapidly that, now, seventy-five pounds per square inch is very usual, and two hundred and fifty pounds has been attained in marine engines built by the Messrs. Perkins, who are said to have reached the remarkable economy of a horse-power for each pound of combustible consumed in the boiler.

102. These high pressures, and the greater expansion of the steam, have, in turn, produced another revolution in engine-construction.

It has at last become generally known, as was seen by well-informed and scientific engineers long ago, that one of the most serious losses of heat, and consequently of power, in the steam-engine, when expansion is carried to a considerable extent, occurs in consequence of condensation and the deposition of moisture upon the interior of the cylinder, which moisture, when the exhaust takes place, carries, by its reëvaporation, large quantities of heat into the condenser, without deriving any power from it.

The steam-jacket furnishes one means of reducing the amount of this loss by keeping up the temperature of the interior of the cylinder, and thus preventing, in some degree, this deposition, and by reëvaporating this moisture during expansion, and thus deriving useful effect from heat so expended before the exhaust-valve opens, and it is thrown unutilized into the condenser.

James Watt, therefore, applied the steam-jacket more wisely than he knew, for this matter was not, in his time, understood. Indeed, he gave up its use, thinking it could have no possible economical value, but the consequent falling off in the duty of the engine induced him to restore it, and we still find it on the Cornish engine of to-day.

103. This loss is also, in some degree, prevented, by dividing the expansive working of the steam among two or more cylinders, as in the compound or Woolf system described in the preceding lectures.

Here the heat wasted in either cylinder is less, in consequence of the lessened range of temperature, and that lost by one cylinder is carried into the second, and then, to some extent, utilized.

The amount of saving effected by these means is quite considerable—so great, in fact, as to have produced a complete revolution in engineering practice in the construction of marine engines by the best-known builders.

JOHN ELDER.

They have, under the lead of John Elder, adopted the Woolf engine, which had, in earlier times, with lower steam, less expansion, and less intelligent engineering, proved apparently a failure.

104. To-day, nearly all sea-going steamers are fitted with such

engines having surface-condensers, and with tubular boilers, which are fitted, frequently, with superheaters. One of the best examples of these steamers, the City of Peking, a screw-steamer built by Roach

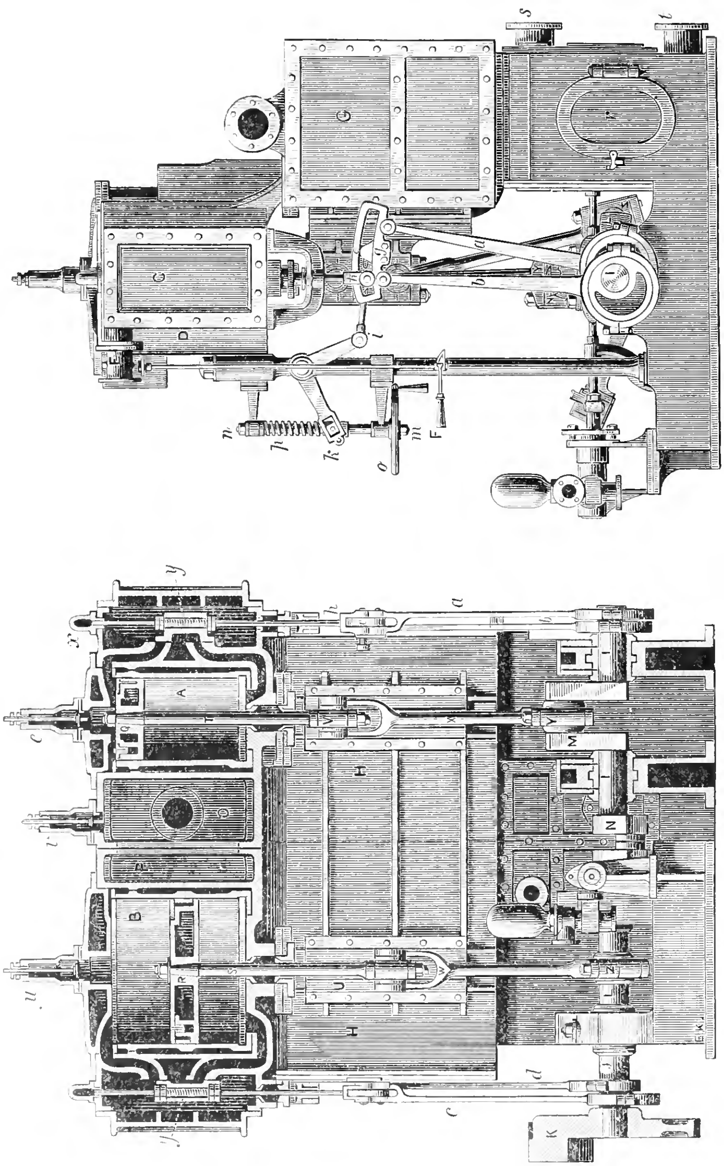


FIG. 60.—THE MODERN COMPOUND MARINE STEAM-ENGINE.

for the Pacific Mail Company, is a vessel of 5,000 tons. There are two pairs of compound-engines, having cylinders of 51 and 88 inches diameter, and $4\frac{1}{2}$ feet stroke of piston. The crank-shafts are 18 inches in diameter. Steam is carried at 60 pounds, and is expanded nine times. The boilers are ten in number, cylindrical in form, and with cylindrical flues; they are 13 feet in diameter, $10\frac{1}{2}$ feet long, with shells of iron $\frac{13}{16}$ inch thick, and have 520 feet of grate-surface, 16,500 square feet of heating-surface, and 1,600 square feet of superheating-surface. The smoke-funnels, or stacks, are $8\frac{1}{2}$ feet in diameter and 70 feet high.

Fig. 60 shows a section of the simplest and the least costly form of compound-engine, as it is now built on the Clyde, in Great Britain, and in the United States, on the Delaware.

Here, the cranks *Y Z* are coupled at an angle of ninety degrees, only two cylinders, *A B*, being used, and an awkward distribution of pressure is avoided by having a considerable volume of steam-pipe, or by a steam-reservoir, *O P*, between the two cylinders.

The valves, *y y*, are set like those of an ordinary engine, the peculiarity being that the steam exhausted by the one cylinder, *A*, is used again in the second and larger one, *B*. In this combination, the expansion is generally carried to about six times, the pressure of steam in the boiler being usually between sixty and seventy-five pounds per square inch.

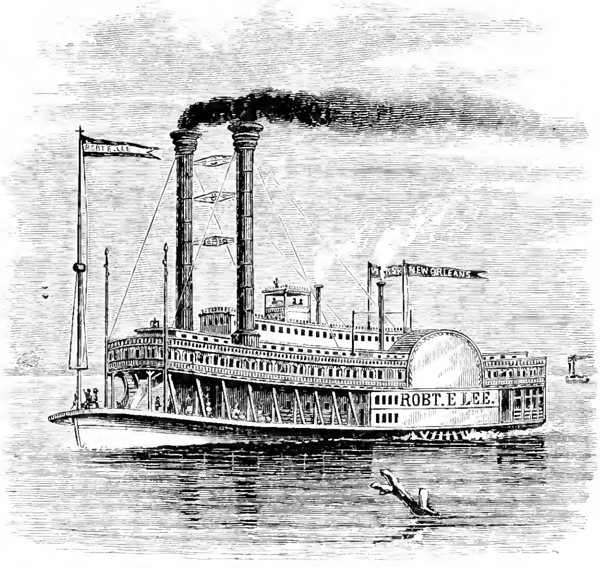


Fig. 61.—The Mississippi Steamboat, 1876.

105. The revolution by which the screw has superseded the paddle-wheel elsewhere, has not taken place in our shallow American rivers, where there is not depth enough for the screw.

In the West, boats are driven by the horizontal high-pressure engine usually, as in the days of Oliver Evans, and retain their peculiarities of construction. Some of the Mississippi steamboats (Fig. 61) make the trip from St. Louis to New Orleans—about 1,200 miles—in four days, and can make, in still water, more than twenty miles an hour.

In the East, we have a form of engine which is distinctively known as the American steamboat-engine. It is shown in Fig. 62.

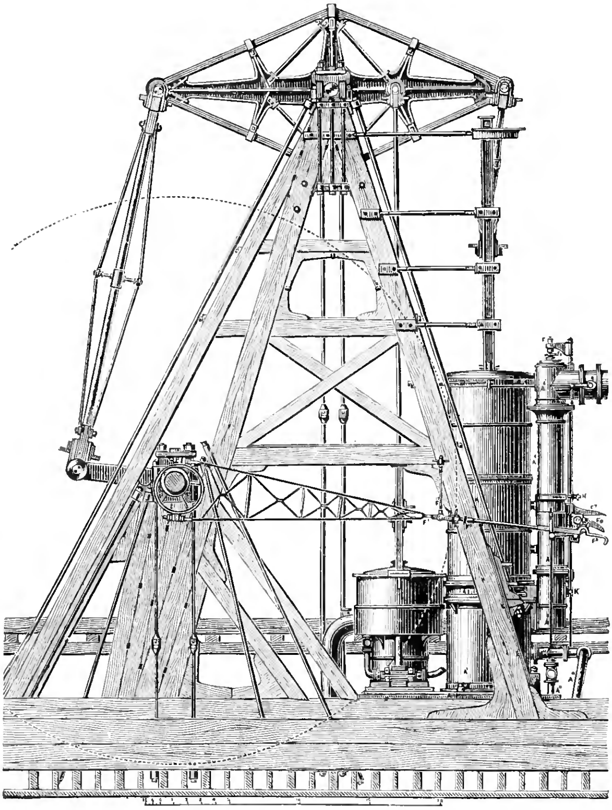


Fig. 62.—The American Beam-Engine.

This engine is recognized throughout the engineering world as one of the most complete and thoroughly perfected of known *types* of steam-engine.

106. This peculiarly effective and easy-working engine, and the equally peculiar vessel (Fig. 63) which is usually impelled by it, are, in all their peculiarities, characteristically American.

The "skeleton-beam," which is one of the prominent features, was first used by Robert L. Stevens on the ferry-boat Hoboken, in 1822.

The valve-gear is usually that known as the "Stevens valve-gear." It was invented by Messrs. Robert L. and Francis B. Stevens, in 1841. The "gallows-frame" took its present form in the hands of

Messrs. Stevens. The hull of the Phœnix had hollow water-lines sixty-five years ago, and this important characteristic of modern vessels is, therefore, an American improvement.

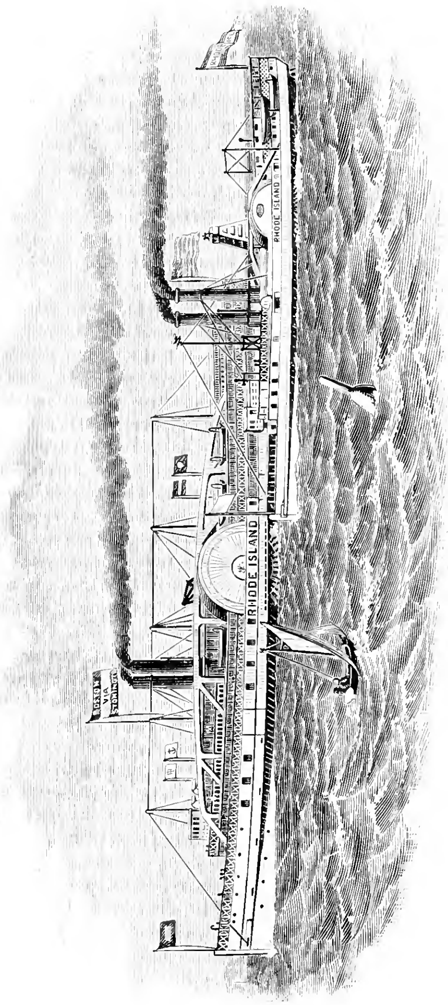


Fig. 63.—The Two Rhode Islands, 1836-1876.

The North America (Fig. 64) was built in 1827. The hull was stiffened by the "hog-frame," now as distinctive a characteristic of the vessel as are the gallows-frame and the skeleton-beam of the engine.

This engine is not usually quite as economical in fuel as are the screw-engines last described; but it has the advantages—which are so extremely important in the shallow, flexible hulls of our river-boats

—of being the easiest working and least easily injured, by "getting out of line," of all known forms of engines.

The British and Continental engineers also still retain the paddle-wheel in some of the steamers plying in their narrower and more

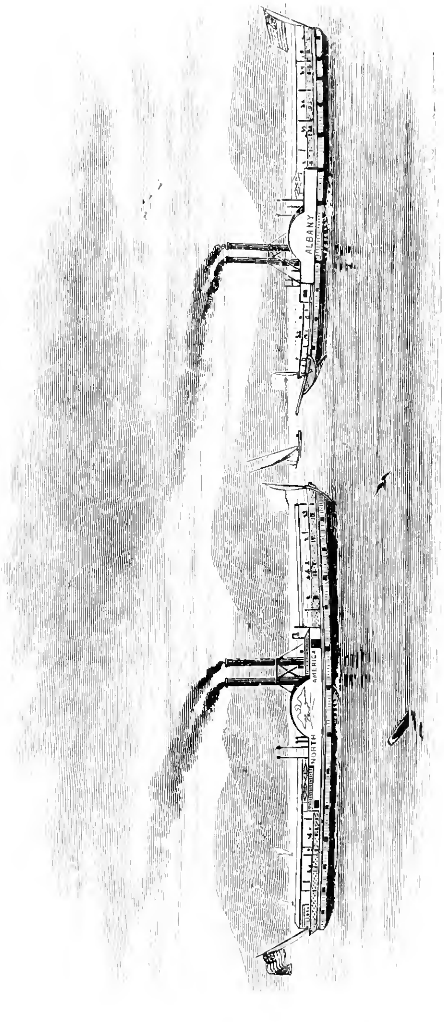


Fig. 64.—The North America and the Albany, 1827.

closely-crowded rivers and harbors, in consequence of the greater facility which it gives for manœuvring.

107. The magnitude of our modern steamships excites the wonder and admiration of even the people of our own time. There is certainly no creation of art that can be grander in appearance than a transatlantic steamer, a hundred and fifty yards in length, and weighing,

with her stores, 5,000 or 6,000 tons, as she starts on her voyage, moved by engines more than equal in power to the united strength of 5,000 horses. Nothing can more thoroughly awaken a feeling of awe than the sight of immense structures like the great modern iron-clads (Fig. 65), vessels having a total weight of 8,000 to 10,000 tons,

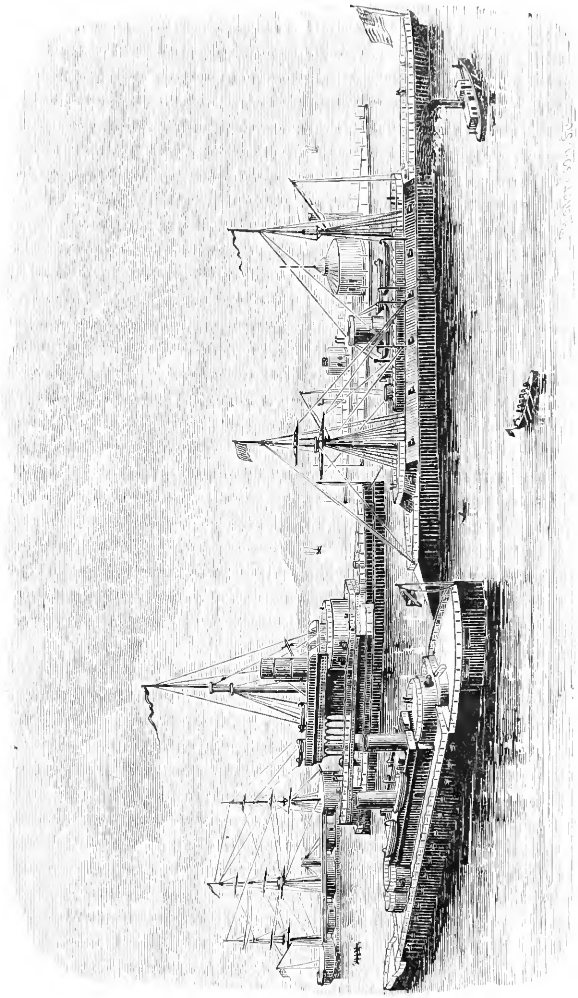


FIG. 65.—MODERN IRON-CLADS.

and propelled by steam-engines of 8,000 or 10,000 horse-power, carrying guns whose shot penetrate solid iron fifteen inches thick, and having a power of impact, when steaming moderately, sufficient to raise 35,000 tons a foot high.

108. Far more huge than the Monarch among the iron-clads even is that prematurely-built monster, the Great Eastern (Fig. 66), more

than the eighth of a mile (680 feet) long, of 84 feet beam, and drawing thirty feet of water at load-draught, when the weight of ship and contents amounts to over 25,000 tons. This great vessel

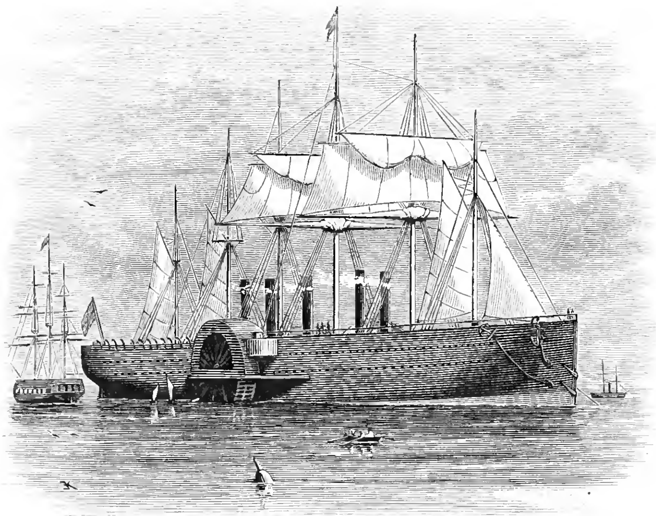


FIG. 66.—THE GREAT EASTERN.

is driven by steam-engines of 10,000 horse-power, turning huge paddle-wheels 56 feet in diameter, and a screw-propeller having a diameter of 24 feet.

109. We are evidently fulfilling at least a part of that well-known poetical prophecy which Darwin wrote in the early days of the steam-engine, and possibly before Watt had told him of the great advance which had been produced by his inventive genius:

"Soon shall thy arm, unconquered steam, afar
Drag the slow barge, or drive the rapid car;
Or, on wide-waving wings expanded, bear
The flying chariot through the fields of air."

NOTE.—We are compelled to omit the sketch of the development of the stationary engine, and for it must refer our readers to the publication of which this is an abstract. We shall conclude this series by an abstract of that portion which outlines the Philosophy of the Steam-Engine, and exhibits the direction of improvement, and the changes which must precede the production of a possible new type, "the steam-engine of the future."

[1] "Botanic Garden," London, 1781.

EVOLUTION OF CEREMONIAL GOVERNMENT.

By HERBERT SPENCER.

II. TROPHIES.

EFFICIENCY of every kind is a source of self-satisfaction; and proofs of it are prized as bringing applause. The sportsman, narrating his successes when opportunity serves, keeps such spoils of the chase as he conveniently can. Is he a fisherman? Then, occasionally, the notches cut on the butt of his rod show the number and lengths of his salmon; or, in a glass case, there is preserved the great Thames-trout he once caught. Has he stalked deer? Then in his hall, or dining-room, are fixed up their heads; which he greatly esteems when the attached horns have many "points." Still more, if he is a successful hunter of tigers, does he value the skins demonstrating his prowess.

Trophies of such kinds, even among ourselves, give to their owner some influence over those around him. A traveler who has brought from Africa a pair of elephant's tusks, or the formidable horn of a rhinoceros, impresses those who come in contact with him as a man of courage and resource, and, therefore, as one not to be trifled with. A vague kind of governing power accrues to him.

Naturally, by primitive men, whose lives are predatory, and whose respective values largely depend on their powers as hunters, animal-trophies are still more prized, and tend, in a greater degree, to bring honor and influence. Hence the fact that rank in Vate is indicated by the number of bones of all kinds suspended in the house. Of the Shoshone warrior we are told that, "killing a grizzly bear also entitles him to this honor, for it is considered a great feat to slay one of these formidable animals, and only he who has performed it is allowed to wear their highest insignia of glory, the feet or claws of the victim." Among the Santals "it is customary to hand these trophies (skulls of beasts, etc.) down from father to son." And when, with such facts to give us the clews, we read that the habitation of the king of the Koossas "is no otherwise distinguished than by the tail of a lion or a panther hanging from the top of the roof," we can scarcely doubt that this symbol of royalty was originally a trophy displayed by a chief whose prowess had gained him supremacy.

But, as, among the uncivilized and semi-civilized, human enemies are more to be feared than beast enemies, and conquests over men are therefore occasions of greater triumphs than conquests over animals, it results that proofs of such conquests are usually still more valued. A brave who returns from battle does not get honor if his boasts are unsupported by evidence; but if he proves that he has killed his man by bringing back some part of him—especially a part which the corpse could not yield in duplicate—he raises his character in the tribe and increases his power. Preservation of trophies, with a view to display and consequent strengthening of personal influence, therefore becomes an established custom. In Ashantee "the smaller joints, bones, and teeth of the slain are worn by the victors about their persons." Among the Ceris and Opatas of North Mexico, "many cook and eat the flesh of their captives, reserving the bones as trophies." And another Mexican race, "the Chichimecs, carried with them a bone on which, when they killed an enemy, they marked a notch, as a record of the number each had slain." The meaning of trophy-taking, and its social effects, being recognized, let us consider in groups the various forms of it.

Of parts cut from the bodies of the slain, heads are the commonest; probably as being the most unmistakable proofs of victory.

We need not go far afield for illustrations both of the practice and its motives. The most familiar of books contains them. In Judges vii. 25, we read: "And they took two princes of the Midianites, Oreb and Zeeb; and they slew Oreb upon the rock Oreb, and Zeeb they slew at the wine-press of Zeeb, and pursued Midian, and brought the heads of Oreb and Zeeb to Gideon on the other side Jordan." The decapitation of Goliath by David, followed by carrying of his head to Jerusalem, further illustrates the custom. And, if, by so superior a race, heads were taken home as trophies, we shall not wonder at finding the custom of so taking them among inferior races all over the globe. By the Chichimecs in North America "the heads of the slain were placed on poles and paraded through their villages in token of victory, the inhabitants meanwhile dancing round them." In South America, by the Abipones, heads are brought back from battle "tied to their saddles;" and the Mundrucus "ornament their rude and miserable cabanas with these horrible trophies." Of Malayo-Polynesians having a like habit, may be named the New-Zealanders; they dry and treasure up the heads of their slain foes. In Madagascar, during Queen Ranavalona's reign, heads raised on poles were placed along the coast. Skulls of enemies are preserved as trophies by the natives on the Congo, and by other African peoples: "The skull and thigh-bones of the last monarch of Dinkira are still trophies of the court of Ashantee." Among the Hill-tribes of India, the Kukis may be instanced as having this practice. Morier tells us that in Persia, under the stimulus of money-payments, "prisoners" (of war) "have been put to death in cold blood, in order that the heads, which are immediately dispatched to the king and deposited in heaps at the palace-gate, might make a more considerable show." And that among other Asiatic races head-taking persists spite of semi-civilization, we are reminded by the recent doings of the Turks, who have in some cases exhumed the bodies of slain foes and decapitated them.

This last instance draws attention to the fact that this barbarous custom has been, and is, carried to the greatest extremes, along with militancy the most excessive. Among ancient examples there are the doings of Timour, with his exaction of 90,000 heads from Bagdad. Of modern examples the most notable comes from Dahomey. "The sleeping-apartment of a Dahoman king," says Burton, "was paved with the skulls of neighboring princes and chiefs, placed there that the king might tread upon them." And, according to Dalzel, the king's statement, that "his house wanted thatch," was "used in giving orders to his generals to make war, and alludes to the custom of placing the heads of the enemy killed in battle, or those of the prisoners of distinction, on the roofs of the guard-houses at the gates of his palaces."

But now, ending instances, let us observe how this taking of heads as trophies initiates a means of strengthening political power; how it becomes a factor in sacrificial ceremonies; and how it enters into social intercourse as a controlling influence. That the pyramids and towers of heads built by Timour at Bagdad and Aleppo, must have conduced to his supremacy by striking terror into the subjugated, as well as by exciting dread of vengeance for insubordination among his followers, cannot be doubted; and that living in a dwelling paved and decorated with skulls, implies, in a Dahoman king, a character generating fear among enemies and obedience among subjects, is obvious. In Northern Celebes, where, before 1822, "human skulls were the great ornaments of the chiefs' houses," these proofs of victory in battle, used as symbols of authority, could not fail to exercise a governmental effect.

That heads are offered in propitiation of the dead, and that the ceremony of offering them is thus made part of a quasi-worship, there are clear proofs. One is supplied by the people just named. "When a chief died his tomb must be adorned with two fresh human heads, and if those of enemies could not be obtained slaves were killed for the occasion." Among the Dyaks, who, though in many respects advanced, have retained this barbarous practice sanctified by tradition, it is the same: "the aged warrior could not rest in his grave till his relatives had taken a head in his name." By the Kukis of Northern India sacrificial head-taking is carried still further. Making raids into the plains to procure heads, they "have been known in one night to carry off fifty. These are used in certain ceremonies performed at the funerals of the chiefs, and it is always after the death of one of their rajahs that these incursions occur."

That the possession of these grisly tokens of success gives an influence in social intercourse, proof is yielded by the following passage from St. John: "Head-hunting is not so much a religious ceremony among the Pakatans, Borneo, as merely to show their bravery and manliness. When they quarrel, it is a constant phrase, 'How many heads did your father or grandfather get?' If less than his own number, 'Well, then, you have no occasion to be proud.'"

The head of an enemy is of inconvenient bulk; and when the journey home is long there arises a question—cannot proof that an enemy has been killed be given by carrying back a part only? In some places the savage infers that it can, and acts on the inference.

This modification and its meaning are well shown in Ashantee, where "the general in command sends to the capital the jawbones of the slain enemies;" and where, as Ramseyer further tells us, "a day of rejoicing occurred on July 3d, when nineteen loads of jaws arrived from the seat of war as trophies of victory." When first found, the Tahitians, too, carried away the jawbones of their enemies; and Cook saw fifteen of them fastened up at the end of a house. Similarly of Vate, where "the greater the chief, the greater the display of bones," we read that, if a slain enemy was "one who spoke ill of the chief, his jaws are hung up in the chief's house as a trophy:" a tacit threat to others who vilified him. A recent account of another Papuan race inhabiting Boigu, on the coast of New Guinea, further illustrates the practice, and also its social effect. Mr. Stone writes: "By nature these people are bloody and warlike among themselves, frequently making raids to the 'Big Land,' and returning in triumph with the heads and jawbones of their slaughtered victims, the latter becoming the property of the murderer, and the former of him who decapitates the body. The jawbone is consequently held as the most valued trophy, and the more a man possesses the greater he becomes in the eyes of his fellow-men." It may be added that, by the Tupis of South America, trophies of an allied kind were worn. In honoring a victorious warrior, "among some tribes they rubbed his pulse with one of the eyes of the dead, and hung the mouth upon his arm like a bracelet."

With the display of jaws as trophies, there may be named a kindred use of teeth. America furnishes instances. The Caribs "strung together the teeth of such of their enemies as they had slain in battle, and wore them on their legs and arms." The Tupis, after devouring a captive, preserved "the teeth strung in necklaces." The Moxos women wore "a necklace made of the teeth of enemies killed by their husbands in battle." In the times of the Spanish invaders, the Central Americans made an image, "and in its mouth were inserted teeth taken from the Spaniards whom they had killed." And a passage quoted above specifies teeth as among the trophies worn by the Ashantees.

Other parts of the head, easily detached and carried, also serve. Where many enemies are slain, the collected ears yield in small bulk a means of counting; and probably Zenghis Khan had this end in view when, in Poland, he "filled nine sacks with the right ears of the slain." Noses, again, are in some cases chosen as easily-enumerated trophies. Anciently, by Constantine V., "a plate of noses was accepted as a grateful offering;" and, at the present time, the noses they have taken are carried by soldiers to their leaders in Montenegro. That the slain Turks thus deprived of their noses, even to the extent of 500 on one battle-field, were so treated in retaliation for the decapitations the Turks had been guilty of, is true; but this excuse does not alter the fact that "the Montenegrin chiefs could not be persuaded to give up the practice of paying their clansmen for the number of noses produced."

The ancient Mexicans, having for gods their deified cannibal ancestors, in whose worship the most horrible rites were daily performed, in some cases took as trophies the entire skins of the vanquished. "The first prisoner made in a war was flayed alive. The soldier who had captured him dressed himself in his bleeding skin, and thus, for some days, served the god of battles. . . . He who was dressed in the skin walked from one temple to another; men and women followed him, shouting for joy." While we here see that the trophy was taken by the victor primarily as a proof of his prowess, we are also shown how there resulted a religious ceremony : the trophy was displayed for the supposed gratification of deities delighting in bloodshed. There is further evidence that this was the intention. "At the festival of the goldsmiths' god Totec, one of the priests put on the skin of a captive, and, being so dressed, he was the image of that god Totec." Nebel (plate 3, Fig. 1) gives the basalt figure of a priest (or idol) clothed in a human skin; and additional evidence is yielded by the custom of the neighboring state of Yucatan, where "the bodies were thrown down the steps, flayed, the priest put on the skins, and danced, and the body was buried in the yard of the temple. They took prisoners in war for these sacrifices, and condemned some of their own people to them."

Usually, however, the skin-trophy is relatively small: the requirement being simply that it shall be one of which the body yields no duplicate. The origin of it is well shown by the following description of a practice among the Abipones. They preserve the heads of enemies, and—

"When apprehension of approaching hostilities obliges them to remove to places of greater security, they strip the heads of the skin, cutting it from ear to ear beneath the nose, and dexterously pulling it off along with the hair. . . . That Abipon who has most of these skins at home excels the rest in military renown."

Evidently, however, the whole skin is not needful to prove previous possession of a head: the part covering the crown of the head, distinguished from other parts by the arrangement of its hairs, serves the purpose: hence scalping. Tales of Indian life have so far familiarized us with this custom that illustrations are needless. How in some cases, after a victory, "scalps are fixed on a pole" and danced round —how they are "highly prized as trophies, and publicly exhibited at feasts," need not be proved in detail. But one piece of evidence, supplied by the Shoshones, may be named; because it clearly shows us the use of the trophy as an accepted evidence of victory—a kind of legal proof regarded as alone conclusive. We read that—

> "Taking an enemy's scalp is an honor quite independent of the act of vanquishing him. To kill your adversary is of no importance unless the scalp is brought from the field of battle; and were a warrior to slay any number of his enemies in action, and others were to obtain the scalps or first touch the dead, they would have all the honors, since they have borne off the trophy."

Though we usually think of scalp-taking in connection with the North American Indians, yet it is not restricted to them. Herodotus describes the Scythians as scalping their conquered enemies; and at the present time the Nagas of the Indian hills take scalps and preserve them.

Preservation of hair alone, as a trophy, is less general; doubtless because the evidence of victory which it yields is inconclusive; one head might supply hair for two trophies. Still there are cases in which an enemy's hair is displayed in proof of success in war. Speaking of a Naga, Grange says his shield "was covered over with the hair of the foes he had killed." The tunic of a Mandan chief is described by Catlin as "fringed with locks of hair taken by his own hand from the heads of his enemies." And we are told of the Cochimis that "at certain festivals their sorcerers . . . . wore long robes of skins, ornamented with human hair."

Among easily-transported parts carried home to prove victory, may next be named hands and feet. By the Mexican tribes, Ceris and Opatas, "the slain are scalped, or a hand is cut off, and a dance performed round the trophies on the field of battle." So, too, of the Californian Indians, who also took scalps, we are told that "the yet more barbarous habit of cutting off the hands, feet, or head, of a fallen enemy, as trophies of victory, prevailed more widely. They also plucked out and carefully preserved the eyes of the slain." Though this is not said, we may assume that either the right or the left foot or hand was the trophy; since, in the absence of any distinction, victory over two enemies instead of one might be alleged. Hands were trophies among ancient peoples of the Old World also. The inscription on a tomb at El Kab in Upper Egypt tells how Aahmes, the son of Abuna, the chief of the steersmen, "when he had won a hand" (in battle), "he received the king's commendation, and the golden necklace in token of his bravery;" and a wall-painting in the temple of Medinet Abou, at Thebes, shows the presentation of a heap of hands to the king.

This last instance introduces us to yet another kind of trophy. Along with the heap of hands thus laid before the king, there is represented a phallic heap; and an accompanying inscription, narrating the victory of Meneptah I. over the Libyans, besides mentioning the "cut hands of all their auxiliaries," as being carried on donkeys following the returning army, mentions these other trophies as taken from men of the Libyan nation. And here a natural transition brings us to trophies of an allied kind, the taking of which, once common, has continued in the neighborhood of Egypt down to modern times. The great significance of the account Bruce gives of a practice among the Abyssinians must be my excuse for quoting part of it. He says:

> "At the end of a day of battle, each chief is obliged to sit at the door of his tent, and each of his followers, who has slain a man, presents himself in his turn, armed as in fight, with the bloody foreskin of the man he has slain. . . . If he has killed more than one man, so many more times he returns. . . . After this ceremony is over, each man takes his bloody conquest, and retires to prepare it in the same manner the Indians do their scalps. . . . The whole army . . . on a particular day of review, throws them before the king, and leaves them at the gate of the palace."

Here it is noteworthy that the trophy, first serving to demonstrate a victory gained by the individual warrior, is subsequently made an offering to the ruler, and further becomes a means of recording the number slain—facts verified by the more recent French traveler d'Hericourt. That like purposes were similarly served among the Hebrews, proof is yielded by the passage which narrates Saul's endeavor to betray David when offering him Michal to wife: "And Saul said, Thus shall ye say to David, The king desireth not any dowry, but an hundred foreskins of the Philistines, to be avenged of the king's enemies;" and David "slew of the Philistines two hundred men; and David brought their foreskins, and gave them in full tale to the king."

Associated with the direct motive for taking trophies there is an indirect motive, which probably aids considerably in developing the custom. Numerous facts unite to prove that the unanalytical mind of the savage thinks the qualities of any object reside in all its parts; and that, among others, the characteristics of human beings are thus conceived by him. From this we found there arise such customs as swallowing parts of the bodies of dead relatives, or their ground bones in water, with the view of inheriting their virtues; devouring the heart of a slain brave to gain his courage, or his eyes in the expectation of seeing further; avoiding the flesh of certain timid animals, lest their timidity should be acquired. A further implication of this belief that the spirit of each person is diffused throughout him is, that possession of a part of his body gives possession of a part of his spirit, and, consequently, a power over his spirit: one corollary being that anything done to a preserved part of a corpse is done to the corresponding part of the ghost; and that thus a ghost may be coerced by maltreating a relic. Hence the origin of sorcery all over the world; hence the rattle of dead men's bones so prevalent with primitive medicine-men; hence "the powder ground from the bones of the dead" used by the Peruvian necromancers; hence the portions of corpses which our own traditions of witchcraft name as used in composing charms.

Besides proving victory over an enemy, the trophy therefore serves for the subjugation of his ghost; and that possession of it is, at any rate, in some cases, supposed to make his ghost a slave, we have good evidence. The primitive belief everywhere found, that the doubles of men and animals slain at the grave accompany the double of the deceased, to serve him in the other world—the belief which leads here to the immolation of wives, who are to manage the future household of the departed, there to the sacrifice of horses needed to carry him on his journey after death, and elsewhere to the killing of dogs as guides—is a belief which, in many places, initiates the kindred belief that, by placing portions of bodies on his tomb, the men and animals they belonged to are made subject to the deceased. Hence the bones of cattle, etc., with which graves are in many cases decorated; hence the placing on graves the heads of enemies or slaves, as above indicated; and hence a like use of the scalp. Concerning the Osages, Mr. Tylor cites from McCoy and Waitz the fact that they sometimes "plant on the cairn raised over a corpse a pole with an enemy's scalp hanging to the top. Their notion was that, by taking an enemy and suspending his scalp over the grave of a deceased friend, the spirit of the victim became subjected to the spirit of the buried warrior in the land of spirits." The Ojibways have a like practice, of which a like idea is probably the cause.

A collateral devolopment of trophy-taking, which eventually has a share in governmental regulation, must not be forgotten. I refer to the display of parts of the bodies of criminals.

In our more advanced minds the enemy, the criminal, and the slave, are well discriminated; but they are little discriminated by the primitive man. Almost or quite devoid as he is of the feelings and ideas we call moral—holding by force whatever he owns, wresting from the weaker the woman or other object he has possession of, killing his own child without hesitation if it is an incumbrance, or his wife if she offends him, and sometimes proud of being a recognized killer of his fellow-tribesmen—the savage has no distinct ideas of right and wrong in the abstract. The immediate pleasures or pains they give are his sole reasons for classing things and acts as good or bad. Hence, hostility and the injuries he suffers from it excite in him the same feeling, whether the aggressor is without the tribe or within it: the enemy and the felon are undistinguished. This confusion, now seeming strange to us, we shall understand better on remembering that, even in early stages of civilized nations, the family-groups which formed the units of the national group were in large measure independent communities, standing to one another on terms much like those on which the nation stood to other nations; that they had their small blood-feuds as the nation had its great blood-feuds; that each family-group was responsible to other family-groups for the acts of its members, as each nation to other nations for the acts of its citizens; that vengeance was taken on innocent members of a sinning family, as vengeance was taken on innocent citizens of a sinning nation; and that so the inter-family aggressor (answering to the modern criminal) stood in a like relative position with the international aggressor. Hence the naturalness of the fact that he was similarly treated. Already we have seen how, in mediæval days, the heads of slain family-enemies (murderers of its members or stealers of its property) were exhibited as trophies. And from the Salic law we also learn "that there was beside each dwelling a forked gibbet, as there was beside the public tribunals." Since, at the same time, the heads of foes slain in battle were brought back and displayed—since it is alleged by Lehuerou, on the authority of Strabo, that sometimes such heads were nailed up to the chief door of the house along with those of private foes—we have evidence that identification of the public and the private foe was associated with the practice of taking trophies from them both. A kindred alliance is traceable in the usages of the Jews. Along with the slain Nicanor's head, Judas orders that his hand be cut off; and he brings both with him to Jerusalem as trophies: the hand being that which he had stretched out in blasphemous boasts. And this treatment of the transgressor who is an alien is paralleled by the treatment of non-alien transgressors by David, who, besides hanging up the corpses of the men who had slain Ishbosheth, "cut off their hands and their feet."

It may, then, be reasonably inferred that the display of executed felons on gibbets, or their heads on spikes, originates from the bringing back of trophies taken from slain enemies. Though usually a part only of the slain enemy is fixed up, yet sometimes the whole body is, as when the dead Saul, minus his head, was fastened by the Philistines to the wall of Bethshan; and that fixing up the whole body of the felon is more frequent, probably arises from the fact that it has not to be brought from a great distance, as would usually have to be the body of an enemy.

Though no direct connection exists between trophy-taking and ceremonial government, the foregoing facts reveal such indirect connections as make it needful to note the custom. It enters as a factor into the three forms of control—social, political, and religious.

If, in primitive states, men are honored according to their prowess—if their prowess is estimated here by the number of heads they can show, there by the number of jawbones, and elsewhere by the number of scalps—if such trophies are treasured up for generations, and the pride of families is proportioned to the number of them taken by ancestors—if of the Gauls in the time of Posidonius we read that "the heads of their enemies that were the chiefest persons of quality they carefully deposit in chests, embalming them with the oil of cedars, showing them to strangers, glory and boast" that they or their forefathers had refused great sums of money for them—then, obviously, a kind of class-distinction is initiated by trophies. On reading that in some places a man's rank varies with the quantity of bones in or upon his dwelling, we cannot deny that the display of these proofs of personal superiority originates a regulative influence in social intercourse.

As political control evolves, trophy-taking becomes in several ways instrumental to the maintenance of authority. Beyond the awe felt for the chief whose many trophies show his powers of destruction, there comes the greater awe which, on growing into a king with subordinate chiefs and dependent tribes, he excites by accumulating the trophies others take on his behalf; rising into dread when he exhibits in numbers the relics of slain rulers. As the practice assumes this developed form, the receipt of such vicariously-taken trophies passes into a political ceremony. The heap of hands laid before an ancient Egyptian king served to propitiate; as now serves the mass of jawbones sent by an Ashantee captain to the court. When we read of Timour's soldiers that "their cruelty was enforced by the peremptory command of producing an adequate number of heads," we are conclusively shown that the presentation of trophies hardens into a form expressing obedience. Nor is it thus only that a political effect results. There is the derived kind of governmental restraint produced by fixing up the bodies or heads of felons.

Though offering part of a slain enemy to propitiate a ghost does not enter into what is commonly called religious ceremonial, yet it obviously so enters when the aim is to propitiate a god developed from an ancestral ghost. We are shown the transition by such a fact as that, in a battle between two tribes of Khonds, the first man who "slew his opponent struck off his right arm and rushed with it to the priest in the rear, who bore it off as an offering to Laha Pennoo in his grave;" Laha Pennoo being their "god of arms." Joining with this such other facts as that, before the Tahitian god Oro, human immolations were frequent, and the preserved relics were built into walls "formed entirely of human skulls," which were "principally, if not entirely, the skulls of those who have been slain in battle," we are shown that gods are worshiped by bringing to them, and accumulating round their shrines, these portions of enemies killed—killed, not unfrequently, in fulfillment of their supposed commands. And the inference is verified on seeing similarly used other kinds of spoils. The Philistines, besides otherwise displaying relics of the dead Saul, put "his armor in the house of Ashtaroth." By the Greeks the trophy, formed of arms, shields, and helmets, taken from the defeated, was consecrated to some divinity; and the Romans deposited the spoils brought back from battle in the temple of Jupiter Capitolinus. Similarly of the Feejeeans, who are solicitous in every way to propitiate their bloodthirsty deities, we read that, "when flags are taken they are always hung up as trophies in the *mbure*," or temple. That hundreds of gilt spurs of French knights vanquished by the Flemish in the battle of Courtrai were deposited in the church of that place, and that in France flags taken from enemies were suspended from the vaults of churches (a practice not unknown in Protestant England), are facts that might be joined with these, did not so joining them imply the impossible supposition that Christians think to please "the God of love" by acts like those used to please the diabolical gods of cannibals.

Because of inferences to be hereafter drawn, one remaining general truth must be named, though it is so obvious as to seem scarcely worth mention. Trophy-taking is directly related to militancy. It begins during a primitive life that is wholly occupied in hostilities with men and animals; it develops with the growth of conquering societies in which perpetual wars generate the militant type of structure; it diminishes as growing industrialism more and more substitutes productive activities for destructive activities; and it is a truism to say that complete industrialism necessitates entire cessation of it.

The chief significance of trophy-taking, however, has yet to be pointed out. The reason for dealing with it under the general head of Ceremonial Government, though in itself scarcely to be classed as a ceremony, is that it furnishes us with the key to a large class of ceremonies which have prevailed all over the world among the uncivilized and semi-civilized. From the practice of cutting off and taking away portions of the dead body, there grows up the practice of cutting off portions of the living body.

OPIUM AND ITS ANTIDOTE.[1]

By CHARLES RICHET.

OPIUM is the juice of the poppy, and, as there are many varieties of the poppy, so too are there many kinds of opium; the mode of collecting the juice is, however, always the same. In Egypt, Syria, and India, the three countries which produce opium, a number

[1] From the *Revue des Deux Mondes;* translated and condensed by J. Fitzgerald, A. M.

of semicircular incisions are made in the capsule of the poppy, and the juice which exudes is carefully gathered. This juice, on being dried in the sun, becomes of a dark color, thickens, and forms a brown, firm paste: this is opium. Laudanum is a solution of opium in alcohol and water. Both opium and laudanum are to be regarded as a mixture of several similar but not identical substances. Since the time of Derosne (1804) and Robiquet (1817), who first isolated narcotine and morphine, chemists have very carefully investigated the different chemical compounds occurring in opium. Thus they have discovered codeine, narceine, thebaïne, papaverine, and other substances, all of them bases, i. e., bodies that unite with acids to form crystallizable salts.

These bases do not all affect in the same way the organic functions. Thus, narcotine possesses very little or no soporific power: two grammes of it can be injected without perceptible effect, while a centigramme of morphine is quite sufficient to produce therapeutic and physiological results. Thebaïne does not cause sleep, and in animals produces convulsions like those caused by strychnine, while morphine in the same dose produces deep comatose sleep. Another curious thing about these opium alkaloids is, that they do not act alike on man and animals, as has been demonstrated by Claude Bernard. Man is specially sensitive to the action of morphine, while thebaïne is almost without effect upon his nervous system: animals, on the other hand, feel the effects of morphine only when it is given in large doses, while thebaïne is for them a violent poison. So, too, with belladonna, and atropine, its active principle, they are a deadly poison for man, but almost without effect on rabbits: the dose of atropine that would suffice to kill ten men would hardly be enough to kill one rabbit. The difference is not so great with respect to morphine, yet morphine specially affects man; hence in this article we will consider only this one opium alkaloid.

When, in "Le Malade imaginaire," honest *Argan* is asked why opium causes sleep, his artless reply is, "Quia habet proprietatem dormitivam." Nowadays we are not content with this kind of explanation, and some authors have sought for the "dormitive property" of opium in the state of the cerebral circulation; and, though the true cause has not yet been certainly established, still it is something that research has been made.

It is not yet positively decided whether opium produces anæmia or whether it produces congestion of the brain; indeed, we know little more than did *Argan*, namely, that it sets one asleep. This sleep, however, is in some respects different from ordinary sleep. From thirty to sixty minutes after taking opium one feels a slight excitation; there is a general feeling of buoyancy and contentment, soon followed by drowsiness and a state of reverie rather than of dreaming. There is a pleasurable feeling of *abandon*, and an agreeable sense of torpor creeps over the whole frame; the thoughts are like the ever-shifting scenes of a phantasmagoria, on which we passively gaze, without will or effort to alter the series. Still, so long as the intoxication is not deep, such effort is possible. One feels that he is falling asleep, and that if he would but bestir himself he might overcome his drowsiness. But little by little the legs grow heavy, the arms fall to the sides almost powerless, and the weighted eyelids refuse to remain open. A dreamy, rambling sort of thinking still goes on, and there is as yet no sleep; we are still conscious of the world around. We indistinctly hear the tic-tac of the clock and the rumble of passing vehicles, but it is as though, so to speak, another person were listening and not we. The active, conscious *Me* exists no more, and another personality seems to have taken its place. Gradually everything becomes more and more indistinct, our thoughts are enveloped in a haze, we feel ourselves detached from matter, detached from our bodies, and transformed into thought, which flits about, so to speak, becoming more and more brilliant, but at the same time more and more confused. Then the outer world disappears, and there remains only an inner world, sometimes full of tumult and delirium, and producing feverish excitement, or, as is more frequently the case, calm and quiet, and full of delightful repose. This intoxication is purely psychical, and far superior to the intoxication produced by alcohol or hasheesh, for, though hasheesh gives one a few hours of insanity, opium gives sleep, and with this boon there is nothing that can compare. One must have suffered from insomnia in order to appreciate the value of opium. It brings sleep, and it banishes pain.

It is one of the most powerful agents we possess for modifying the sensibility, but whether it does this by acting upon the sensor nerves or on the brain we know not with certainty. Even where it does not procure sleep, it has the singular power of calming the excitability of the nerves, and of subduing that morbid state of the sensibility called by physicians hyperæsthesia. It has been observed that when it reduces hyperæsthesia it does not cause sleep, all its force seemingly being spent in combating pain. In cases of stubborn neuralgia opium appeases suffering, and a larger dose is required to produce sleep. But is it not enough that it allays the irritability of a diseased nerve? Some persons cannot live without opium, and they swallow enormous quantities of it without perceptible effect. Herein opium differs widely from alcohol. Alcohol is cumulative in its effects, and the more one is addicted to its use, the more easily is he intoxicated by it. One does not become habituated to alcohol intoxication, but with opium the case is different; one may become so accustomed to it as to be able to drink daily a litre of laudanum, twenty drops of which would be a strong enough medicinal dose for a non-habituated person.

In China there is the same popular demand for opium that exists in Europe for alcohol and tobacco. The use of opium does not date very far back, and it is probably the only innovation that China has adopted from the West. The importation of opium from India into China amounted in 1798 to 300 tons, in 1863 to 3,000 tons, in 1866 to 3,903, and since then the increase has been still more rapid.[1]

Opium is chewed, or smoked in a pipe, the latter mode of using it being the more common. The bowl of a long-stemmed pipe is filled with the drug, and, as the opium swells and adheres to the pipe, a needle is in constant use to keep open an air-passage. As the drug burns with difficulty, the smoker must have a light ready at hand for use whenever his pipe goes out.

The number of opium-smokers is considerable, but the great majority of them use the drug only in moderation. The wealthiest mandarins, the most intelligent merchants, smoke opium, as do the humblest coolies. The use of opium is like the use of tobacco among ourselves; nor does it produce any greater mischief, at least among the well-to-do classes; but with the common people it is different. There are establishments specially devoted to opium—smoking-places where, for a trifling sum of money, one may gratify this appetite. Rarely does a smoker leave before he is fully under the influence of the drug, just as the drunkard does not quit the gin-shop until he is fuddled. So used, opium is certainly a dangerous poison, and, according to the testimony of all travelers, the wretches who daily commit such excesses speedily fall to a fearful state of degradation, both moral and physical. Pale, wan, gaunt, shambling along with difficulty, they must have recourse to artificial stimulation in order to regain a part of their wasted energy. Still the injurious effects of opium have in all probability been very much exaggerated: the number of deaths caused by the abuse of the drug is not very great; and many of those who smoke it, even in considerable quantity, retain unimpaired their mental faculties. True, the digestive functions rarely escape impairment. Dyspepsia and general emaciation are the result of this sad habit; but, however that may be, China is not yet by any means on the brink of ruin, and, if she is in a state of decadence, the blame does not attach to opium.

Opium has its antidote: just as we can produce sleep, so too can we produce sleeplessness, by the employment of a mind-poison whose effects are diametrically opposite to those of the other. The antidote of opium is coffee. One hundred years ago coffee was almost unknown, but now there is hardly another beverage that is so widely distributed. Every one has it in his power to judge of the effects of coffee. For some persons it is a stimulus necessary for the performance of intellectual work. In others it produces a painful state of insomnia:

[1] The native production of opium has of late years attained very considerable proportions.—*Trans.*

taken even in weak doses it causes restlessness and anxiety, a sort of feverish activity altogether different from the indolent activity of opium. Under the action of opium the will seems to be lulled to sleep and the imagination runs riot. But under the influence of coffee the imagination is hardly stimulated at all, while there does appear to be excitation of the will. Did I not fear being suspected of having a theory to defend, I should say that the faculties of will and consciousness seem to be superexcited: there is, as it were, a constant strain on attention and memory, whereas in the case of alcohol, hasheesh, and opium, there is a relaxing of attention. Hence coffee produces a true intoxication that fatigues one far more than does the somnolent intoxication of opium, but it leads to the same result. In striving to do too much, the mind does less: under stimulation the will is impaired; and the perfect equilibrium of the mental faculties is disturbed as well by excess as by defect of will.

Coffee is said to produce cerebral anæmia, while opium and alcohol cause congestion; but this theory still needs confirmation. Nevertheless, the part played by coffee in general nutrition is very well understood. It retards organic combustion, and hence it is an *aliment d'épargne*—a food-stuff that effects a saving of other food-stuffs. In the normal state there is always going on within our tissues a multitude of chemical actions, the final result of which is heat-production and liberation of carbonic acid. This carbonic acid passes into the venous blood, and the venous blood, on reaching the lungs, parts with its carbonic acid. Thus the quantity of the carbonic acid is, to some extent, the expression of the nutritive activity. Now, on taking coffee, though no greater quantity of oxygen be inhaled, and without increasing the ration of food, the quantity of the carbonic acid is reduced, and yet the amount of force is not lessened. As illustrating this doctrine, it is usual to cite a fact observed among Belgian miners, who can perform a considerable amount of work almost without food, their strength being maintained solely by the absorption of a large quantity of coffee. Hence coffee is a food-stuff which moderates nutrition by lessening the activity of the chemical transformations incessantly going on within the tissues.

THE TELEPHONE AND HOW IT WORKS.

By GEORGE M. SHAW.

AMONG the innumerable uses of electricity none is more remarkable than its employment for the transmission of sound. The ultimate mystery of the action we cannot, of course, undertake to explain, but the mechanism by which it is produced is by no means difficult to understand.

If a wire, from a galvanic battery such as is shown in Fig. 1, through which a current of electricity is passing, be wound around a piece of steel or soft iron, as represented in Fig. 2, some curious things will happen. If the bar be soft iron, it will be made magnetic, and kept in that condition as long as the current continues to pass round it, and its ends will then attract and hold bits of iron, but drop them when the battery is taken away. If the bar be of steel, instead of soft iron, it will be magnetized and attract iron just as before; but, unlike the soft-iron bar, it will *keep* its magnetism and attract the iron even after the battery is removed. Its magnetism will be permanent. Since, however, electricity made the magnet, we can, in turn, make the magnet a source of electricity. Suppose the magnetized steel bar has attracted and is holding on to a piece of iron. We can now take the battery away and join the ends of the wire, as in Fig. 3; then, if the piece of iron be pulled off and stuck on again, a current of electricity will run through the wire every time it is done. Electricity produced in this way is called magneto-electricity, and the current in the wire is said to be an induced electric current. If, now, the wire from bar No. 1 (Fig. 4), be extended to a distance, and coiled around another magnetized bar (No. 2), the currents induced in it, by making and breaking the contact of the piece of soft iron with the first magnet, will simultaneously affect the magnetism in the distant magnet also. Though the magnets be a mile or a hundred miles apart, the disturbance in one is immediately and equally manifested in the other.

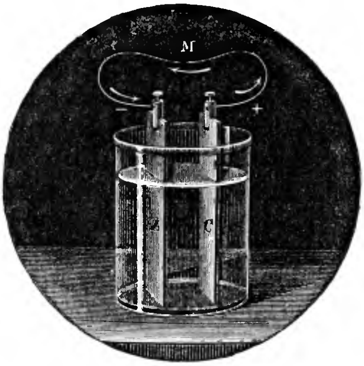


Fig. 1.

Fig. 2.

But, what is still more remarkable, these induced currents may be sent through the wire without the actual contact of the soft iron with the steel bar. If this piece of iron is brought very near to one magnet without touching it, and then withdrawn, an electric thrill or wave is induced in the wire which is felt in the distant magnet, just as if the contact had been actually made and broken. And so if we play the piece of soft iron backward and forward, before the magnet, no matter how rapidly or slightly, each motion is felt as an electric pulse in the magnet at the other end. To borrow a metaphor from life, it is as if the close approach and quick oscillation of the piece of soft iron fretted or tantalized the magnet, and sent a series of electrical shudders through the iron nerve.

We have here the fundamental principle of the telephone. No galvanic battery is employed to furnish an electrical current, as in the case of the telegraph; but the currents in the wires are produced by the motions of the piece of soft iron near the magnet. Thus far we have represented these motions in a very rude and coarse way, as if the piece of iron were vibrated backward and forward by the hand; but what we have really to deal with is something infinitely more delicate than this. The piece of soft iron of which we have been speaking, shown at *a*, Figs. 3 and 4, represents what is called the *diaphragm* of the telephone, which is a thin, circular sheet of iron, a couple of inches in diameter, held by its rim, and adjusted so that its centre comes very close to the end of the magnetized bar. And the motions which now concern us are simply the vibrations produced in this iron membrane by the beats against it of agitated air. Everybody knows that sounds are propagated through the aërial medium by waves that travel swiftly from their sources, and that we hear them because the waves strike in rapid succession upon the drum of the ear. It is also well understood that these waves differ greatly in their rates, depending upon the rapidity of vibration in the sounding body; and, moreover, that they are very complex, there being waves within waves of various orders in a single tone. It is the special complexity of these wave-systems, in the different cases, that gives those peculiarities of tone that mark different musical instruments and distinguish the voice in different individuals. These

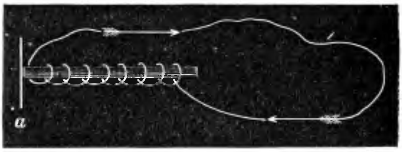


FIG. 3.

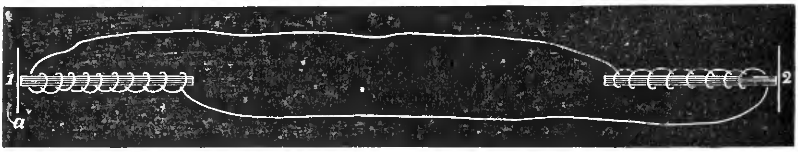


FIG. 4.

waves, started by a person talking, beat against the diaphragm of the telephone as they beat against the tympanum of the ear, and throw it into vibrations, which are reproduced in the thrills of the magnet that again excite tremors in the wires, and these, affecting the magnet, at the other end set the other diaphragm into vibration, and this gives out a new set of air-waves which, falling on the tympanum of the listener, reproduces the original sound or voice. The arrangement being the same at each end, the machine, of course, works both ways, so that when a person is talking to the distant diaphragm the direction is reversed, and the sounds are emitted by the diaphragm near by, and thus the original talker gets his response. The action set up in one telephone is instantaneously repeated or copied by the other. And so by this marvelous chain of effects a person discoursing, apparently, to a piece of iron, may be intelligibly heard hundreds of miles away, and a conversation kept up between the distant parties as if they were in the same room. The "ear-shot" from the beginning of the world has been but a few hundred feet; by the invention of this little contrivance it is now extended to hundreds of miles.

So much for the theory of the telephone; let us now note how it may be practically constructed. To make one, procure a tube, *b b* (Fig. 5), of thin sheet-brass, one inch long, two inches in diameter,

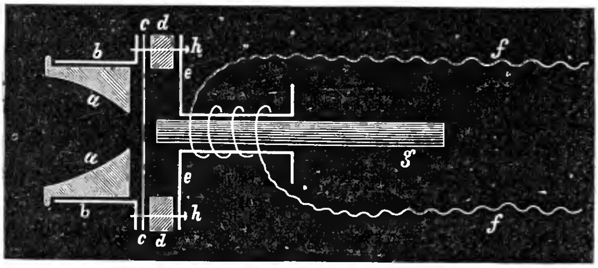


Fig. 5.

and with a flange one-half inch wide. Then from a ferrotype-plate—the photographer's "tin-type"—cut a round plate, shown edgewise, at *c c*, to cover the tube *b b* over the flange. This is the vibrator or diaphragm. Next cut a wooden ring or "washer," *d d*, the width of the flange, and about one-eighth of an inch thick. Then make a spool, *e e*, one inch long, of thin sheet-brass again, with one flange wide enough to cover the wooden ring, the tube of the spool being made so as to fit tightly the magnet *g*, which is a strongly-magnetized steel rod, four inches long and three-eighths of an inch in diameter. The parts will then fit together, and may be screwed firmly through the flanges *b b*. The least polished side of the plate *c c* should face the magnet, and it is well to scrape the part opposite the end of the bar, so as to expose the iron. The spool is to be wound with about fifty yards of No. 36 or 38 silk-covered copper wire, the thickness of a bristle. The magnet is then shoved in, till it nearly touches the plate *c c*. After joining the ends of the spool-wire to the line-wires *f f*, that run to another instrument just like it, the telephone will be ready for use. It is important to concentrate the voice upon a narrow space at the middle of the plate, and for this purpose a movable wooden mouth-piece, *a a*, is used, with an opening at the bottom about the size of a dime. This mouth-piece should fit neatly, and reach to within about one-eighth of an inch of the diaphragm.

Fig. 6 represents a section of Bell's telephone. *E E* is the diaphragm, *F* the tube, *B* the silk-covered wire wound upon the spool, extending *C C*, to the binding-screws *D D*, where they are connected with the line-wires. The magnet *A* has its distance from the diaphragm adjusted by the screw at the opposite end. Fig. 7 represents the form and aspect of the instrument as used. It is about five or six inches long and two and a half inches broad at its widest part. In sending a message, the instrument is held to the mouth,

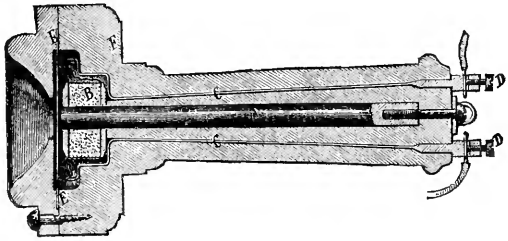


FIG. 6.

and the words distinctly spoken in ordinary tones or even a whisper. The instrument is then held to the ear to receive the answer. Instead of this, two telephones connected may be used at each station, so that one may be held to the ear all the time, while the other is used for telephoning, as illustrated in Fig. 8; and this one, too, in hearing a long message, or in a noisy room, may be held to the other ear, and so shut out all other sounds. This also gives two persons a chance to hear at the same time, by giving a telephone to each.

Several telephones may be connected together in one office, so that any number of persons, by having one each, may hear the same message. In singing, each singer has a telephone. At the late fair of the American Institute, we were one evening listening to a quartet of college-boys, uproariously singing "Upidee i-dee-i-da," in the *Tribune* Building, through six miles of wire, when suddenly all was still. "Hello!" we shouted. "Hello you!" was answered back. "What's the matter?" "Big fire in Leonard Street. The fire is—" "Never mind the fire; go on with the singing," we rejoined, and the singing went on with "The Red, White, and Blue." The impression produced by listening to a communication through this instrument has been aptly described as follows: "The voice, whether in speaking or singing, has a weird, curious sound in the telephone. It is in a measure ventriloqual in character; and, with the telephone held an inch or two from the ear, it has the effect as if some one were singing far off in the building, or the sound were coming up from a vaulted cellar or through a massive stone-wall." The singing or speaking is heard microscopically, as it were, or rather microphonically, but wonderfully distinct and clear in character. The enchantment of distance is there, and one listens as to sounds from fairy-land.

The longest distance at which conversation has been carried on, so far, through the telephone, is about 250 miles. With a submarine cable conversation has been carried on between England and France across the English Channel. Conversation has also been held through the bodies of sixteen persons standing hand-in-hand.

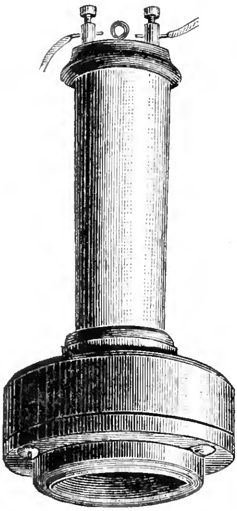


Fig. 7.

The telephone has been regarded as a toy, or a curiosity to be played with; but, while it is undoubtedly extremely interesting as a novelty, it is very much more than this; it is, scientifically and practically, a great success. There are, undoubtedly, difficulties in its use, but, considering that it is a contrivance but of yesterday, the wonder is that it is so perfect. The telegraph was much longer regarded as an impracticable invention, and it is impossible to say how soon the telephone may not take rank among the necessities of common life. If we may trust the analogies of experience, its difficulties are certain to be overcome, although it will probably never meet the exaggerated expectations of many people. Some of the obstacles to the realization of the popular impression of its capabilities have been so well stated in *Chambers's Journal*, by a gentleman skilled in the working of the telegraph, and who made a series of interesting experiments on the telephone, that we may fitly close our article by making free extracts from his paper, accompanied by some slight revision: "When a telegraphist first gets into his hand this beautifully simple and electrically delicate instrument, his first inclination is to test its carrying-power. This is, of course, a closet experiment, not working with actual telegraph-line, but with 'resistance' equivalent to a telegraph-line of stated length. An experiment of this nature gives better results than could be obtained by a veritable line, because the insulation is, so to speak, perfect. No leakage at undesigned points of contact, or disturbance from unfavorable atmospheric conditions, is felt, and the experiment is entirely under the observer's control. The apparatus used is designed to offer the same labor for the electric current to overcome as would be offered by a stated length of outside telegraph-line. This artificial resistance is nicely graduated, and, as the method of testing was suggested by Ohm, a German electrician, the unit of resistance is termed an 'ohm.' Removing the telephone to such a distance that the two observers were 'out of ear-shot,' the test with resistance was tried, and with a resistance of 1,000 ohms—roughly speaking, equal to seventy miles of a well-constructed line—the sound was perfect, although not very loud. Every articulation of the speaker at the other end could be distinguished so long as silence was maintained in the room, or so long as no heavy lorry rumbling over the stones outside sent in harsh noises which drowned the faint whisper of the instrument. The resistance was gradually raised to 4,000 ohms—nearly 300 miles—with like favorable results; and for some little distance beyond, articulation could still be made out. But, by the time 10,000 ohms had been applied, putting the speaker at a distance of, say, 700 miles, sound only, but not articulate sound, reached the ear. The tone was there, and every inflection of the voice could be followed; but articulation was absent, although the listener strained every nerve to catch the sound, which the speaker, as

Fig. 8.

was afterward ascertained, was shouting in a loud, clear voice. The prolonged notes of an air sung could be heard with the resistance named, but again no words could be distinguished."

The next experiment was to join up the telephones in the office with different line-wires in succession going to various distances, and working with different kinds of telegraph-instruments. "When this was done, the real obstacle to telephonic progress at once asserted itself in the shape of 'induction.' The first wire experimented with was partly 'overhouse' and partly underground, and the offices upon it were working A B C, or printing-instruments. It is difficult to render clear to the person ignorant of telegraphic phenomena the idea expressed by the word *induction*. Briefly, it may be put thus: that, when a strong electric current is passing on a wire, it has the faculty of setting up a current of opposite character in any wire not then working, or working with a feebler current, that may be in its vicinity. The why or the wherefore cannot be explained, but there is the fact.

"In various recent articles on the telephone, mention has been made of 'contact' as the cause of disturbance. This word, however although it has been used by telegraphists, is misleading, and can only be used as an endeavor to express popularly an electric fact. Actual contact of one wire with another would spoil the business altogether. A wire bearing an electric current seems to be for the time surrounded, to an undefined distance, by an electric atmosphere, and all wires coming within this atmosphere have a current in an opposite direction set up in them. This is as near an explanation of the phenomena of induction as the state of telegraph science at present affords. Now, the telephone works with a very delicate magnetic current, and is easily overpowered by the action of a stronger current in any wire near which the telephone-wire may come. To work properly, it 'requires a silent line.'

"In the place where the observations were made, there were a large number of wires traveling under the floor, along passages to the battery-room, and to a pole on the outside, whence they radiate, or out to a pipe underground, where many gutta-percha-covered wires lie side by side. On applying the ear to a telephone joined into a circuit working in such an office, a curious sound is heard, comparable most nearly to the sound of a pot boiling. But the practised ear could soon separate the boiling into distinct sounds. There was one masterful Morse instrument—probably on the wire lying nearest the one on which we were joined up—whose peremptory 'click, cli-i-i-ck, click,' representing 'dot, dash, dot' on the printed slip we read from, could be heard over all. Then there was the rapid whir of a fast-speed transmitter sending dots and dashes at express speed by mechanical means; and, most curious of all, the 'rrrrr-op, rr-op, rrrrrrr-rrrrrr-op, rrrrr-op, rr-op' of the A B C, or printing-instrument, the deadliest foe to the telephone in its endeavors to gain admission into the family of telegraph-instruments. There may be reason in this, for as the A B C, or printing-instrument, is the instrument used for private telegraphy, or for the least important public offices, because it requires no 'code' to be learned by the manipulator, so it would likely be the first to be displaced if an acoustic telegraph permanently took the field. So the sentient little A B C opens its mitrailleuse-fire on the intruder, on whose delicate currents, in the words of an accomplished electrician, it plays 'old Harry.' The peculiar character of the sounds we borrow on the telephone from this instrument arises from the fact that, as the needle flies round the dial, a distinct current or pulsation passes for each letter, and the final ' op' we have tried to represent shows the stoppage of the needle at the letters as words were spelled out.

"It must not be understood that the *sounds* of those various instruments are actually heard in the telephone. What happens is, that the currents stealing along the telephone-wire by induction produce vibrations in the diaphragm of that instrument, the little metal membrane working on the magnet in ready response to every current set up the latter. When it is remembered that the principle of the telephone is that the sound-caused vibrations in the filmy diaphragm at one end create similar but magnetically-caused vibrations in the diaphragm at the other end, and so reproduce the sound, it will be obvious why the rapid roll of the A B C currents, or the swift sending of the fast-speed transmitter, when brought by induction into the telephone-wire, cause disturbances in the sound-vibrations, and thereby cripple the instrument. One instrument of either kind named would have a certain effect, but one Morse would not have any greatly prejudicial effect. But a number of Morses going together, such as were heard in our experiments, would combine to be nearly as bad as one A B C or fast-speed Morse. So delicate is the diaphragm to sound (and necessarily so) that, in all experiments with the telephone itself, every sound from without broke in, giving an effect like the well-known 'murmur of the shell.'"

"Joining up our wire now to a more distant station at some miles along the railway, and having on its poles a number of what are known as 'heavy' circuits, the pot-boiling sound assumed even more marked characteristics. The A B C no longer affected us; but a number of Morse instruments were in full gear, and the fast-speed transmitter was also at work. While we were listening, the circuit to which we were joined began to work, and the effect was literally electrical. Hitherto we had only borrowed currents—or, seeing they were so unwelcome, we might call them currents thrust upon us—and the sounds, though sharp and incessant, were gentle and rather low. But, when the strong current was set up in the wire itself, the listener who held one of our telephones nearly jumped from the floor when an angry 'pit-*pat*, pit-*pat*, pit-*pat*-pit' assailed his ear, causing him to drop the instrument as if he had been shot. It was a result none of us had expected, for it did not seem possible that the delicate metal diaphragm and the little magnet of the telephone could produce a sound so intense. Of course, it was only intense when the ear was held close to the orifice of the instrument. Held in the hand away from the ear, the telephone now made a first-rate 'sounder,' and we could tell without difficulty not only the signals that were passing, but found in it a more comfortable tone than that given by the Morse sounder in common use.

"Other experiments of a like character led to results so similar that they may be left unnoticed; and we proceed now to describe one of a different character, designed to test the telephone itself. At a distance of about half a mile, access was obtained to a Morse instrument in private use, and joined to the office by 'overhouse' wire. Dividing our party and arranging a programme of operations, two remained with a telephone in the office, while other two, of whom the writer was one, proceeded with the second telephone to the distant instrument. By an arrangement which a practical telegraphist will understand, the key of the Morse was kept in circuit, so that signals could be exchanged in that way. It may be noticed, however, that this was hardly necessary, as the diaphragm of the telephone can be used as a key, with the finger or a blunt point, so that dot and dash signals are interchangeable, should the voice fail to be heard. As the wire in this instance traveled almost alone over part of its course, we were in hopes that induced currents would be conspicuous by their absence. In this we were, however, disappointed, for the pot was boiling away, rather more faintly, but with the 'plop-plop-plop' distinctly audible, and once more a sharp masterful Morse click was heard coming in now and again. The deadly A B C was, however, absent, so that our experiment proved highly successful. For some reason or another—probably an imperfect condition of the wire, or the effects of 'induction' over and above what made itself audible to us—the spoken sounds were deficient in distinctness; but songs sung at either end were very beautifully heard, and, indeed, the sustained note of sung words had always a better carrying-power than rapidly-spoken words. Every syllable and every turn of melody of such a song as 'My Mother bids me bind my Hair,' sung by a lady at one end, or 'When the Heart of a Man,' sung at the other, could be distinctly heard, but with the effect before noticed, that the voice was muffled or shut in, as if the singer were in a cellar, while it was not always possible to say at once whether the voice was that of a man or a woman.

"In the course of some domestic experiments it was remarked that, in playing the scale downward from C in alt. on the piano, the result to the listener was a 'tit' only for the four upper notes, although all below that had a clear 'ting,' and the octaves below were mostly distinct, although at the low notes of the piano the sound was again lost. The ringing notes of a musical-box were not so successful, but, with close attention, its rapid execution of 'Tommy Dodd' could be well enough made out. An endeavor was made to catch the ticking of a watch, but this was not successful, and the experiment is not recommended, as the near presence of a watch to a magnet is not desirable; and the watch exposed to it in this instance was, it is thought, affected for a short time thereafter, although it received no permanent damage.

"The observations made in the course of these experiments convinced those present that the telephone presents facilities for the dangerous practice of 'tapping the wires,' which may make it useful or dangerous, according as it is used for proper or improper purposes. It might be an important addition for a military commander to make to his flying cavalry; as an expert sound-reader, accompanying a column sent to cut off the enemy's telegraph-connections, might precede the act of destruction by robbing him of some of his secrets. The rapidity and simplicity of the means by which a wire could be 'milked,' without being cut or put out of circuit, struck the whole of the party engaged in the various trials that are described above. Of course, the process of tapping by telephone could not be carried out if the instrument in use was an A B C or single needle, or if the wire was being worked duplex or with a fast-speed Morse, for in these cases the sounds are too rapid or too indefinite to be read by ear. The danger is thus limited to ordinary sounder or Morse telegraphs; but these still form the mainstay of every public system.

"Since the trials above described were made, the newspapers have recorded a beautiful application, by Sir William Thomson, of the electric part of the telephone to exhibit at a distance the motions of an anemometer; the object being to show the force of air-currents in coal-mines. This is a useful application of an electric fact, and doubtless points the way to further discoveries. But it is to be noticed that the experiment, interesting as it is, hardly comes under the head of a tele*phone*, what is reproduced at a distance being not sound but motion.

"Obviously the invention cannot rest where it is; and no one more readily than the practical telegraphist will welcome an instrument at once simple, direct, and reliable. Even in its present form the telephone may be successfully used where its wire is absolutely *isolated* from all other telegraph-wires. But the general impression is that its power of reproducing the sound must be intensified before its use can become general, or come up to the popular expectation."

The realization of so marvelous a device as the telephone cannot fail to stimulate speculation as to where such wonders will stop. If words may be converted into electricity and back again into words, what is to hinder their being converted into something more lasting than electricity—something that will endure, so that spoken words may be reproduced in the future exactly as spoken now; that persons, though dead, may yet speak? What is to hinder? Nothing! The thing is already done; the spirit of the Phonograph has taken on more than a shadowy form, as will be explained to our readers next month. And what next?—

"Ah! Science, give us one more link,
That we may hear our neighbors think."

TECHNICAL EDUCATION.[1]

By Prof. T. H. HUXLEY, F. R. S.

ANY candid observer of the phenomena of modern society will readily admit that bores must be classed among the enemies of the human race; and a little consideration will probably lead him to the further admission that no species of that extensive genus of noxious creatures is more objectionable than the educational bore. Convinced, as I am, of the truth of this great social generalization, it is not without a certain trepidation that I venture to address you on an educational topic. For, in the course of the last ten years, to go back no further, I am afraid to say how often I have ventured to speak of education, from that given in the primary schools to that which is to be had in the universities and medical colleges; indeed, the only part of this wide region into which as yet I have not adventured is that into which I propose to intrude to-day.

Thus I cannot but be aware that I am dangerously near becoming the thing which all men fear and fly. But I have deliberately elected to run the risk. For, when you did me the honor to ask me to address you, an unexpected circumstance had led me to occupy myself seriously with the question of technical education; and I had acquired the conviction that there are few subjects respecting which it is more important for all classes of the community to have clear and just ideas than this, while certainly there is none which is more deserving of attention by the Working-Men's Club and Institute Union.

It is not for me to express an opinion whether the considerations which I am about to submit to you will be proved by experience to be just or not; but I will do my best to make them clear. Among the many good things to be found in Lord Bacon's works, none is more full of wisdom than the saying that "truth more easily comes out of error than out of confusion." Clear and consecutive wrong-thinking is the next best thing to right-thinking; so that, if I succeed in clearing your ideas on this topic, I shall have wasted neither your time nor my own.

"Technical education," in the sense in which the term is ordinarily used, and in which I am now employing it, means that sort of education which is specially adapted to the needs of men whose business in life it is to pursue some kind of handicraft; it is, in fact, a fine Greco-Latin equivalent for what in good vernacular English would be called "the teaching of handicrafts." And probably, at this stage of our progress, it may occur to many of you to think of the story of the cobbler and his last, and to say to yourselves, though you will be too

[1] An address delivered to the Working-Men's Club and Institute Union, December, 1, 1877.

polite to put the question openly to me: "What does the speaker know practically about this matter? What is his handicraft?" I think the question is a very proper one, and, unless I were prepared to answer it, I hope satisfactorily, I should have chosen some other theme.

The fact is, I am, and have been any time these thirty years, a man who works with his hands—a handicraftsman. I do not say this in the broadly metaphorical sense in which fine gentlemen, with all the delicacy of Agag about them, trip to the hustings about election-time, and protest that they, too, are working-men. I really mean my words to be taken in their direct, literal, and straightforward sense. In fact, if the most nimble-fingered watchmaker among you will come to my workshop, he may set me to put a watch together, and I will set him to dissect, say, a black-beetle's nerves. I do not wish to vaunt, but I am inclined to think that I shall manage my job to his satisfaction sooner than he will do his piece of work to mine.

In truth, anatomy, which is my handicraft, is one of the most difficult kinds of mechanical labor, involving, as it does, not only lightness and dexterity of hand, but sharp eyes and endless patience. And you must not suppose that my particular branch of science is especially distinguished for the demand it makes upon skill in manipulation. A similar requirement is made upon all students of physical science. The astronomer, the electrician, the chemist, the mineralogist, the botanist, are constantly called upon to perform manual operations of exceeding delicacy. The progress of all branches of physical science depends upon observation, or on that artificial observation which is termed experiment, of one kind or another; and the further we advance the more practical difficulties surround the investigation of the conditions of the problems offered to us; so that mobile and yet steady hands, guided by clear vision, are more and more in request in the workshops of science.

Indeed, it has struck me that one of the grounds of that sympathy between the handicraftsmen of this country and the men of science, by which it has so often been my good fortune to profit, may, perhaps, lie here. You feel and we feel that, among the so-called learned folks, we alone are brought into contact with tangible facts in the way that you are. You know well enough that it is one thing to write a history of chairs in general, or to address a poem to a throne, or to speculate about the occult powers of the chair of St. Peter; and quite another thing to make with your own hands a veritable chair, that will stand fair and square, and afford a safe and satisfactory resting-place to a frame of sensitiveness and solidity.

So it is with us, when we look out from our scientific handicrafts upon the doings of our learned brethren, whose work is untrammeled by anything "base and mechanical," as handicrafts used to be called when the world was younger, and, in some respects, less wise than now. We take the greatest interest in their pursuits; we are edified by their histories and are charmed with their poems, which sometimes illustrate so remarkably the powers of man's imagination; some of us admire and even humbly try to follow them in their high philosophical excursions, though we know the risk of being snubbed by the inquiry whether groveling dissectors of monkeys and black-beetles can hope to enter into the empyreal kingdom of speculation. But still we feel that our business is different; humbler if you will, though the diminution of dignity is, perhaps, compensated by the increase of reality; and that we, like you, have to get our work done in a region where little avails, if the power of dealing with practical, tangible facts is wanting. You know that clever talk touching joinery will not make a chair; and I know that it is of about as much value in the physical sciences. Mother Nature is serenely obdurate to honeyed words; only those who understand the ways of things, and can silently and effectually handle them, get any good out of her.

And now, having, as I hope, justified my assumption of a place among handicraftsmen, and put myself right with you as to my qualification, from practical knowledge, to speak about technical education, I will proceed to put before you the results of my experience as a teacher of a handicraft, and tell you what sort of education I should think best adapted for a boy whom one wanted to make a professional anatomist.

I should say, in the first place, let him have a good English elementary education. I do not mean that he shall be able to pass in such and such a standard—that may or may not be an equivalent expression—but that his teaching shall have been such as to have given him command of the common implements of learning and created a desire for the things of the understanding.

Further, I should like him to know the elements of physical science, and especially of physics and chemistry, and I should take care that this elementary knowledge was real. I should like my aspirant to be able to read a scientific treatise in Latin, French, or German, because an enormous amount of anatomical knowledge is locked up in those languages. And especially I should require some ability to draw —I do not mean artistically, for that is a gift which may be cultivated but cannot be learned, but with fair accuracy. I will not say that everybody can learn even this; for the negative development of the faculty of drawing in some people is almost miraculous. Still everybody, or almost everybody, can learn to write; and, as writing is a kind of drawing, I suppose that the majority of the people who say they cannot draw, and give copious evidence of the accuracy of their assertion, could draw, after a fashion, if they tried. And that "after a fashion" would be better than nothing for my purposes.

Above all things, let my imaginary pupil have preserved the freshness and vigor of youth in his mind as well as his body. The educational abomination of desolation of the present day is the stimulation of young people to work at high pressure by incessant competitive examinations. Some wise man (who probably was not an early riser) has said of early risers in general, that they are conceited all the forenoon and stupid all the afternoon. Now, whether this is true of early risers in the common acceptation of the word or not, I will not pretend to say; but it is too often true of the unhappy children who are forced to rise too early in their classes. They are conceited all the forenoon of life, and stupid all its afternoon. The vigor and freshness, which should have been stored up for the purposes of the hard struggle for existence in practical life, have been washed out of them by precocious mental debauchery—by book-gluttony and lesson-bibbing. Their faculties are worn out by the strain put upon their callow brains, and they are demoralized by worthless childish triumphs before the real work of life begins. I have no compassion for sloth, but youth has more need for intellectual rest than age; and the cheerfulness, the tenacity of purpose, the power of work which make many a successful man what he is, must often be placed to the credit, not of his hours of industry, but to that of his hours of idleness, in boyhood. Even the hardest worker of us all, if he has to deal with anything above mere details, will do well, now and again, to let his brain lie fallow for a space. The next crop of thought will certainly be all the fuller in the ear and the weeds fewer.

This is the sort of education which I should like any one who was going to devote himself to my handicraft to undergo. As to knowing anything about anatomy itself, on the whole I would rather he left that alone until he took it up seriously in my laboratory. It is hard work enough to teach, and I should not like to have superadded to that the possible need of unteaching.

Well, but, you will say, this is Hamlet with the Prince of Denmark left out; your "technical education" is simply a good education, with more attention to physical science, to drawing, and to modern languages, than is common, and there is nothing specially technical about it.

Exactly so; that remark takes us straight to the heart of what I have to say, which is, that, in my judgment, the preparatory education of the handicraftsman ought to have nothing of what is ordinarily understood by "technical" about it.

The workshop is the only real school for a handicraft. The education which precedes that of the workshop should be entirely devoted to the strengthening of the body, the elevation of the moral faculties, and the cultivation of the intelligence; and especially to the imbuing the mind with a broad and clear view of the laws of that natural world with the components of which the handicraftsman will have to deal. And the earlier the period of life at which the handicraftsman has to enter into actual practice of his craft, the more important is it that he should devote the precious hours of preliminary education to things of the mind, which have no direct and immediate bearing on his branch of industry, though they lie at the foundation of all realities.

Now let me apply the lessons I have learned from my handicraft to yours. If any of you were obliged to take an apprentice, I suppose you would like to get a good, healthy lad, ready and willing to learn, handy, and with his fingers not all thumbs, as the saying goes. You would like that he should read, write, and cipher well; and, if you were an intelligent master, and your trade involved the application of scientific principles, as so many trades do, you would like him to know enough of the elementary principles of science to understand what was going on. I suppose that in nine trades out of ten it would be useful if he could draw; and many of you must have lamented your inability to find out for yourselves what foreigners are doing or have done. So that some knowledge of French and German might, in many cases, be very desirable.

So it appears to me that what you want is pretty much what I want; and the practical question is, How you are to get what you need, under the actual limitations and conditions of life of handicraftsmen in this country?

I think I shall have the assent both of the employers of labor and of the employed as to one of these limitations; which is, that no scheme of technical education is likely to be seriously entertained which will delay the entrance of boys into working-life, or prevent them from contributing toward their own support, as early as they do at present. Not only do I believe that any such scheme could not be carried out, but I doubt its desirableness, even if it were practicable.

The period between childhood and manhood is full of difficulties and dangers, under the most favorable circumstances; and even among the well-to-do, who can afford to surround their children with the most favorable conditions, examples of a career ruined, before it has well begun, are but too frequent. Moreover, those who have to live by labor must be shaped to labor early. The colt that is left at grass too long makes but a sorry draught-horse, though his way of life does not bring him within the reach of artificial temptations. Perhaps the most valuable result of all education is the ability to make yourself do the thing you have to do, when it ought to be done, whether you like it or not; it is the first lesson that ought to be learned; and, however early a man's training begins, it is probably the last lesson that he learns thoroughly.

There is another reason to which I have already adverted, and which I would reiterate, why any extension of the time devoted to ordinary school-work is undesirable. In the newly-awakened zeal for education, we run some risk of forgetting the truth that, while under-instruction is a bad thing, over-instruction may possibly be a worse.

Success in any kind of practical life is not dependent solely, or indeed chiefly, upon knowledge. Even in the learned professions knowledge, alone, is of less consequence than people are apt to suppose. And, if much expenditure of bodily energy is involved in the day's work, mere knowledge is of still less importance when weighed against the probable cost of its acquirement. To do a fair day's work with his hands, a man needs, above all things, health, strength, and the patience and cheerfulness which, if they do not always accompany these blessings, can hardly in the nature of things exist without them; to which we must add honesty of purpose and a pride in doing what is done well.

A good handicraftsman can get on very well without genius, but he will fare badly without a reasonable share of what is a more useful possession for work-a-day life, namely, mother-wit; and he will be all the better for a real knowledge, however limited, of the ordinary laws of Nature, and especially of those which apply to his own business.

Instruction carried so far as to help the scholar to turn his store of mother-wit to account, to acquire a fair amount of sound elementary knowledge, and to use his hands and eyes, while leaving him fresh, vigorous, and with a sense of the dignity of his own calling, whatever it may be, if fairly and honestly pursued, cannot fail to be of invaluable service to all those who come under its influence.

But, on the other hand, if school instruction is carried so far as to encourage bookishness; if the ambition of the scholar is directed, not to the gaining of knowledge, but to the being able to pass examinations successfully; especially if encouragement is given to the mischievous delusion that brain-work is, in itself, and apart from its quality, a nobler or more respectable thing than handiwork—such education may be a deadly mischief to the workman, and lead to the rapid ruin of the industries it is intended to serve.

I know that I am expressing the opinion of some of the largest as well as the most enlightened employers of labor, when I say that there is a real danger that, from the extreme of no education, we may run to the other extreme of over-education of handicraftsmen. And I apprehend that what is true for the ordinary hand-worker is true for the foreman. Activity, probity, knowledge of men, ready mother-wit, supplemented by a good knowledge of the general principles involved in his business, are the making of a good foreman. If he possess these qualities, no amount of learning will fit him better for his position; while the course of life and the habit of mind required for the attainment of such learning may, in various direct and indirect ways, act as direct disqualifications for it.

Keeping in mind, then, that the two things to be avoided are, the delay of the entrance of boys into practical life, and the substitution of exhausted bookworms for shrewd, handy men in our works and factories, let us consider what may be wisely and safely attempted in the way of improving the education of the handicraftsman.

First, I look to the elementary schools now happily established all over the country. I am not going to criticise or find fault with them; on the contrary, their establishment seems to me to be the most important and the most beneficent result of the corporate action of the people in our day. A great deal is said of British interests just now, but, depend upon it, that no Eastern difficulty needs our intervention as a nation so seriously as the putting down both the Bashi-Bazouks of ignorance and the Cossacks of sectarianism at home. What has already been achieved in these directions is a great thing; you must have lived some time to know how great. An education, better in its processes, better in its substance, than that which was accessible to the great majority of well-to-do Britons a quarter of a century ago, is now obtainable by every child in the land. Let any man of my age go into an ordinary elementary school, and, unless he was unusually fortunate in his youth, he will tell you that the educational method, the intelligence, patience, and good temper, on the teachers' part, which are now at the disposal of the veriest waifs and wastrels of society, are things of which he had no experience in the costly middle-class schools; which were so ingeniously contrived as to combine all the evils and shortcomings of the great public schools with none of their advantages. Many a man, whose so-called education cost a good deal of valuable money and occupied many a year of invaluable time, leaves the inspection of a well-ordered elementary school devoutly wishing that, in his young days, he had had the chance of being as well taught as these boys and girls are.

But while, in view of such an advance in general education, I willingly obey the natural impulse to be thankful, I am not willing altogether to rest. I want to see instruction in elementary science and in art more thoroughly incorporated in the educational system. At present, it is being administered by driblets, as if it were a potent medicine, "a few drops to be taken occasionally in a teaspoon." Every year I notice that that earnest and untiring friend of yours and of mine, Sir John Lubbock, stirs up the government of the day in the House of Commons on this subject; and also that, every year, he, and the few members of the House of Commons, such as Mr. Playfair, who sympathize with him, are met with expressions of warm admiration for science in general, and reasons at large for doing nothing in particular. But now that Mr. Forster, to whom the education of the country owes so much, has announced his conversion to the right faith, I begin to hope that, sooner or later, things will mend.

I have given what I believe a good reason for the assumption that the keeping at school of boys who are to be handicraftsmen beyond the age of thirteen or fourteen is neither practicable nor desirable;

and as it is quite certain that, with justice to other and no less important branches of education, nothing more than the rudiments of science and art teaching can be introduced into elementary schools, we must seek elsewhere for a supplementary training in these subjects, and, if need be, in foreign languages, which may go on after the workman's life has begun.

The means of acquiring the scientific and artistic part of this training already exists in full working order, in the first place, in the classes of the Science and Art Department, which are for the most part held in the evening, so as to be accessible to all who choose to avail themselves of them after working-hours. The great advantage of these classes is that they bring the means of instruction to the doors of the factories and workshops; that they are no artificial creations, but by their very existence prove the desire of the people for them; and, finally, that they admit of indefinite development in proportion as they are wanted. I have often expressed the opinion, and I repeat it here, that, during the eighteen years they have been in existence, these classes have done incalculable good; and I can say, of my own knowledge, that the department spares no pains and trouble in trying to increase their usefulness and insure the soundness of their work.

No one knows better than my friend Colonel Donnelly, to whose clear views and great administrative abilities so much of the successful working of the science classes is due, that there is much to be done before the system can be said to be thoroughly satisfactory. The instruction given needs to be made more systematic, and especially more practical; the teachers are of very unequal excellence, and not a few stand much in need of instruction themselves, not only in the subjects which they teach, but in the objects for which they teach. I dare say you have heard of that proceeding, reprobated by all true sportsmen, which is called "shooting for the pot." Well, there is such a thing as "teaching for the pot"—teaching, that is, not that your scholar may know, but that he may count for payment among those who pass the examination; and there are some teachers, happily not many, who have yet to learn that the examiners of the department regard them as poachers of the worst description.

Without presuming in any way to speak in the name of the department, I think I may say, as a matter which has come under my own observation, that it is doing its best to meet all these difficulties. It systematically promotes practical instruction in the classes; it affords facilities to teachers who desire to learn their business thoroughly; and it is always ready to aid in the suppression of pot-teaching.

All this is, as you may imagine, highly satisfactory to me. I see that spread of scientific education, about which I have so often permitted myself to worry the public, become, for all practical purposes, an accomplished fact. Grateful as I am for all that is now being done, in the same direction, in our higher schools and universities, I have ceased to have any anxiety about the wealthier classes. Scientific knowledge is spreading by what the alchemists called a "distillatio per ascensum;" and nothing now can prevent it from continuing to distill upward and permeate English society, until, in the remote future, there shall be no member of the Legislature who does not know as much of science as an elementary schoolboy; and even the heads of houses in our venerable seats of learning shall acknowledge that natural science is not merely a sort of university back-door, through which inferior men may get at their degrees. Perhaps this apocalyptic vision is a little wild; and I feel I ought to ask pardon for an outbreak of enthusiasm, which, I assure you, is not my commonest failing.

I have said that the Government is already doing a great deal in aid of that kind of technical education for handicraftsmen which, to my mind, is alone worth seeking. Perhaps it is doing as much as it ought to do, even in this direction. Certainly there is another kind of help of the most important character, for which we may look elsewhere than to the Government. The great mass of mankind have neither the liking, nor the aptitude, for either literary, or scientific, or artistic, pursuits; nor, indeed, for excellence of any sort. Their ambition is to go through life with moderate exertion and a fair share of ease, doing common things in a common way. And a great blessing and comfort it is that the majority of men are of this mind; for the majority of things to be done are common things, and are quite well enough done when commonly done. The great end of life is not knowledge, but action. What men need is as much knowledge as they can assimilate and organize into a basis for action; give them more and it may become injurious. One knows people who are as heavy and stupid from undigested learning as others are from over-fullness of meat and drink. But a small percentage of the population is born with that most excellent quality, a desire for excellence, or with special aptitudes of some sort or another; Mr. Galton tells us that not more than one in four thousand may be expected to attain distinction, and not more than one in a million some share of that intensity of instinctive aptitude, that burning thirst for excellence, which is called genius.

Now, the most important object of all educational schemes is to catch these exceptional people and turn them to account for the good of society. No man can say where they will crop up; like their opposites, the fools and knaves, they appear sometimes in the palace and sometimes in the hovel; but the great thing to be aimed at, I was almost going to say the most important end of all social arrangements, is to keep these glorious sports of Nature from being either corrupted by luxury or starved by poverty, and to put them into the position in which they can do the work for which they are specially fitted.

Thus, if a lad in an elementary school showed signs of special capacity, I would try to provide him with the means of continuing his education after his daily working-life had begun; if, in the evening classes, he developed special capabilities in the direction of science or of drawing, I would try to secure him an apprenticeship to some trade in which those powers would have applicability. Or, if he chose to become a teacher, he should have the chance of so doing. Finally, to the lad of genius, the one in a million, I would make accessible the highest and most complete training the country could afford. Whatever that might cost, depend upon it the investment would be a good one. I weigh my words when I say that, if the nation could purchase a potential Watt, or Davy, or Faraday, at the cost of a hundred thousand pounds down, he would be dirt-cheap at the money. It is a mere commonplace and every-day piece of knowledge, that what these three men did has produced untold millions of wealth, in the narrowest economical sense of the word.

Therefore, as the sum and crown of what is to be done for technical education, I look to the provision of a machinery for winnowing out the capacities and giving them scope. When I was a member of the London School Board, I said, in the course of a speech, that our business was to provide a ladder, reaching from the gutter to the university, along which every child in the three kingdoms should have the chance of climbing as far as he was fit to go. This phrase was so much bandied about at the time, that, to say truth, I am rather tired of it; but I know of no other which so fully expresses my belief, not only about education in general, but about technical education in particular.

The essential foundation of all the organization needed for the promotion of education among handicraftsmen will, I believe, exist in this country when every working-lad can feel that society has done what lies in its power to remove all needless and artificial obstacles from his path; that there is no barrier, except such as exist in the nature of things, between himself and whatever place in the social organization he is fitted to fill; and, more than this, that, if he has capacity and industry, a hand is held out to help him along any path which is wisely and honestly chosen.

I have endeavored to point out to you that a great deal of such an organization already exists; and I am glad to be able to add that there is a good prospect that what is wanting will, before long, be supplemented.

Those powerful and wealthy societies, the livery companies of the city of London, remembering that they are the heirs and representatives of the trade-guilds of the middle ages, are interesting themselves in the question. So far back as 1872 the Society of Arts organized a system of instruction in technology of arts and manufactures, for persons actually employed in factories and workshops, who desired to extend and improve their knowledge of the theory and practice of their particular avocations;[1] and a considerable subsidy was liberally granted in aid of the efforts of the Society by the Clothworkers' Company. We have here the hopeful commencement of a rational organization for the promotion of excellence among handicraftsmen. Quite recently other of the livery companies have determined upon giving their powerful and, indeed, almost boundless aid to the improvement of the teaching of handicrafts. They have already gone so far as to appoint a committee to act for them; and I betray no confidence in adding that, some time since, the committee sought the advice and assistance of several persons, myself among the number.

Of course, I cannot tell you what may be the result of the deliberations of the committee; but we may all fairly hope that, before long, steps which will have a weighty and a lasting influence on the growth and spread of sound and thorough teaching among the handicraftsmen[2] of this country will be taken by the livery companies of London.—*Fortnightly Review.*

THE DEBASEMENT OF COINAGES.

By E. R. LELAND.

IN primitive days the parties to a trade had in every case first to agree as to the quantity and quality of the articles to be exchanged. When gold and silver first made their appearance in the list of commodities they were, along with other metals, in an unfashioned state, and the processes of barter were carried on with them precisely as with more bulky and inconvenient articles, so that at each transfer it became necessary to determine their quality and quantity, that is, their purity and weight, by the crude methods which then obtained. Such is still the case among some of the far-away, half-civilized nations, and in the early days of California and Australia gold-digging, "nuggets" and "dust" were in common use as currency.

With all the perfection of modern scientific appliances the work of assaying is one of great difficulty and nicety, and it must have been impossible for primitive merchants to reach anything but the rudest approximations. To do even this involved a great deal of trouble and loss of time, so that the necessity of devising some means by which

[1] *See* the "Programme" for 1878, issued by the Society of Arts, p. 14.

[2] It is perhaps advisable to remark that the important question of the professional education of managers of industrial works is not touched in the foregoing remarks.

the weight and fineness of a piece of gold or silver could be easily determined was early felt.

The first forms which could be called by the name of money were ingots in various shapes, stamped or sealed with the seal of the ruler as a certificate of the quality and weight of the piece, no attempt being made to so fashion the coin as to guard against alteration of weight. Some of the early pieces were stamped on but one side, and it was only by very gradual steps that the handsome circular pieces which we know as coins were evolved. But these are still defined by Jevons as "*ingots*, of which the weight and fineness are certified by the integrity of the designs impressed upon the surface of the metal."

The stamping of the bits of metal has always been assumed as a prerogative of the ruler, and to supply the people with coin has come to be generally considered a function of government. It will be well to bear the above definition of coin in mind; for the fashioning, stamping, and certification, have often caused a very important fact to be lost sight of, which is, that throughout these changes the metals continue to be commodities and nothing more. The stamp works no alteration in the metal, any more than does the label on a bolt of muslin, showing the width and the number of yards, convert it into something other than cotton cloth. The conversion of the unfashioned metal into coin in no way affects the principle of exchanges, and its transfer is barter just as much as it was in the beginning.

Coins command other commodities by the amount of pure metal in them.

The silver dollar buys just as much food or clothing as would so many grains of silver in any other shape; and the stamp—whether it show the classical features of Kaiser William or the graceful figure of the Goddess of Liberty—does not increase its purchasing power, except to the very slight degree which is the measure of the convenience of having it converted from bullion into coin at public cost, but this percentage is so small that it may for present purposes be neglected.

But it has come about that, instead of being looked upon as simply certified bullion, coin is frequently regarded as something mysterious in its nature and function.

Gold and silver, from their physical properties, are the most fit of all known substances for mediums of exchange. From their general use as money they are commonly spoken of as measures of value, and there is no objection to this expression if it be understood to mean that they constitute a term or factor constantly used in arriving at the ratio which exists between the various articles of commerce; but it should be remembered that this factor is not constant, though for purposes of convenience it is generally assumed to be so. As a matter of fact, gold and silver measure the value of commodities in precisely the same way that the commodities measure the value of gold and silver. Value is based on utility, but utility is not intrinsic in any substance; and a thing is only useful so far as it is supplied in needful quantities at the right time, the degree of utility constantly varying. And so, although we may get the value of x (gold and silver) in terms of y (other commodities), and the value of y in terms of x, both x and y remain unknown and variable quantities, however glibly we may talk about them.

Although the same difficulty confronts us here that is met in all attempts at the ultimate analysis of things, none the less is it imperative that there should be a fixity of standards, rigidly adhered to. To define a pound avoirdupois is as difficult as to define a pound sterling; but commerce and science are alike dependent upon absolute adherence to certain standards of weight, and upon the assumption that the law of gravitation, by which weight is determined, is inflexible.

Until the indestructibility of matter and the persistence of force were demonstrated, there was nothing absurd in the supposition that matter could be created and annihilated, force produced and destroyed; and men of genius and learning vainly sought to turn dross to gold, to find the elixir of life, to construct machines which should create their own force. Modern chemistry has dispelled the dreams of the alchemist; physiology has determined the laws of waste and supply and fixed pretty definitely the limitations of life; and the discoveries of Meyer and Joule have shown the fallacy of perpetual motion. These things are now pretty generally understood, although a lunatic is still occasionally to be found who wastes his life because of his inability to comprehend them: but it is not so generally recognized that the principle of the correlation of forces is universal; that it applies rigidly to all human activities; and that it is quite as impossible in economical dynamics as elsewhere to get something for nothing.

That coins are simply stamped bullion, and that the purchasing power of money is regulated by the quantity of pure metal only is now conceded by all economic writers; but the establishment of this principle is comparatively recent. In early times most extraordinary delusions prevailed on this subject, nor are they yet wholly dissipated. It will be interesting and instructive to note some of the mutations which have been caused in the world's coinage by the numerous royal and legislative attempts to make a part equal to the whole.

The coins of all countries seem to have been called by the same name as the weights used in them, and to have originally contained the quantity of metal indicated by their names. The coins used in Greece, Italy, France, and England, weighed in the first instance just a *talent*, an *as*, or *pond*, a *livre*, or a *pound*.

The Roman *as*, or *libra*, at first contained twelve ounces of copper, and was divided into twelve parts or *unciæ*, a division which was maintained for a long time. It is not known who first falsified the certificate and gained an illusory augmentation of wealth by reducing the weight of metal in the *as*, still calling it by the same name. But this fraudulent plan, once adopted, was worked with such assiduity by the successive emperors, that in 175 B. C. the *as* contained but half an ounce of copper, or $\frac{1}{24}$ part of its original weight. In the case of so cheap a metal, diminishing the quantity was the only way in which the coin could be degraded. The principal silver coin was the *denarius*, rated at ten *asses*, and weighing one-seventh of an ounce. Its weight was tolerably well maintained, but adulteration was carried to its utmost extent, and eventually the imperial *denarii* came to be only copper coins plated with silver! Similar vicissitudes marked the career of Roman gold. When first coined, 204 B. C., the *aureus* weighed $\frac{1}{40}$ part of a pound of pure gold, but through various degradations came to be only $\frac{1}{72}$ part of a pound in weight, and this bore 20 per cent. of alloy.

The French money-unit, the *livre*, up to the reign of Charlemagne, contained exactly a pound weight of pure silver, and was divided into 20 *sols*. It was reserved for Philip I. to violate this standard. He considerably diminished the amount of silver contained in a *sol*, and his example was followed with such zeal that by the time of the Revolution the *livre* contained less than a seventy-eighth part of the silver which it had in the eleventh century.

Nor is this an extreme case. In 1220 the Spanish *maravedi* weighed 84 grains of gold, and was equal in value to about $3.50; it descended until it became a small copper coin valued at one-third of a cent.

The German *florin* was originally a gold coin worth $2.50; when abolished it was 40 cents' worth of silver.

These examples are taken from the history of the most stable and best-governed European states, and from them may be inferred the rapacity and swindling of the lawless, irresponsible feudal princes during the middle ages, which caused this particular fraud to fall into the deepest discredit even in those early days.

The Chinese probably illustrate in the most extreme manner the length to which loose views concerning currency can be carried. The history of their currency presents that mingling of the grotesque with the tragic which most of their actions have when viewed through Western eyes. Coined money was known among them as early as the eleventh century before Christ, but their inability to comprehend the principles upon which a currency should be based has led them into all sorts of extravagances, which have been attended by disorder, famine, and bloodshed. Coins came at last to be made so thin that 1,000 of them piled together were only three inches high; then gold and silver were abandoned; and copper, tin, shells, skins, stones, and paper, were given a fixed value, and used until, by abuse, all the advantages to be derived from the use of money were lost, and there was nothing left for the people to do but to go back to barter, and this they did more than once. They cannot be said now to have a coinage; 2,900 years ago they made round coins with a square hole in the middle, and they have made no advance beyond that since. The well-known *cash* is a cast-brass coin of that description, and, although it is valued at about one mill and a half of our money, and has to be strung in lots of 1,000 to be computed with any ease, it is the sole measure of value and legal tender of the country. Spanish, Mexican, and our new trade-dollars, are employed in China; they pass because they are necessary for larger operations, and because faith in their standard value has become established; but they are current simply as stamped ingots, with their weight and fineness indicated.

The coinage of England, although it has suffered less than that of any of the older countries, has still undergone great debasement, which has begotten misery and trouble enough to make her experience of great value. At the time of the Norman Conquest the silver or money pound weighed 12 ounces, the system of coinage being the same as that of Charlemagne, and it was continued untouched until the year 1300, when the standard was tampered with by Edward I. By increasing the number of shillings made from a pound, he set a pernicious example which was followed only too well, so that in the reign of Queen Elizabeth 58 shillings instead of 20 shillings were coined out of the pound weight of silver. Up to the reign of Henry VIII., although the weight was decreased, the sterling fineness of coins was not debased; but that eminent head of the Church, after dissipating the immense wealth which he received from his father, resorted to the most disgraceful means to supply his riot and extravagance. He so adulterated and degraded the silver coinage that the pound sterling contained but four ounces of silver, £2 8*s*. of it being equivalent to the pound sterling of 500 years before. Under the reigns of his children, Edward VI., Mary, and Elizabeth, the fineness of the coin was gradually restored, and its degradation arrested, so that it was the boast of Elizabeth that she "had conquered now that monster which so long had devoured her people." The coinage of England has had nothing further to endure at the hands of her princes.

The reign of James II., bad enough in all ways, was in no instance more disgraceful than the state to which he brought the coinage of Ireland during his brief kingship there. His coins of gun-metal, copper, brass, pewter, the sorriest tokens, were made unlimited tender, and forced into circulation by every device. His loyal Irish subjects were the sufferers from this swindle, for they had in their possession nearly the whole of his worthless money. As he was compelled to abandon England before his necessities became very great, her money escaped violation.

Of course, all this tampering with money has been accompanied by tyrannical laws which were intended to make the debased coin pass for just as much as the pure. Nothing would be gained unless this could be done. Mint-officers were sworn to secrecy, but the melting-pot revealed the fraud. Proclamations were issued by Edward II., commanding, under heavy penalties, that the money should be kept current at the stamped value, and that no one should enhance the price of his goods on that account, for it was the king's pleasure that the coins should be kept up to the same value they were wont to bear! Later, in the reign of Edward VI., when the debasement reached its lowest depths, a *maximum* was set on the price of corn, and those who refused to carry their grain to market were to be punished.

Absurd as such compulsory laws may seem to us, they are perfectly logical outcomes of any attempts to lower the standard of money. There is nothing to be gained by debasing coinage unless the operations of commerce can be regulated upon the assumption that a part *is* equal to the whole. Edward's proclamation, that it was his pleasure that the coins should be kept up to the value that they were wont to bear, and that people should be compelled to market their goods at the old prices, was more difficult of enforcement, but not different in principle, no whit more dishonest, than a law which shall make 90 cents a legal tender for 100, in the discharge of all debts.

It was hardly to be expected that a higher standard of morality would be found among subjects than that held to by their rulers. The tampering was begun by the people on their own account, the more readily as the nature of the coin made this an easy matter. In making the coins the metal was divided with shears, and afterward shaped and stamped by hand with the hammer. They were not exact in size or weight: some contained more, and some less, than the correct quantity of silver; few pieces were exactly round; and, as the edges were smooth, nothing was easier than to take a slight paring from the pieces as they passed from hand to hand.

Coin-clipping was discovered to be profitable and comparatively safe, and it was practised with great industry. As early as the reign of Elizabeth it was prohibited, on the pain of life and limb, and the forfeiture of all lands. But the practice was too lucrative to be thus checked, and by the time of the Restoration the larger part of the silver in circulation was mutilated. Macaulay has described in most graphic manner this episode in the history of British coinage. All trade and industry was deranged by the confusion which arose from the disgraceful state of the money. "Nothing could be purchased without a dispute. Over every counter there was wrangling from morning till night. The workman and his employer had a quarrel as regularly as the Saturday came round."

Guineas, which had originally been coined to be equal to 20*s.*, rose as the silver grew worse, till they were current at 30*s.* of the base trash which passed by the name of silver coin. The shrinkage on the average of the pieces in circulation amounted to nearly or quite 50 per cent. The most rigorous and cruel laws were passed, but they were ineffectual, and, while scores of miserable wretches were dangling from the gibbets, clipping was as rife as ever.

Clipping is here referred to at some length, because it differs from other degradations of coinage only in respect to the parties by whom it is done. It is reducing the value of coin without public authority, and is the least mischievous of the two forms, because, as no one is compelled to take clipped coins, the loss is forced on no one.

The first effort to correct the evils which had thus arisen was, by furnishing a large supply of fresh, honest, milled coins. The politicians of that day believed that, if the people were given plenty of new and good money, it would soon displace the old; and so the mints were run to their utmost capacity, but the new coins vanished from sight as fast as they were put ont. Gresham's law, that "bad money drives out good money, but that good money cannot drive out bad money," although not then formulated, worked its inevitable result. The statesmen marveled that men would not pay 12 ounces of silver when 10 could be made to serve the purpose, but they persistently refused to do so. By the time of William III., the necessity of resorting to some measures which should be effectual was generally felt.

It was evident to all that the old coinage must in some way be supplanted by a new, but the manner in which this should be done was warmly disputed. Mr. William Lowndes, then Secretary of the Treasury, was ordered to make a report and did so, recommending that the standard of the new coin should be depreciated to the level of the trash in circulation, by making the new shilling worth ninepence or thereabouts. He asserted, and attempted to prove, "that making the pieces less, or ordaining the respective pieces (of the present weight) to be current at a higher rate, might equally raise the value of silver in our coins;" and seriously argued that, if an ounce of silver were but cut up finer, other nations would be induced to sell their products for a smaller number of ounces. He had a considerable following, composed, Macaulay says, "partly of dull men who really believed what he told them, and partly of shrewd men who were perfectly willing to be authorized by law to pay a hundred pounds with eighty"—a description which fits with sufficient accuracy the advocates of the Bland Bill.

Lowndes's fallacies were exposed with great ability by Locke, and fortunately wiser counsels prevailed. The old standard was maintained in the new issues, and the clipped coins were called in, the loss falling, as it should do, on the public at large. Space forbids the introduction here of the arguments by which this wise course was sustained. The controversy is interesting and instructive, and deserves attention, for it was revived 116 years later when Bank-of-England notes became depreciated, and is raging now that silver has undergone a similar decline. It is true that the situation is not precisely the same, but the principle involved is: the arguments against restoring a degraded coinage or degrading an established one are substantially the same.

The object of the Bland Bill and similar measures, though nominally a restoration of a former standard, is in fact a debasement of the present one. The value fixed for the United States dollar under the act of 1792 was by accident put below that of the dollars with which it then came into competition. The act provided that the dollar should be of the value of the Spanish milled dollar, and also provided that it should contain 371¼ grains of pure silver, whereas the Spanish dollar contained 377¼ grains. This discrepancy resulted from a blunder in assaying the Spanish coin, but was perpetuated until the old silver dollar was abolished. Owing to the unprecedented fall in the price of silver, the real value of 371¼ grains is now only about ninety cents in the market, a decline which would be a very serious matter if this accidental dollar were still a legal tender and in use in trade; but fortunately the act of 1873 put it where it is incapable of doing mischief.

It is one of the compensations of the disordered state of our finances growing out of irredeemable war-issues, that, coin being virtually out of circulation, we could put our coinage on the footing aimed at by all great commercial nations, without incurring the loss and distress which such revolutions are apt to involve. And now it is proposed to undo all this, to restore this impaired dollar to its old position, and put upon the nation all the loss and inconvenience which would grow out of such a change. For states of transition are always states of suffering and, were there two or three hundred millions of silver in the hands of the people to-day, the statesman well might hesitate to raise the standard of the old dollar, making it equivalent to the gold one. The load of silver which France is carrying interferes seriously with her efforts to resume on her paper currency, and yet she very properly hesitates to enter upon an experience similar to that which Germany has recently had; but we, virtually starting anew with our coinage system, with the experience of all the past to light us, are asked to plunge into a quagmire from which we could only emerge after much floundering and defilement!

And who is to be benefited by the remonetization of silver? If remonetization will, as is claimed for it, enhance the price of silver, so that it will make the dollar of 1792 and the gold dollar equal, then the holders of silver and they only will reap the advantage. Is the disposable silver stock of the world held by the class of men into whose pockets the Western voters are anxious to legislate money? The American mine-owners hold a large amount in the shape of ore; the German Empire has ninety millions of surplus she would be glad to dispose of; the Bank of France has one hundred and forty odd millions in its vaults, that is a source of great present disquietude; England has a fair stock, and as creditor of India is likely to become the holder of much more; she is deeply interested in seeing the price of silver sustained, and would be very grateful for relief from any quarter. It is from these sources the silver would flow if the United States should decide to assume the function of pulling chestnuts for the entire commercial world, and these are the men who would profit by remonetization—provided that step should have the effect on the price of silver that is claimed for it. But the assumption that it will bring the gold and silver dollar upon a par is entirely unwarranted.

The Monetary Commission, of which Mr. Jones was chairman and Mr. Bland a member, are at great pains to show, in their report, that, owing to the magnitude of the stocks of silver and gold in the world, the value of the precious metals cannot be visibly affected by current production; that no current supply was ever yet sufficiently great to affect the value of the metals except slowly and by almost imperceptible degrees. This may or may not be so, but it is a little curious to note that the same gentlemen who in their report maintained that the effect of an annual *supply* of $65,000,000 or $70,000,000 would have no appreciable effect on the price of silver, are now gravely arguing that an annual *demand* of say $25,000,000—the utmost capacity of our mints—would at once enhance the price by 10 per cent. Here they forget the insignificance of the amount in comparison with the enormous accumulated stock of the world.

A further decline in the price of silver is far more probable than an advance, and it is only because the old silver dollar is worth but 90 cents, and likely to be worth less rather than more, that it is so loudly clamored for. The avowed object of its restoration is to relieve those who have debts to pay.

Neither in motive nor in method does this differ from the disreputable frauds of the feudal princes who adulterated their coins that they might pay their debts more easily. Both the act and its consequences are identical. The image and the superscription of the monarch lied in the older example: in the modern instance the image and the superscription are no less lying ones. And the consequences will in no wise differ. Henry VIII. was enabled to cheat his creditors in precisely the same unscrupulous way that is proposed for the United States to cheat theirs, by paying them in coins of diminished value; and the losses he entailed upon his subjects—far exceeding his own gains—were precisely those we should suffer. All creditors are placed in the position of the creditors of the swindling government. Debtors are indiscriminately benefited at the expense of creditors. To pay the public debt in a depreciated currency, whether it can be done legally or not, is to weaken if not destroy public faith. If they had a rational conception of what national credit is, this consideration alone would give the agitators pause. When nearly two hundred years ago England was struggling to restore order to her finances, William III. pressed upon the House of Commons the importance of taking care of the public credit, and assured them that it could only be preserved by keeping sacred the maxim that "they shall never be losers who trust to a parliamentary security." Our national credit has rapidly advanced to the very first rank, and with upright dealing can easily be maintained there. It would not be necessary to perfect a great deal of the kind of legislation that is now being urged to put it on a level with the credit of Spain, or the defaulting states of South America.

There is a prevailing misconception as to where the gains and losses arising from the proposed change will fall.

A depreciated coinage will diminish the revenue of the Government by a far greater amount than will be saved in the payment of the bonds, so that the burden of taxes cannot be lightened in that way. It will cripple all institutions of learning and of charity that are maintained by endowments; it will tithe the assets of all the savings-banks and life-insurance companies; it will curtail the trust funds of widows and orphans, no matter in what form they may be held; it will defraud the frugal and prudent wholesale, for the benefit of the improvident and reckless. Relatively, the loss will fall heaviest on those who are too poor to get in debt, who work for wages or a salary. Those of the bond-holders to whom the now familiar term of "money-sharks" will in any degree apply will be found quite competent to take care of themselves. They live in the money-centres of the world; their finger is on the arteries of commerce, and they can watch the pulsations and guard against the perturbations; in the unsettled condition of things which would attend such a change, they will be best able, because in the best position, to hedge against their losses. Prices will, of course, adjust themselves to the new standard, but the adjustment will not be so sharp and rapid or exact as to cause the loss to fall just where it is intended it shall fall. The "sharks," we may be sure, will get from under, and the brunt of the suffering will strike just where it does in most cases—upon the poor, the ill-informed, the unready.

Of the ability of this nation to pay its debts in full, there is not the slightest question, and it is essentially dishonest for a debtor to compound at 90 cents when he can pay 100; but, if it be determined that it is necessary and right for the Government and other debtors to make such a composition—if it can be shown that it is a step dictated by a sincere desire to execute fair and impartial justice—we shall still be as much entitled as ever to object to its being done by reducing the standard of money. It is an attempt to accomplish by mean and paltry subterfuge that which, if done at all, should be done in a manly way. If debts are to be scaled, let it be done openly, and the dividends, whatever they may be, paid in money at par.

A proposition to restore the old dollar, and make it a legal tender for everything except the interest and principal of the public debt and for customs duties, is said to find considerable favor. It is hard to understand how, after our prolonged experience of the derangement caused by having two unequal kinds of currency, such a scheme should be advocated. With one currency fit for paying bonds, customs duties, and foreign payments, and another not so fit, and therefore, of course, at a discount, we have a condition of affairs that is profitable to "money-sharks" and brokers alone. Every dollar which is paid as brokerage, growing out of the use of two kinds of currency, is a tax levied upon the people. If the sums which have been annually paid by consumers in the way of brokers' commissions since 1862, as a result of the depreciation of our currency, could be stated, and it could be shown by whom this tax has ultimately been paid, it would raise a party in favor of a single standard that would sweep everything before it. The tax has been levied indirectly, and paid unknowingly, but this has not lessened the burden of it—economic laws are none the less inexorable when their workings are obscure. And now, when we have almost emerged from under this load, it is proposed to put us back under it, not temporarily, but permanently, without even a distant hope of release.

There is one other proposition in regard to the reissue of silver: it is, to coin a silver dollar which shall contain enough metal to make it the equal of the present gold dollar. To this there is no moral objection, but there are grave economic ones. The rapid and violent fluctuations of the silver-market during the last two years show that forces are at work which are unusual in their nature and not yet understood, and the appeal can well be made to all prudent men whether it would not be better to wait a little before reintroducing into our currency so unstable an element. When the disturbing forces have expended themselves, and the silver-market has settled down to a normal condition, so that we may know what the price of silver really is in relation to other commodities, it will then be time enough to try to establish some fixed ratio between it and gold, and admit it as a legal tender.

But obvious as the lessons of history are, and pitilessly as the fallacies of those who think to make 90 equal 100 have been criticised, both by the pens of economists and the workings of natural laws, there is too much ground to fear that no reliance can be placed on the clearness or rectitude of popular convictions, and that we shall be called upon to vindicate once more the principles of monetary economy in the most painful and expensive way. There does not seem to be among our leaders either knowledge or virtue enough to protect us. A minority of the press and the business-men of the larger towns of the country are alone opposing this scheme compounded of fraud and folly, and it is to be feared that their political influence is quite inadequate to stand against the urgency of the great majorities of the West and South.

SPONTANEOUS GENERATION.

By Prof. JOHN TYNDALL, F. R. S.

II.

LET us now return to London and fix our attention on the dust of *its* air. Suppose a room in which the house-maid has finished her work to be completely closed, with the exception of an aperture in a shutter through which a sunbeam enters and crosses the room. The floating dust reveals the track of the light. Let a lens be placed in the aperture to condense the beam. Its parallel rays are now converged to a cone, at the apex of which the dust is raised to almost unbroken whiteness by the intensity of its illumination. Defended from all glare, the eye is peculiarly sensitive to this scattered light. The floating dust of London rooms is organic, and may be burned without leaving visible residue. The action of a spirit-lamp flame upon the floating matter has been elsewhere thus described:

"In a cylindrical beam which strongly illuminated the dust of our laboratory, I placed an ignited spirit-lamp. Mingling with the flame, and round its rim, were seen curious wreaths of darkness resembling an intensely black smoke. On placing the flame at some distance below the beam, the same dark masses stormed upward. They were blacker than the blackest smoke ever seen issuing from the funnel of a steamer; and their resemblance to smoke was so perfect as to prompt the conclusion that the apparently pure flame of the alcohol-lamp required but a beam of sufficient intensity to reveal its clouds of liberated carbon.

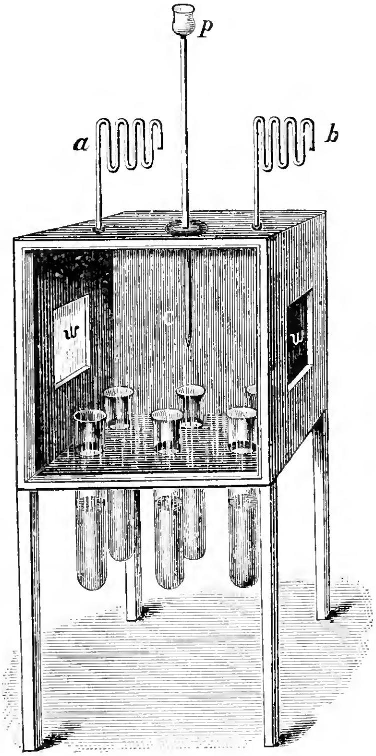
"But is the blackness smoke? This question presented itself in a moment, and was thus answered: A red-hot poker was placed underneath the beam; from it the black wreaths also ascended. A large hydrogen-flame, which emits no smoke, was next employed, and it also produced with augmented copiousness those whirling masses of darkness. Smoke being out of the question, what is the darkness? It is simply that of stellar space; that is to say, blackness resulting from the absence from the track of the beam of all matter competent to scatter its light. When the flame was placed below the beam, the floating matter was destroyed *in situ;* and the heated air, freed from this matter, rose into the beam, jostled aside the illuminated particles, and substituted for their light the darkness due to its own perfect transparency. Nothing could more forcibly illustrate the invisibility of the agent which renders all things visible. The beam crossed, unseen, the black chasm formed by the transparent air, while, at both sides of the gap, the thick-strewed particles shone out like a luminous solid under the powerful illumination."[1]

[1] "Fragments of Science," fifth edition, pp. 128, 129.

Supposing an infusion intrinsically barren, but readily susceptible of putrefaction when exposed to common air, to be brought into contact with this unilluminable air, what would be the result? It would never putrefy. It might, however, be urged that the air is spoiled by its violent calcination. Oxygen passed through a spirit-lamp flame is, it may be thought, no longer the oxygen suitable for the development and maintenance of life. We have an easy escape from this difficulty, which is based, however, upon the unproved assumption that the air has been affected by the flame. Let a condensed beam be sent through a large flask or bolt-head containing common air. The track of the beam is seen within the flask—the dust revealing the light, and the light revealing the dust. Cork the flask, stuff its neck with cotton-wool, or simply turn it mouth downward and leave it undisturbed for a day or two. Examined afterward with the luminous beam, no track is visible; the light passes through the flask as through a vacuum. The floating matter has abolished itself, being now attached to the interior surface of the flask. Were it our object, as it will be subsequently, to effectually detain the dirt, we might coat that surface with some sticky substance. Here, then, without "torturing" the air in any way, we have found a means of ridding it, or rather of enabling it to rid itself, of floating matter.

We have now to devise a means of testing the action of such spontaneously purified air upon putrescible infusions. Wooden chambers, or cases, are accordingly constructed having glass fronts, side-windows, and back-doors. Through the bottoms of the chambers test-tubes pass air-tight, their open ends, for about one-fifth of the length of the tubes, being within the chambers. Provision is made for a free connection through sinuous channels between the inner and the outer air. Through such channels, though open, no dust will reach the chamber. The top of each chamber is perforated by a circular hole two inches in diameter and closed air-tight by a sheet of India-rubber. This is pierced in the middle by a pin, and through the pin-hole is pushed the shank of a long pipette, ending above in a small funnel. The shank also passes through a stuffing-box of cotton-wool moistened with glycerine; so that, tightly clasped by the rubber and wool, the pipette is not likely in its motions up and down to carry any dust into the chamber. The annexed woodcut shows a chamber with six test-tubes, its side-windows *w w*, its pipette *p C*, and its sinuous channels *a b* which connect the air of the chamber with the outer air.

The chamber is carefully closed and permitted to remain quiet for two or three days. Examined at the beginning by a beam sent through its windows, the air is found laden with floating matter, which in three days has wholly disappeared. To prevent its ever rising again into the chambers, the internal surface is coated with glycerine. The fresh but putrescible liquid is introduced into the six tubes in succession by means of the pipette. Permitted to remain without further precaution, every one of the tubes would putrefy and fill itself with life. The liquid has been in contact with dust-laden air by which it has been infected, and the infection must be destroyed. This is done by plunging the six tubes into a bath of heated oil and boiling the infusion. The time requisite to destroy the infection depends wholly upon its nature. Two minutes' boiling suffices to destroy some contagia, whereas two hundred minutes' boiling fails to destroy others. After the infusion has been sterilized, the oil-bath is withdrawn, and the liquid, whose putrescibility has been in no way affected by the boiling, is abandoned to the air of the chamber.



With such chambers I tested, in the autumn and winter of 1875–'76, infusions of the most various kinds, embracing natural animal liquids, the flesh and viscera of domestic animals, game, fish, and vegetables. More than fifty moteless chambers, each with its series of infusions, were then tested, many of them repeatedly. There was no shade of uncertainty in any of the results. In every instance we had, within the chamber, perfect limpidity and sweetness, which in some cases lasted for more than a year—without the chamber, with the same infusion, putridity, and its characteristic smells. In no instance was the least countenance lent to the notion that an infusion deprived by heat of its inherent life, and placed in contact with air cleansed of its visibly suspended matter, has any power whatever to generate life anew.

Remembering, then, the number and variety of the infusions employed, and the strictness of our adherence to the rules of preparation laid down by the heterogenists themselves; remembering that we have operated upon the very substances recommended by them as capable of furnishing even in untrained hands easy and decisive proofs of spontaneous generation, and that we have added to their substances many others of our own—if this pretended generative power were a reality, surely it must have manifested itself somewhere. Speaking roundly, I should say that at least 500 chances have been given to it, but it has nowhere appeared. The argument is now to be closed and clinched by an experiment which will remove every residue of doubt as to the ability of the infusions to sustain life. We open the back-doors of our sealed chambers, and permit the common air with its floating particles to have access to our tubes. For three months they have remained pellucid and sweet—flesh, fish, and vegetable extracts, purer than ever cook manufactured. Three days' exposure to the dusty air suffices to render them muddy, fetid, and swarming with infusorial life. The liquids are thus proved, one and all, ready for putrefaction when the contaminating agent is applied. I invite my colleague to reflect on these facts. How will he account for the absolute immunity of a liquid exposed for months in a warm room to optically pure air, and its infallible putrefaction in a few days when exposed to dust-laden air? He must, I submit, bow to the conclusion that the dust-particles are the cause of putrefactive life. And, unless he accepts the hypothesis that these particles, being dead in the air, are, in the liquid, miraculously kindled into living things, he must conclude that the life we have observed springs from germs or organisms diffused through the atmosphere.

The experiments with hermetically-sealed flasks have reached the number of 940. A sample group of 130 of them were laid before the Royal Society on January 13, 1876. They were utterly free from life, having been completely sterilized by three minutes' boiling. I took special care that the temperatures to which the flasks were exposed should include those previously alleged to be efficient. I copied, indeed, accurately the conditions laid down by our most conspicuous heterogenist, but I failed to corroborate him. He then laid stress on the question of warmth, suddenly adding 30° to the temperatures with which both he and I had previously worked. Waiving all argument or protest against the caprice thus manifested, I met this new requirement also. The sealed tubes, which had proved barren in the Royal Institution, were suspended in perforated boxes, and placed under the supervision of an intelligent assistant in the Turkish Bath in Jermyn Street. From two to six days had been allowed for the generation of organisms in hermetically-sealed tubes. Mine remained in the washing-room of the bath for nine days. Thermometers placed in the boxes, and read off twice or three times a day, showed the temperature to vary from a minimum of 101° to a maximum of 112° Fahr. At the end of nine days the infusions were as clear as at the beginning. They were then removed to a warmer position. A temperature of 115° had been mentioned as particularly favorable to spontaneous generation. For fourteen days the temperature of the Turkish bath hovered about this point, falling once as low as 106°, reaching 116° on three occasions, 118° on one, and 119° on two. The result was quite the same as that just recorded. The higher temperatures proved perfectly incompetent to develop life.

Taking the actual experiment we have made as a basis of calculation, if our 940 flasks were opened on the hay-loft of the Bel Alp 858 of them would become filled with organisms. The escape of the remaining 82 strengthens our case against the heterogenists, proving as it does conclusively that not in the air, nor in the infusions, nor in anything continuous diffused through the air, but in *discrete particles* nourished by the infusions, we are to seek the cause of life. Our experiment proves these particles to be in some cases so far apart on the hay-loft as to permit 10 per cent. of our flasks to take in air without contracting contamination. A quarter of a century ago Pasteur proved the cause of "so-called spontaneous generation" to be *discontinuous.* I have already referred to his observation that 12 out of 20 flasks opened on the plains escaped infection, while 19 out of 20 flasks opened on the Mer de Glace escaped. Our own experiment at the Bel Alp is a more emphatic instance of the same kind, 90 per cent. of the flasks opened in the hay-loft being smitten, while not one of those opened on the free mountain-ledge was attacked. The power of the air as regards putrefactive infection is incessantly changing through natural causes, and we are able to alter it at will. Of a number of flasks opened in 1876 in the laboratory of the Royal Institution, 42 per cent. were smitten, while 58 per cent. escaped. In 1877 the proportion in the same laboratory was 68 per cent. smitten to 32 intact. The greater mortality, so to speak, of the infusions in 1877 was due to the presence of hay which diffused its germinal dust in the laboratory air, causing it to approximate, as regards infective virulence, to the air of the Alpine loft. I would ask my friend to bring his scientific penetration to bear upon all the foregoing facts. They do not prove spontaneous generation to be "impossible." My assertions, however, relate not to "possibilities," but to *proofs*, and the experiments just described do most distinctly prove the evidence on which the heterogenist relies to be written on waste paper.

My friend will not, I am persuaded, dispute these results; but he may be disposed to urge that other able and honorable men working at the same subject have arrived at conclusions different from mine. Most freely granted, but let me here recur to the remarks already made in speaking of the experiments of Spallanzani, to the effect that the failure of others to confirm his results by no means upsets their evidence. To fix the ideas, let us suppose that my colleague comes to the laboratory of the Royal Institution, repeats there my experiments, and obtains confirmatory results; and that he then goes to University or King's College, where, operating with the same infusions, he obtains contradictory results. Will he be disposed to conclude that the self-same snbstance is barren in Albemarle Street and fruitful in Gower Street or the Strand? His Alpine experience has already made known to him the literally infinite differences existing between different samples of air as regards their capacity for putrefactive infection. And, possessing this knowledge, will he not substitute, for the adventurous conclusion that an organic infusion is barren at one place and spontaneously generative at another, the more rational and obvious one that the air of the two localities which has had access to the infusion is infective in different degrees?

As regards workmanship, moreover, he will not fail to bear in mind that *fruitfulness* may be due to errors of manipulation, while *barrenness* involves the presumption of correct experiment. It is only the careful worker that can secure the latter, while it is open to every novice to obtain the former. Barrenness is the result at which the conscientious experimenter, whatever his theoretic convictions may be, ought to aim, omitting no pains to secure it, and resorting, only when there is no escape from it, to the conclusion that the life observed comes from no source which correct experiment could neutralize or avoid. Let us again take a definite case. Supposing my colleague to operate with the same apparent care on 100 infusions—or rather on 100 samples of the same infusion—and that 50 of them prove fruitful and 50 barren. Are we to say that the evidence for and against heterogeny is equally balanced? There are some who would not only say this, but who would treasure up the 50 fruitful flasks, as "positive results, and lower the evidential value of the 50 barren flasks by labeling them "negative" results. This, as shown by Dr. William Roberts, is an exact inversion of the true order of the terms positive and negative.[1] Not such, I trust, would be the course pursued by my friend. As regards the 50 fruitful flasks he would, I doubt not, repeat the experiment with redoubled care and scrutiny, and, not by one repetition only, but by many, assure himself that he had not fallen into error. Such faithful scrutiny fully carried out would infallibly lead him to the conclusion that here, as in all other cases, the evidence in favor of spontaneous generation crumbles in the grasp of the competent inquirer.

The botanist knows that different seeds possess different powers of resistance to heat.[2] Some are killed by a momentary exposure to the boiling temperature, while others withstand it for several hours. Most of our ordinary seeds are rapidly killed, while Pouchet made known to the Paris Academy of Sciences, in 1866, that certain seeds, which had been transported in fleeces of wool from Brazil, germinated after four hours' boiling. The germs of the air vary as much among themselves as the seeds of the botanist. In some localities the diffused germs are so tender that boiling for five minutes, or even less, would be sure to destroy them all; in other localities the diffused germs are

[1] *See* his truly philosophical remarks on this head in the *British Medical Journal*, 1876, p. 282.

[2] I am indebted to Dr. Thistleton Dyer for various illustrations of such differences. It is, however, surprising that a subject of such high scientific importance should not have been more thoroughly explored. Here the scoundrels who deal in killed seeds might be able to add to our knowledge.

so obstinate that many hours' boiling would be requisite to deprive them of their power of germination. The absence or presence of a truss of desiccated hay would produce differences as great as those here described. The greatest endurance that I have ever observed—and I believe it is the greatest on record—was a case of survival after eight hours' boiling. As regards their power of resisting heat, the infusorial germs of our atmosphere might be classified under the following and intermediate heads: Killed in five minutes; not killed in five minutes but killed in fifteen; not killed in fifteen minutes but killed in thirty; not killed in thirty minutes but killed in an hour; not killed in an hour but killed in two hours; not killed in two but killed three hours; not killed in three but killed in four hours. I have had several cases of survival after four and five hours' boiling, some survivals after six, and one after eight hours' boiling. Thus far has experiment actually reached, but there is no valid warrant for fixing upon even eight hours as the extreme limit of vital resistance. Probably more extended researches (though mine have been very extensive) would reveal germs more obstinate still. It is also certain that we might begin earlier, and find germs which are destroyed by a temperature far below that of boiling water. In the presence of such facts, to speak of *a* death-point of bacteria and their germs would be mere nonsense—but of this more anon.

We have now to test one of the principal foundations of the doctrine of spontaneous generation as formulated in this country. With this view, I place before my friend and co-inquirer two liquids which have been kept for six months in one of our sealed chambers, exposed to optically pure air. The one is a mineral solution containing in proper proportions all the substances which enter into the composition of bacteria, the other is an infusion of turnip—it might be any one of a hundred other infusions, animal or vegetable. Both liquids are as clear as distilled water, and there is no trace of life in either of them. They are, in fact, completely sterilized. A mutton-chop, over which a little water has been poured to keep its juices from drying up, has lain for three days upon a plate in our warm room. It smells offensively. Placing a drop of the fetid mutton-juice under a microscope, it is found swarming with the bacteria which live by putrefaction, and without which no putrefaction can occur. With a speck of the swarming liquid I inoculate the clear mineral solution and the clear turnip-infusion, as a surgeon might inoculate an infant with vaccine lymph. In four-and-twenty hours the transparent liquids have become turbid throughout, and, instead of being barren as at first, they are teeming with life. The experiment may be repeated a thousand times with the same invariable result. To the naked eye the liquids at the beginning were alike, being both equally transparent—to the naked eye they are alike at the end, being both equally muddy. Instead of putrid mutton-juice we might take as a source of infection any one of a hundred other putrid liquids, animal or vegetable. So long as the liquid contains the living bacteria, a speck of it communicated to the clear mineral solution, or to the clear turnip-infusion, produces in twenty-four hours the effect that we have described.

We now vary the experiment thus: Opening the back-door of another closed chamber which has contained for months the pure mineral solution and the pure turnip-infusion side by side, I drop into each of them a small pinch of laboratory dust. The effect here is tardier than when the speck of putrid liquid was employed. In three days, however, after its infection with the dust, the turnip-infusion is muddy, and swarming as before with bacteria. But what about the mineral solution which, in our first experiment, behaved in a manner undistinguishable from the turnip-juice? At the end of three days there is not a bacterium to be found in it. At the end of three weeks it is equally innocent of bacterial life. We may repeat the experiment with the solution and the infusion a hundred times, with the same invariable result. Always in the case of the latter the sowing of the atmospheric dust yields a crop of bacteria—never in the former does the dry germinal matter kindle into active life.[1] What is the inference which the reflecting mind must draw from this experiment? Is it not as clear as day that while both liquids are able to feed the bacteria and to enable them to increase and multiply, *after they have been once fully developed*, only one of the liquids is able to develop into active bacteria the germinal dust of the air?

I invite my friend to reflect upon this conclusion; he will, I think, see that there is no escape from it. He may, if he prefers it, hold the opinion, which I consider erroneous, that bacteria exist in the air, not as germs but as desiccated organisms. The inference remains that, while the one liquid is able to force the passage from the inactive to the active state, the other is not.

But this is not at all the inference which has been drawn from experiments with the mineral solution. Seeing its ability to nourish bacteria when once inoculated with the living active organism, and observing that no bacteria appeared in the solution after long exposure to the air, the inference was drawn that *neither bacteria nor their germs existed in the air.* Throughout Germany the ablest literature of the subject, even that opposed to heterogeny, is infected with this error; while heterogenists at home and abroad have based upon it a triumphant demonstration of their doctrine. It is proved, they say, by the deportment of the mineral solution that neither bacteria nor their germs exist in the air; hence, if, on exposing a thoroughly sterilized turnip-infusion to the air, bacteria appear, they must of necessity have been spontaneously generated. In the words

[1] This is the deportment of the mineral solution as described by others. My own experiments would lead me to say that the development of the bacteria, though exceedingly slow and difficult, is not impossible.

of Dr. Bastian, uttered not in a popular book, but in the "Proceedings of the Royal Society,"[1] with reference to this very experiment: "We can only infer that while the boiled saline solution is quite incapable of engendering bacteria, such organisms are able to arise *de novo* in the boiled organic infusion." I would ask my eminent colleague what he thinks of this reasoning now? The *datum* is, "A mineral solution exposed to common air does not develop bacteria:" the *inference* is, "Therefore, if a turnip-infusion similarly exposed develop bacteria, they must be spontaneously generated." The inference, on the face of it, is an unwarranted one. But, while as matter of logic it is inconclusive, as matter of fact it is chimerical. London air is as surely charged with the germs of bacteria as London chimneys are with smoke. The inference just referred to is completely disposed of by the simple question: "Why, when your sterilized organic infusion is exposed to optically pure air, should this generation of life *de novo* utterly cease? Why should I be able to preserve my turnip-juice side by side with your saline solution for the three hundred and sixty-five days of the year, in free connection with the general atmosphere, on the sole condition that the portion of that atmosphere in contact with the juice shall be visibly free from floating dust, while three days' exposure to that dust fills it with bacteria?" Am I over-sanguine in hoping that, as regards the argument here set forth, he who runs may read, and he who reads may understand? Let me add, however, that while exposing the fallacy of the inferences drawn from it, I regard the observation that the boiled saline solution can sustain the developed organisms, while it cannot develop them from the dry germinal matter of the air, as an important addition to our knowledge. We are indebted for it to Dr. Burdon-Sanderson, who soon saw that his first interpretation of it went too far, and who, in a communication recently presented to the Royal Society, abandons the interpretation altogether.

We now proceed to the calm and thorough consideration of another subject, more important if possible than the foregoing one, but like it somewhat difficult to seize by reason of the very opulence of the phraseology, logical and rhetorical, in which it has been set forth. The subject now to be considered relates to what has been called "the death-point of bacteria." Those who happen to be acquainted with the modern English literature of the question will remember how challenge after challenge has been issued to panspermatists in general, and to one or two home workers in particular, to come to close quarters on this cardinal point. It is obviously the stronghold of the English heterogenist. "Water," he says, "is boiling merrily over a fire, when some luckless person upsets the vessel so that the heated fluid exercises its scathing influence upon an uncovered portion of the body—hand, arm, or face. Here at all events there is no room for

[1] Vol. xxi., p. 130.

doubt. Boiling water unquestionably exercises a most pernicious and rapidly-destructive effect upon the living matter of which we are composed."[1] And, lest it should be supposed that it is the high organization which, in this case, renders the body susceptible to heat, he refers to the action of boiling water on the hen's-egg to dissipate the notion. "The conclusion," he says, "would seem to force itself upon us that there is something intrinsically deleterious in the action of boiling water upon living matter—whether this matter be of high or of low organization."[2] Again, at another place, "It has been shown that the briefest exposure to the influence of boiling water is destructive of all living matter."[3] Throughout his prolonged disquisitions on this subject, Dr. Bastian makes special kinds of living matter do duty for *all* kinds. To invalidate the foregoing statements it is only necessary to say that eight years before they were made it had been known to the wool-staplers of Elbœuf, and Pouchet had published the fact in the *Comptes-Rendus of the Paris Academy of Sciences*,[4] that the desiccated seeds of the Brazilian plant *medicago* survived fully four hours' boiling. Pouchet himself boiled the seeds, and found some of them swollen and disintegrated, while others remained hard and unswollen. Sown in the same earth, the latter germinated while the former did not. So much for the heterogenist's mistake regarding ordinary seeds; we must now examine whether no error underlies his experiments and his reasonings as to "the death-point of bacteria."

The experiments already recorded plainly show that there is a marked difference between the dry bacterial matter of the air, and the wet, soft, and active bacteria of putrefying organic liquids. The one can be luxuriantly bred in the saline solution, the others refuse to be born there, while both of them are copiously developed in a sterilized turnip-infusion. Inferences, as we have already seen, founded on the deportment of the one liquid cannot with the warrant of scientific logic be extended to the other. But this is exactly what the heterogenist has done, thus repeating, as regards the death-point of bacteria, the error into which he fell concerning the germs of the air. Let us boil our muddy mineral solution with its swarming bacteria for five minutes. In the soft, succulent condition in which they exist in the solution not one of them escapes destruction. The same is true of the turnip-infusion if it be inoculated with the living bacteria only—the aërial dust being carefully excluded. In both cases the dead organisms sink to the bottom of the liquid, and without reinoculation no fresh organisms will arise. But the case is entirely different when we inoculate our turnip-infusion with the desiccated germinal matter afloat in the air.

The "death-point" of bacteria is the maximum temperature at

[1] Bastian, "Evolution," p. 133. [2] Ibid., p. 135. [3] Ibid., p. 46.
[4] Vol. lxiii., p. 939.

which they can live, or the minimum temperature at which they cease to live. If, for example, they survive a temperature of 140°, and do not survive a temperature of 150°, the death-point lies somewhere between these two temperatures. Vaccine lymph, for example, is proved by Messrs. Braidwood and Vacher to be deprived of its power of infection by brief exposure to a temperature between 140° and 150° Fahr. This may be regarded as the death-point of the lymph, or rather of the particles diffused in the lymph, which constitute the real contagium. If no time, however, be named for the application of the heat, the term "death-point" is a vague one. An infusion, for example, which will resist five hours' continuous exposure to the boiling temperature, will succumb to five days' exposure to a temperature 50° below that of boiling. The fully-developed, soft bacteria of putrefying liquids are not only killed by five minutes' boiling, but by less than a single minute's boiling—indeed, they are slain at about the same temperature as the vaccine. The same is true of the plastic, active bacteria of the turnip-infusion.[1] But, instead of choosing a putrefying liquid for inoculation, let us prepare and employ our inoculating substance in the following simple way: Let a small wisp of hay, desiccated by age, be washed in a glass of water, and let a perfectly sterilized turnip-infusion be inoculated with the washing liquid. After three hours' continuous boiling the infusion thus infected will often develop luxuriant bacterial life. Precisely the same occurs if a turnip-infusion be prepared in an atmosphere well charged with desiccated hay-germs. The infusion in this case infects itself without special inoculation, and its subsequent resistance to sterilization is often very great. On the 1st of March last I purposely infected the air of our laboratory with the germinal dust of a sapless kind of hay mown in 1875. Ten groups of flasks were charged with turnip infusion prepared in the infected laboratory, and were afterward subjected to the boiling temperature for periods varying from 15 minutes to 240 minutes. Out of the ten groups only one was sterilized—that, namely, which had been boiled for four hours. Every flask of the nine groups which had been boiled for 15, 30, 45, 60, 75, 90, 105, 120, and 180 minutes respectively, bred organisms afterward. The same is true of other vegetable infusions. On the 28th of February last, for example, I boiled six flasks, containing cucumber-infusion prepared in an infected atmosphere, for periods of 15, 30, 45, 60, 120, and 180 minutes. Every flask of the group subsequently developed organisms. On the same day, in the case of three flasks, the boiling was prolonged to 240, 300, and 360 minutes; and these three flasks were completely

[1] In my paper in the "Philosophical Transactions" for 1876, I pointed out and illustrated experimentally the difference, as regards rapidity of development, between water-germs and air-germs; the growth from the already softened water-germs proving to be practically as rapid as from developed bacteria. This preparedness of the germ for rapid development is associated with its preparedness for rapid destruction.

sterilized. Animal infusions, which under ordinary circumstances are rendered infallibly barren by five minutes' boiling, behave like the vegetable infusions in an infective atmosphere. On the 30th of March, for example, five flasks were charged with a clear infusion of beef and boiled for 60 minutes, 120 minutes, 180 minutes, 240 minutes, and 300 minutes respectively. Every one of them became subsequently crowded with organisms, and the same happened to a perfectly pellucid mutton-infusion prepared at the same time. The cases are to be numbered by hundreds in which similar powers of resistance were manifested by infusions of the most diverse kinds.

In the presence of such facts I would ask my eminent colleague whether it is necessary to dwell for a single instant on the one-sidedness of the evidence which led to the conclusion that all living matter has its life destroyed by "the briefest exposure to the influence of boiling water." An infusion proved to be barren by six months' exposure to moteless air kept at a temperature of 90° Fahr., when inoculated with full-grown, active bacteria, fills itself in two days with organisms so sensitive as to be killed by a few minutes' exposure to a temperature much below that of boiling water. But the extension of this result to the desiccated germinal matter of the air is without warrant or justification. This is obvious without going beyond the argument itself. But we have gone far beyond the argument and proved by multiplied experiment the alleged destruction of all living matter by the briefest exposure to the influence of boiling water to be a delusion. The whole logical edifice raised upon this basis falls, therefore, to the ground; and the argument that bacteria and their germs being destroyed at 140° must, if they appear after exposure to 212°, be spontaneously generated, is, I trust, silenced forever.

Through the precautions, variations, and repetitions observed and executed with the view of rendering its results secure, the separate vessels employed in this inquiry have mounted up in two years to nearly 10,000. Here, however, and with good reason, the editor cries, "Halt!" I had hoped, when I began, to carry the argument further. Besides the philosophic interest attaching to the problem of life's origin, which will be always immense, there are the practical interests involved in the application of the doctrines here discussed to surgery and medicine. The antiseptic system, at which I have already glanced, illustrates the manner in which beneficent results of the gravest moment follow in the wake of clear theoretic insight. Surgery was once a noble art; it is now, as well, a noble science. Prior to the introduction of the antiseptic system, the thoughtful surgeon could not have failed to learn empirically that there is something in the air which often defeated the most consummate operative skill. That something the antiseptic treatment destroys or renders innocuous. At King's College Mr. Lister operates and dresses while a fine shower of mixed carbolic acid and water, produced in the simplest manner, falls upon the wound, the lint and gauze employed in the subsequent dressing being duly saturated with the antiseptic. At St. Bartholomew's Mr. Callender employs the dilute carbolic acid without the spray; but, as regards the real point aimed at—the preventing of the wound from becoming a nidus for the propagation of septic bacteria—the practice in both hospitals is the same. Commending itself as it does to the scientifically-trained mind, the antiseptic system has struck deep root in Germany.

It would also have given me pleasure to point out the present position of the "germ-theory" in reference to the phenomena of infectious disease, distinguishing arguments based on analogy—which, however, are terribly strong—from those based on actual observation. I should have liked to follow up the account I have already given[1] of the truly excellent researches of a young and an unknown German physician named Koch, on splenic fever, by an account of what Pasteur has recently done with reference to the same subject. Here we have before us a living contagium of the most fatal power, which we can follow from the beginning to the end of its life-cycle.[2] We find it in the blood or spleen of a smitten animal in the state say of short motionless rods. We place these rods in a nutritive liquid on the warm stage of the microscope, and see them lengthening into filaments which lie side by side, or, crossing each other, become coiled into knots of a complexity not to be unraveled. We finally see those filaments resolving themselves into innumerable spores, each with death potentially housed within it, yet not to be distinguished microscopically from the harmless germs of *Bacillus subtilis*. The bacterium of splenic fever is called *Bacillus anthracis*. This formidable organism was shown to me by M. Pasteur in Paris last July. His recent investigations regarding the part it plays pathologically certainly rank among the most remarkable labors of that remarkable man. Observer after observer had strayed and fallen in this land of pitfalls, a multitude of opposing conclusions and mutually-destructive theories being the result. In association with his younger physiological colleague M. Joubert, Pasteur struck in amid the chaos, and soon reduced the whole of it to harmony. They proved, among other things, that in cases where previous observers in France had supposed themselves to be dealing solely with splenic fever, another equally virulent factor was simultaneously active. Splenic fever was often overmastered by septicæmia, and results due solely to the latter had been frequently made the ground of pathological inferences regarding the character and cause of the former. Combining duly the two factors, all the previous irregularities disappeared, every result obtained receiving the fullest explanation. On studying the account

[1] *Fortnightly Review*, November, 1876.

[2] Dallinger and Drysdale had previously shown what skill and patience can accomplish by their admirable observations on the life-history of the monads.

of this masterly investigation, the words wherewith Pasteur himself feelingly alludes to the difficulties and dangers of the experimenter's art came home to me with especial force: "J'ai tant de fois éprouvé que dans cet art difficile de l'expérimentation les plus habiles bronchent à chaque pas, et que l'interprétation des faits n'est pas moins périlleuse."[1]

ILLUSTRATIONS OF THE LOGIC OF SCIENCE.

By C. S. PEIRCE,
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THIRD PAPER.—THE DOCTRINE OF CHANCES.

I.

IT is a common observation that a science first begins to be exact when it is quantitatively treated. What are called the exact sciences are no others than the mathematical ones. Chemists reasoned vaguely until Lavoisier showed them how to apply the balance to the verification of their theories, when chemistry leaped suddenly into the position of the most perfect of the classificatory sciences. It has thus become so precise and certain that we usually think of it along with optics, thermotics, and electrics. But these are studies of general laws, while chemistry considers merely the relations and classification of certain objects; and belongs, in reality, in the same category as systematic botany and zoölogy. Compare it with these last, however, and the advantage that it derives from its quantitative treatment is very evident.

The rudest numerical scales, such as that by which the mineralogists distinguish the different degrees of hardness, are found useful. The mere counting of pistils and stamens sufficed to bring botany out of total chaos into some kind of form. It is not, however, so much from *counting* as from *measuring*, not so much from the conception of number as from that of continuous quantity, that the advantage of mathematical treatment comes. Number, after all, only serves to pin us down to a precision in our thoughts which, however beneficial, can seldom lead to lofty conceptions, and frequently descends to pettiness. Of those two faculties of which Bacon speaks, that which marks differences and that which notes resemblances, the employment of number can only aid the lesser one; and the excessive use of it must tend to narrow the powers of the mind. But the conception of continuous quantity has a great office to fulfill, independently of any attempt at precision. Far from tending to the exaggeration of differences, it is the direct instrument of the finest generalizations. When

[1] *Comptes Rendus*, lxxxiii., p. 177.

a naturalist wishes to study a species, he collects a considerable number of specimens more or less similar. In contemplating them, he observes certain ones which are more or less alike in some particular respect. They all have, for instance, a certain S-shaped marking. He observes that they are not *precisely* alike, in this respect; the S has not precisely the same shape, but the differences are such as to lead him to believe that forms could be found intermediate between any two of those he possesses. He, now, finds other forms apparently quite dissimilar—say a marking in the form of a C—and the question is, whether he can find intermediate ones which will connect these latter with the others. This he often succeeds in doing in cases where it would at first be thought impossible; whereas, he sometimes finds those which differ, at first glance, much less, to be separated in Nature by the non-occurrence of intermediaries. In this way, he builds up from the study of Nature a new general conception of the character in question. He obtains, for example, an idea of a leaf which includes every part of the flower, and an idea of a vertebra which includes the skull. I surely need not say much to show what a logical engine there is here. It is the essence of the method of the naturalist. How he applies it first to one character, and then to another, and finally obtains a notion of a species of animals, the differences between whose members, however great, are confined within limits, is a matter which does not here concern us. The whole method of classification must be considered later; but, at present, I only desire to point out that it is by taking advantage of the idea of continuity, or the passage from one form to another by insensible degrees, that the naturalist builds his conceptions. Now, the naturalists are the great builders of conceptions; there is no other branch of science where so much of this work is done as in theirs; and we must, in great measure, take them for our teachers in this important part of logic. And it will be found everywhere that the idea of continuity is a powerful aid to the formation of true and fruitful conceptions. By means of it, the greatest differences are broken down and resolved into differences of degree, and the incessant application of it is of the greatest value in broadening our conceptions. I propose to make a great use of this idea in the present series of papers; and the particular series of important fallacies, which, arising from a neglect of it, have desolated philosophy, must further on be closely studied. At present, I simply call the reader's attention to the utility of this conception.

In studies of numbers, the idea of continuity is so indispensable, that it is perpetually introduced even where there is no continuity in fact, as where we say that there are in the United States 10.7 inhabitants per square mile, or that in New York 14.72 persons live in the average house.[1] Another example is that law of the distribu-

[1] This mode of thought is so familiarly associated with all exact numerical consideration, that the phrase appropriate to it is imitated by shallow writers in order to produce

tion of errors which Quetelet, Galton, and others, have applied with so much success to the study of biological and social matters. This application of continuity to cases where it does not really exist illustrates, also, another point which will hereafter demand a separate study, namely, the great utility which fictions sometimes have in science.

II.

The theory of probabilities is simply the science of logic quantitatively treated. There are two conceivable certainties with reference to any hypothesis, the certainty of its truth and the certainty of its falsity. The numbers *one* and *zero* are appropriated, in this calculus, to marking these extremes of knowledge; while fractions having values intermediate between them indicate, as we may vaguely say, the degrees in which the evidence leans toward one or the other. The general problem of probabilities is, from a given state of facts, to determine the numerical probability of a possible fact. This is the same as to inquire how much the given facts are worth, considered as evidence to prove the possible fact. Thus the problem of probabilities is simply the general problem of logic.

Probability is a continuous quantity, so that great advantages may be expected from this mode of studying logic. Some writers have gone so far as to maintain that, by means of the calculus of chances, every solid inference may be represented by legitimate arithmetical operations upon the numbers given in the premises. If this be, indeed, true, the great problem of logic, how it is that the observation of one fact can give us knowledge of another independent fact, is reduced to a mere question of arithmetic. It seems proper to examine this pretension before undertaking any more recondite solution of the paradox.

But, unfortunately, writers on probabilities are not agreed in regard to this result. This branch of mathematics is the only one, I believe, in which good writers frequently get results entirely erroneous. In elementary geometry the reasoning is frequently fallacious, but erroneous conclusions are avoided; but it may be doubted if there is a single extensive treatise on probabilities in existence which does not contain solutions absolutely indefensible. This is partly owing to the want of any regular method of procedure; for the subject involves too many subtilties to make it easy to put its problems into equations without such an aid. But, beyond this, the fundamental principles of its calculus are more or less in dispute. In regard to that class of questions to which it is chiefly applied for practical purposes, there is comparatively little doubt; but in regard to others to which it has been sought to extend it, opinion is somewhat unsettled.

the appearance of exactitude where none exists. Certain newspapers which affect a learned tone talk of "the average man," when they simply mean *most men*, and have no idea of striking an average.

This last class of difficulties can only be entirely overcome by making the idea of probability perfectly clear in our minds in the way set forth in our last paper.

III.

To get a clear idea of what we mean by probability, we have to consider what real and sensible difference there is between one degree of probability and another.

The character of probability belongs primarily, without doubt, to certain inferences. Locke explains it as follows: After remarking that the mathematician positively knows that the sum of the three angles of a triangle is equal to two right angles because he apprehends the geometrical proof, he thus continues: "But another man who never took the pains to observe the demonstration, hearing a mathematician, a man of credit, affirm the three angles of a triangle to be equal to two right ones, *assents* to it; i. e., receives it for true. In which case the foundation of his assent is the probability of the thing, the proof being such as, for the most part, carries truth with it; the man on whose testimony he receives it not being wont to affirm anything contrary to, or besides his knowledge, especially in matters of this kind." The celebrated "Essay concerning Humane Understanding" contains many passages which, like this one, make the first steps in profound analyses which are not further developed. It was shown in the first of these papers that the validity of an inference does not depend on any tendency of the mind to accept it, however strong such tendency may be; but consists in the real fact that, when premises like those of the argument in question are true, conclusions related to them like that of this argument are also true. It was remarked that in a logical mind an argument is always conceived as a member of a *genus* of arguments all constructed in the same way, and such that, when their premises are real facts, their conclusions are so also. If the argument is demonstrative, then this is always so; if it is only probable, then it is for the most part so. As Locke says, the probable argument is "*such as* for the most part carries truth with it."

According to this, that real and sensible difference between one degree of probability and another, in which the meaning of the distinction lies, is that in the frequent employment of two different modes of inference, one will carry truth with it oftener than the other. It is evident that this is the only difference there is in the existing fact. Having certain premises, a man draws a certain conclusion, and as far as this inference alone is concerned the only possible practical question is whether that conclusion is true or not, and between existence and non-existence there is no middle term. "Being only is and nothing is altogether not," said Parmenides; and this is in strict accordance with the analysis of the conception of reality given in the last paper. For we found that the distinction of reality and fiction depends on the supposition that sufficient investigation would cause one opinion to be universally received and all others to be rejected. That presupposition involved in the very conceptions of reality and figment involves a complete sundering of the two. It is the heaven-and-hell idea in the domain of thought. But, in the long run, there is a real fact which corresponds to the idea of probability, and it is that a given mode of inference sometimes proves successful and sometimes not, and that in a ratio ultimately fixed. As we go on drawing inference after inference of the given kind, during the first ten or hundred cases the ratio of successes may be expected to show considerable fluctuations; but when we come into the thousands and millions, these fluctuations become less and less; and if we continue long enough, the ratio will approximate toward a fixed limit. We may therefore define the probability of a mode of argument as the proportion of cases in which it carries truth with it.

The inference from the premise, A, to the conclusion, B, depends, as we have seen, on the guiding principle, that if a fact of the class A is true, a fact of the class B is true. The probability consists of the fraction whose numerator is the number of times in which both A and B are true, and whose denominator is the total number of times in which A is true, whether B is so or not. Instead of speaking of this as the probability of the inference, there is not the slighest objection to calling it the probability that, if A happens, B happens. But to speak of the probability of the event B, without naming the condition, really has no meaning at all. It is true that when it is perfectly obvious what condition is meant, the ellipsis may be permitted. But we should avoid contracting the habit of using language in this way (universal as the habit is), because it gives rise to a vague way of thinking, as if the action of causation might either determine an event to happen or determine it not to happen, or leave it more or less free to happen or not, so as to give rise to an *inherent* chance in regard to its occurrence. It is quite clear to me that some of the worst and most persistent errors in the use of the doctrine of chances have arisen from this vicious mode of expression.[1]

IV.

But there remains an important point to be cleared up. According to what has been said, the idea of probability essentially belongs to a kind of inference which is repeated indefinitely. An individual inference must be either true or false, and can show no effect of probability; and, therefore, in reference to a single case considered in

[1] The conception of probability here set forth is substantially that first developed by Mr. Venn, in his "Logic of Chance." Of course, a vague apprehension of the idea had always existed, but the problem was to make it perfectly clear, and to him belongs the credit of first doing this.

itself, probability can have no meaning. Yet if a man had to choose between drawing a card from a pack containing twenty-five red cards and a black one, or from a pack containing twenty-five black cards and a red one, and if the drawing of a red card were destined to transport him to eternal felicity, and that of a black one to consign him to everlasting woe, it would be folly to deny that he ought to prefer the pack containing the larger proportion of red cards, although, from the nature of the risk, it could not be repeated. It is not easy to reconcile this with our analysis of the conception of chance. But suppose he should choose the red pack, and should draw the wrong card, what consolation would he have? He might say that he had acted in accordance with reason, but that would only show that his reason was absolutely worthless. And if he should choose the right card, how could he regard it as anything but a happy accident? He could not say that if he had drawn from the other pack, he might have drawn the wrong one, because an hypothetical proposition such as, "if A, then B," means nothing with reference to a single case. Truth consists in the existence of a real fact corresponding to the true proposition. Corresponding to the proposition, "if A, then B," there may be the fact that *whenever* such an event as A happens such an event as B happens. But in the case supposed, which has no parallel as far as this man is concerned, there would be no real fact whose existence could give any truth to the statement that, if he had drawn from the other pack, he might have drawn a black card. Indeed, since the validity of an inference consists in the truth of the hypothetical proposition that *if* the premises be true the conclusion will also be true, and since the only real fact which can correspond to such a proposition is that whenever the antecedent is true the consequent is so also, it follows that there can be no sense in reasoning in an isolated case, at all.

These considerations appear, at first sight, to dispose of the difficulty mentioned. Yet the case of the other side is not yet exhausted. Although probability will probably manifest its effect in, say, a thousand risks, by a certain proportion between the numbers of successes and failures, yet this, as we have seen, is only to say that it certainly will, at length, do so. Now the number of risks, the number of probable inferences, which a man draws in his whole life, is a finite one, and he cannot be absolutely *certain* that the mean result will accord with the probabilities at all. Taking all his risks collectively, then, it cannot be certain that they will not fail, and his case does not differ, except in degree, from the one last supposed. It is an indubitable result of the theory of probabilities that every gambler, if he continues long enough, must ultimately be ruined. Suppose he tries the martingale, which some believe infallible, and which is, as I am informed, disallowed in the gambling-houses. In this method of playing, he first bets say $1; if he loses it he bets $2; if he loses that he bets $4; if he loses that he bets $8; if he then gains he has lost $1+2+4=7$, and he has gained $1 more; and no matter how many bets he loses, the first one he gains will make him $1 richer than he was in the beginning. In that way, he will probably gain at first; but, at last, the time will come when the run of luck is so against him that he will not have money enough to double, and must therefore let his bet go. This will *probably* happen before he has won as much as he had in the first place, so that this run against him will leave him poorer than he began; some time or other it will be sure to happen. It is true that there is always a possibility of his winning any sum the bank can pay, and we thus come upon a celebrated paradox that, though he is certain to be ruined, the value of his expectation calculated according to the usual rules (which omit this consideration) is large. But, whether a gambler plays in this way or any other, the same thing is true, namely, that if plays long enough he will be sure some time to have such a run against him as to exhaust his entire fortune. The same thing is true of an insurance company. Let the directors take the utmost pains to be independent of great conflagrations and pestilences, their actuaries can tell them that, according to the doctrine of chances, the time must come, at last, when their losses will bring them to a stop. They may tide over such a crisis by extraordinary means, but then they will start again in a weakened state, and the same thing will happen again all the sooner. An actuary might be inclined to deny this, because he knows that the expectation of his company is large, or perhaps (neglecting the interest upon money) is infinite. But calculations of expectations leave out of account the circumstance now under consideration, which reverses the whole thing. However, I must not be understood as saying that insurance is on this account unsound, more than other kinds of business. All human affairs rest upon probabilities, and the same thing is true everywhere. If man were immortal he could be perfectly sure of seeing the day when everything in which he had trusted should betray his trust, and, in short, of coming eventually to hopeless misery. He would break down, at last, as every great fortune, as every dynasty, as every civilization does. In place of this we have death.

But what, without death, would happen to every man, with death must happen to some man. At the same time, death makes the number of our risks, of our inferences, finite, and so makes their mean result uncertain. The very idea of probability and of reasoning rests on the assumption that this number is indefinitely great. We are thus landed in the same difficulty as before, and I can see but one solution of it. It seems to me that we are driven to this, that logicality inexorably requires that our interests shall *not* be limited. They must not stop at our own fate, but must embrace the whole community. This community, again, must not be limited, but must extend to all races of beings with whom we can come into immediate or mediate intellectual relation. It must reach, however vaguely, beyond this geological epoch, beyond all bounds. He who would not sacrifice his own soul to save the whole world, is, as it seems to me, illogical in all his inferences, collectively. Logic is rooted in the social principle.

To be logical men should not be selfish; and, in point of fact, they are not so selfish as they are thought. The willful prosecution of one's desires is a different thing from selfishness. The miser is not selfish; his money does him no good, and he cares for what shall become of it after his death. We are constantly speaking of *our* possessions on the Pacific, and of *our* destiny as a republic, where no personal interests are involved, in a way which shows that we have wider ones. We discuss with anxiety the possible exhaustion of coal in some hundreds of years, or the cooling-off of the sun in some millions, and show in the most popular of all religious tenets that we can conceive the possibility of a man's descending into hell for the salvation of his fellows.

Now, it is not necessary for logicality that a man should himself be capable of the heroism of self-sacrifice. It is sufficient that he should recognize the possibility of it, should perceive that only that man's inferences who has it are really logical, and should consequently regard his own as being only so far valid as they would be accepted by the hero. So far as he thus refers his inferences to that standard, he becomes identified with such a mind.

This makes logicality attainable enough. Sometimes we can personally attain to heroism. The soldier who runs to scale a wall knows that he will probably be shot, but that is not all he cares for. He also knows that if all the regiment, with whom in feeling he identifies himself, rush forward at once, the fort will be taken. In other cases we can only imitate the virtue. The man whom we have supposed as having to draw from the two packs, who if he is not a logician will draw from the red pack from mere habit, will see, if he is logician enough, that he cannot be logical so long as he is concerned only with his own fate, but that that man who should care equally for what was to happen in all possible cases of the sort could act logically, and would draw from the pack with the most red cards, and thus, though incapable himself of such sublimity, our logician would imitate the effect of that man's courage in order to share his logicality.

But all this requires a conceived identification of one's interests with those of an unlimited community. Now, there exist no reasons, and a later discussion will show that there can be no reasons, for thinking that the human race, or any intellectual race, will exist forever. On the other hand, there can be no reason against it;[1] and,

[1] I do not here admit an absolutely unknowable. Evidence could show us what would probably be the case after any given lapse of time; and though a subsequent time

fortunately, as the whole requirement is that we should have certain sentiments, there is nothing in the facts to forbid our having a *hope*, or calm and cheerful wish, that the community may last beyond any assignable date.

It may seem strange that I should put forward three sentiments, namely, interest in an indefinite community, recognition of the possibility of this interest being made supreme, and hope in the unlimited continuance of intellectual activity, as indispensable requirements of logic. Yet, when we consider that logic depends on a mere struggle to escape doubt, which, as it terminates in action, must begin in emotion, and that, furthermore, the only cause of our planting ourselves on reason is that other methods of escaping doubt fail on account of the social impulse, why should we wonder to find social sentiment presupposed in reasoning? As for the other two sentiments which I find necessary, they are so only as supports and accessories of that. It interests me to notice that these three sentiments seem to be pretty much the same as that famous trio of Charity, Faith, and Hope, which, in the estimation of St. Paul, are the finest and greatest of spiritual gifts. Neither Old nor New Testament is a text-book of the logic of science, but the latter is certainly the highest existing authority in regard to the dispositions of heart which a man ought to have.

V.

Such average statistical numbers as the number of inhabitants per square mile, the average number of deaths per week, the number of convictions per indictment, or, generally speaking, the number of x's per y, where the x's are a class of things some or all of which are connected with another class of things, their y's, I term *relative numbers*. Of the two classes of things to which a relative number refers, that one of which it is a number may be called its *relate*, and that one *per* which the numeration is made may be called its *correlate*.

Probability is a kind of relative number; namely, it is the ratio of the number of arguments of a certain genus which carry truth with them to the total number of arguments of that genus, and the rules for the calculation of probabilities are very easily derived from this consideration. They may all be given here, since they are extremely simple, and it is sometimes convenient to know something of the elementary rules of calculation of chances.

Rule I. *Direct Calculation.*—To calculate, directly, any relative number, say for instance the number of passengers in the average trip of a street-car, we must proceed as follows:

Count the number of passengers for each trip; add all these numbers, and divide by the number of trips. There are cases in which this rule may be simplified. Suppose we wish to know the number

might be assigned which that evidence might not cover, yet further evidence would cover it.

of inhabitants to a dwelling in New York. The same person cannot inhabit two dwellings. If he divide his time between two dwellings he ought to be counted a half-inhabitant of each. In this case we have only to divide the total number of the inhabitants of New York by the number of their dwellings, without the necessity of counting separately those which inhabit each one. A similar proceeding will apply wherever each individual relate belongs to one individual correlate exclusively. If we want the number of x's per y, and no x belongs to more than one y, we have only to divide the whole number of x's of y's by the number of y's. Such a method would, of course, fail if applied to finding the average number of street-car passengers per trip. We could not divide the total number of travelers by the number of trips, since many of them would have made many passages.

To find the probability that from a given class of premises, A, a given class of conclusions, B, follow, it is simply necessary to ascertain what proportion of the times in which premises of that class are true, the appropriate conclusions are also true. In other words, it is the number of cases of the occurrence of both the events A and B, divided by the total number of cases of the occurrence of the event A.

Rule II. *Addition of Relative Numbers.*—Given two relative numbers having the same correlate, say the number of x's per y, and the number of z's per y; it is required to find the number of x's and z's together per y. If there is nothing which is at once an x and a z to the same y, the sum of the two given numbers would give the required number. Suppose, for example, that we had given the average number of friends that men have, and the average number of enemies, the sum of these two is the average number of persons interested in a man. On the other hand, it plainly would not do to add the average number of persons having constitutional diseases to the average number over military age, and to the average number exempted by each special cause from military service, in order to get the average number exempt in any way, since many are exempt in two or more ways at once.

This rule applies directly to probabilities. Given the probability that two different and mutually exclusive events will happen under the same supposed set of circumstances. Given, for instance, the probability that if A then B, and also the probability that if A then C, then the sum of these two probabilities is the probability that if A then either B or C, so long as there is no event which belongs at once to the two classes B and C.

Rule III. *Multiplication of Relative Numbers.*—Suppose that we have given the relative number of x's per y; also the relative number of z's per x of y; or, to take a concrete example, suppose that we have given, first, the average number of children in families living in

New York; and, second, the average number of teeth in the head of a New York child—then the product of these two numbers would give the average number of children's teeth in a New York family. But this mode of reckoning will only apply in general under two restrictions. In the first place, it would not be true if the same child could belong to different families, for in that case those children who belonged to several different families might have an exceptionally large or small number of teeth, which would affect the average number of children's teeth in a family more than it would affect the average number of teeth in a child's head. In the second place, the rule would not be true if different children could share the same teeth, the average number of children's teeth being in that case evidently something different from the average number of teeth belonging to a child.

In order to apply this rule to probabilities, we must proceed as follows: Suppose that we have given the probability that the conclusion B follows from the premise A, B and A representing as usual certain classes of propositions. Suppose that we also knew the probability of an inference in which B should be the premise, and a proposition of a third kind, C, the conclusion. Here, then, we have the materials for the application of this rule. We have, first, the relative number of B's per A. We next should have the relative number of C's per B following from A. But the classes of propositions being so selected that the probability of C following from any B in general is just the same as the probability of C's following from one of those B's which is deducible from an A, the two probabilities may be multiplied together, in order to give the probability of C following from A. The same restrictions exist as before. It might happen that the probability that B follows from A was affected by certain propositions of the class B following from several different propositions of the class A. But, practically speaking, all these restrictions are of very little consequence, and it is usually recognized as a principle universally true that the probability that, if A is true, B is, multiplied by the probability that, if B is true, C is, gives the probability that, if A is true, C is.

There is a rule supplementary to this, of which great use is made. It is not universally valid, and the greatest caution has to be exercised in making use of it—a double care, first, never to use it when it will involve serious error; and, second, never to fail to take advantage of it in cases in which it can be employed. This rule depends upon the fact that in very many cases the probability that C is true if B is, is substantially the same as the probability that C is true if A is. Suppose, for example, we have the average number of males among the children born in New York; suppose that we also have the average number of children born in the winter months among those born in New York. Now, we may assume without doubt, at least as a closely approximate proposition (and no very nice calculation would be in place in regard to probabilities), that the proportion of males among all the children born in New York is the same as the proportion of males born in summer in New York, and, therefore, if the names of all the children born during a year were put into an urn, we might multiply the probability that any name drawn would be the name of a male child by the probability that it would be the name of a child born in summer, in order to obtain the probability that it would be the name of a male child born in summer. The questions of probability, in the treatises upon the subject, have usually been such as relate to balls drawn from urns, and games of cards, and so on, in which the question of the *independence* of events, as it is called—that is to say, the question of whether the probability of C, under the hypothesis B, is the same as its probability under the hypothesis A, has been very simple; but, in the application of probabilities to the ordinary questions of life, it is often an exceedingly nice question whether two events may be considered as independent with sufficient accuracy or not. In all calculations about cards it is assumed that the cards are thoroughly shuffled, which makes one deal quite independent of another. In point of fact the cards seldom are, in practice, shuffled sufficiently to make this true; thus, in a game of whist, in which the cards have fallen in suits of four of the same suit, and are so gathered up, they will lie more or less in sets of four of the same suit, and this will be true even after they are shuffled. At least some traces of this arrangement will remain, in consequence of which the number of "short suits," as they are called—that is to say, the number of hands in which the cards are very unequally divided in regard to suits—is smaller than the calculation would make it to be; so that, when there is a misdeal, where the cards, being thrown about the table, get very thoroughly shuffled, it is a common saying that in the hands next dealt out there are generally short suits. A few years ago a friend of mine, who plays whist a great deal, was so good as to count the number of spades dealt to him in 165 hands, in which the cards had been, if anything, shuffled better than usual. According to calculation, there should have been 85 of these hands in which my friend held either three or four spades, but in point of fact there were 94, showing the influence of imperfect shuffling.

According to the view here taken, these are the only fundamental rules for the calculation of chances. An additional one, derived from a different conception of probability, is given in some treatises, which if it be sound might be made the basis of a theory of reasoning. Being, as I believe it is, absolutely absurd, the consideration of it serves to bring us to the true theory; and it is for the sake of this discussion, which must be postponed to the next number, that I have brought the doctrine of chances to the reader's attention at this early stage of our studies of the logic of science.

LIQUEFACTION OF GASES.[1]

By GASTON TISSANDIER.

EVERY one knows that the matter which constitutes the various natural bodies occurs in three different forms, namely, the solid, the liquid, and the gaseous states. So, too, every one knows that the state of a body is not at all immutable: a solid may be fused and volatilized; a liquid may become a solid, or be transformed into vapor; a gas may be changed into a liquid or a solid—all these changes occurring according to the conditions of temperature or of pressure to which the solids, liquids, or gases, are subjected. Water turns into ice under the action of cold; into steam under the action of heat. Sulphur, phosphorus, the metals, and most solid bodies, may in like manner assume these three states. Chlorine, protoxide of nitrogen, carbonic acid, etc., may be liquefied or solidified. To this end we have only to bring the molecules nearer to one another by compressing them, or subjecting them to the action of cold.

Faraday succeeded in liquefying a certain number of gases by compression and refrigeration, but there still remained a number that proved absolutely refractory to the most powerful agencies; hence these gases were called *permanent*. They are hydrogen, nitrogen, oxygen, carbonic oxide, bioxide of nitrogen, and formene (marsh-gas). Chemists, it is true, were quite confident that these gases, like all others, were subject to the general laws of bodies; it was held to be certain that the gases just named would, like the others, yield to sufficiently high pressure or refrigeration. But, nevertheless, they still remained bodies *sui generis*, defying, so to speak, the powers of the chemist, and their change of state presented itself as a weighty problem, the solution of which was all the more alluring in proportion to the difficulties with which it was surrounded. Berthelot, as we know, subjected them to the enormous pressure of 800 atmospheres, and to a refrigeration of more than 100° below zero, Centigrade; but all was in vain, and the permanent gases justified their name.

This is so no longer. A retired manufacturer, who at the same time is a distinguished man of science, M. Cailletet, has subdued the permanent gases, having succeeded in liquefying and solidifying them. This result, which is one of the most interesting achievements of our time, must unquestionably be regarded as a new and a grand conquest of matter by science.

Nearly at the same moment, another ingenious investigator and inventor, M. Raoul Pictet, reached the same result with regard to oxygen gas. We will pass in review successively the experiments of

[1] Translated from the French by J. Fitzgerald, A. M.

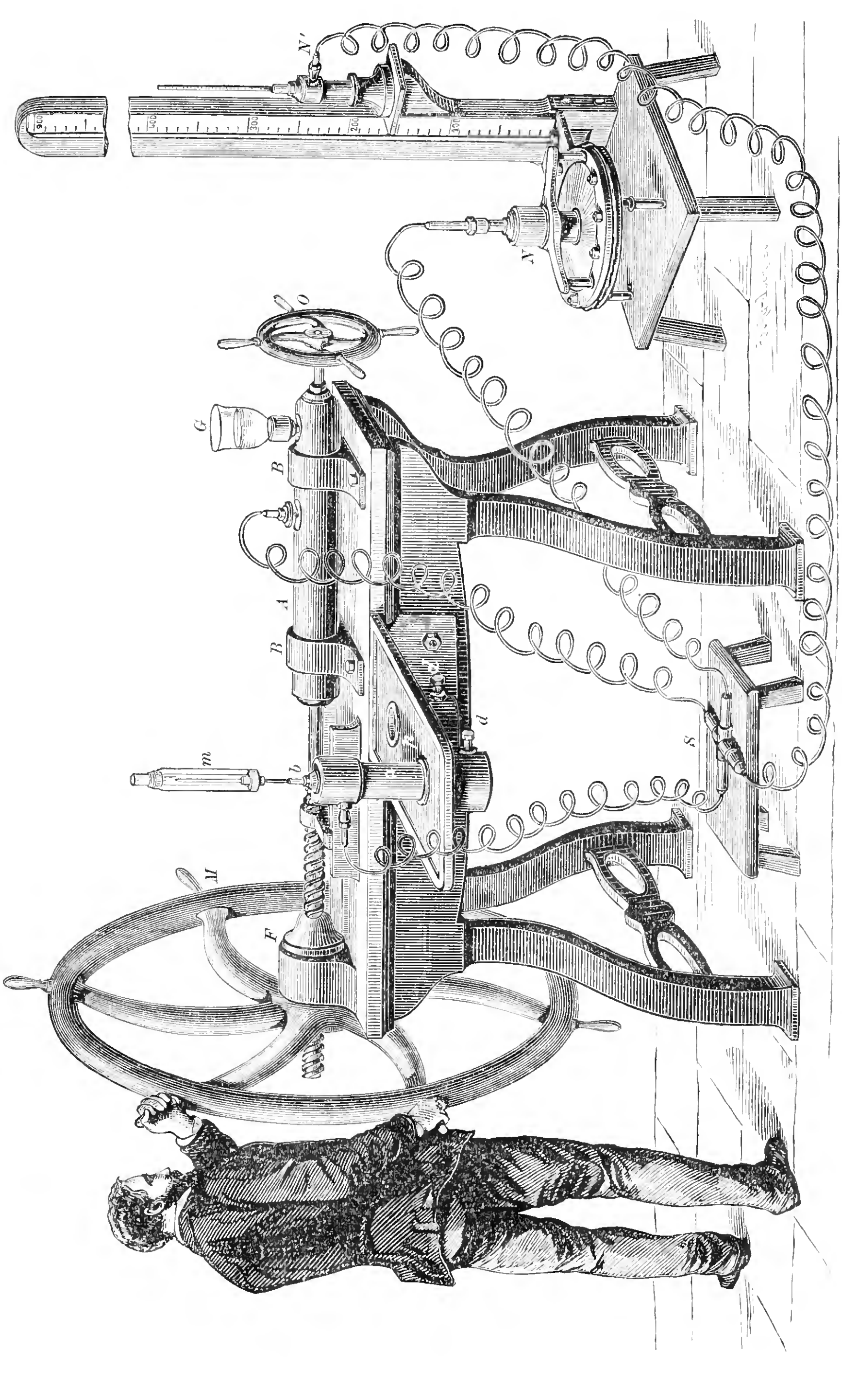

Fig. 1.—Cailletet's Large Apparatus for liquefying Gases. *A*, Screw-press for compression; *m*, flint-glass cylinder inclosing the glass tube in which the gas is liquefied.

these two chemists, commencing with those of Cailletet. Our engraving (Fig. 1) shows the great apparatus constructed by M. Cailletet in his shops at Châtillon-sur-Seine. It consists of a hollow cylinder of steel, *A*, firmly secured on a bed of cast-iron by means of the clamps *B B*. A cylindrical rod of untempered steel, serving as a plunger-piston, enters this cylinder, which must be filled with water. The opposite extremity of the rod terminates in a square-threaded screw, passing through the bronze nut *F* attached to the wheel *M*. According to the direction given to the wheel by means of the pins at its circumference, the plunger-piston may be made to advance or retreat in the axis of the pump-barrel. A packing of leather prevents the compressed liquid from escaping from the cylinder.

In introducing the water, or other liquid designed to be compressed, it is poured into the glass cup *G*, which communicates with the inside of the apparatus. A steel screw, with conical point, closes the narrow passage through which the liquid enters. This screw terminates in a small wheel with handle-pins, *O*. By this arrangement we can suddenly *release* the compressed gases, and see a dense mist form in the capillary glass tube containing them. (This tube is seen in the middle of the cylinder *m*.) The mist is formed under the influence of the external cold produced by the sudden removal of pressure, and it is an infallible sign of the liquefaction, or even the congelation, of the gases which hitherto have been regarded as *permanent*.

a is a steel reservoir, capable of bearing a pressure of 900 or even 1,000 atmospheres; it is connected with the compression-apparatus by a capillary tube of metal. The water in the cylinder, under the pressure of the piston, enters this reservoir, and acts on mercury which compresses the gas.

b is the ajutage which receives the glass apparatus designed to hold the gas under experiment; it is connected with the top of the reservoir by a nut. Fig. 2 represents the arrangement of this part, half the actual size.

m is a flint-glass cylinder, inclosing another glass cylinder, in the middle of which is seen the fine tube in which the gas is to be liquefied. Thus this capillary tube can be surrounded with freezing mixtures, or with liquid protoxide of nitrogen. The outer cylinder *m*, which is concentric with the inner one, and contains substances which have a strong affinity for moisture, prevents the deposit of ice or vapor on the cooled tube, which would hinder observation.

p is a cast-iron stand to hold the reservoir *a*. Screws *d d* serve to raise or lower the reservoir for the purpose of spectroscopic examination, or of projecting the experiments on a screen.

An ajutage *S* connects together the metallic capillary tubes which transmit the pressure to the various portions of the apparatus.

N is a modified Thomasset manometer, verified by means of an open manometer on the flanks of a hill near the laboratory of Châtillon-sur-Seine.

N' is a glass manometer which serves to check the readings of the mercurial apparatus.

This notable apparatus involves no danger, for the glass tube in which the gas is compressed presents a very small surface, and no serious result could follow were it to break.

A few years ago an English physicist, Thomas Andrews, was led to infer that, for permanent gases, there exists a *critical point* of pressure and temperature, above which they cannot be brought to the liquid state. This opinion is confirmed by Cailletet's experiments. Each gas requires that a certain pressure be combined with a certain reduction of temperature: either the one or the other of these two conditions might be employed separately without any effect, even supposing them to reach a high intensity.

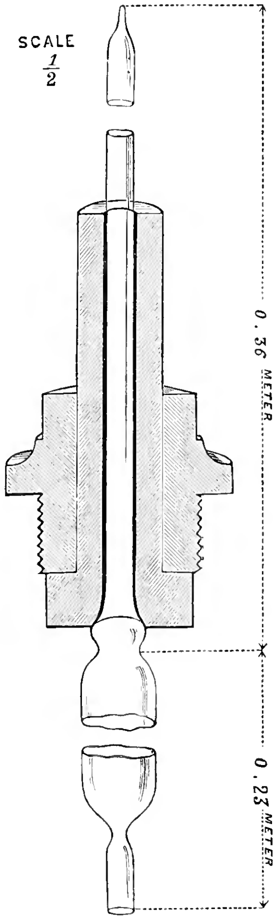

Fig. 2.—Glass Tube with Thick Walls, in which Gases are liquefied. The gas is compressed in the upper part of the tube by a column of mercury forced upward by hydrostatic pressure. The gas condenses into a liquid drop or into a mist, on pressure being removed. This glass tube is inclosed within a glass cylinder holding the freezing mixture.

The first of the permanent gases liquefied by M. Cailletet was bioxide of nitrogen. As we have just said, unless the two conditions of compression and low temperature be united according to the *critical points*, the gas does not liquefy. Hence it is that bioxide of nitrogen has remained gaseous at a pressure of 270 atmospheres and a temperature of +8° Cent. Formene or marsh-gas liquefies at 180 atmospheres and +7° Cent.

"If," says M. Cailletet, "we inclose oxygen or pure carbonic oxide in the compression-apparatus; if we reduce these gases to a temperature of −29° Cent. by the aid of sulphurous acid at a pressure of about 300 atmospheres, both gases still retain their gaseous state. But if they be released suddenly, so, according to Poisson's formula, producing a temperature of at least 200° below the starting-point, we at once see a heavy mist, caused by the liquefaction or even, perhaps, the solidification of the oxygen or carbonic oxide. The same phenomenon is observed in releasing carbonic acid, and protoxide and bioxide of nitrogen, which have been subjected to strong pressure."[1]

After having obtained these results, at a session of the Academy on December 31st, M. Cailletet announced that he had won a complete victory over the other permanent gases. M. Dumas informed the members present at the session that the able experimenter had succeeded in liquefying nitrogen, atmospheric air, even hydrogen itself, which would seem to have been the most refractory gas of them all.

We take from the *Comptes Rendus* the following details:

Nitrogen.—Pure or dry nitrogen, compressed under about 200 atmospheres, at a temperature of nearly +13° Cent., and then suddenly released, becomes very clearly condensed. There first appears a body resembling a pulverized liquid, in drops of appreciable volume, and then this liquid gradually disappears from the walls of the tube toward the middle, at length forming a sort of vertical column in the axis of the tube; this phenomenon persists for more than three seconds. These appearances remove all doubt as to the true character of the phenomenon. M. Cailletet first made this experiment at home with a temperature of −29° Cent.; he repeated it again and again at the laboratory of the Normal School, in the presence of several men of science.

Hydrogen.—Hydrogen has always been regarded as the most refractory of gases, owing to its slight density, and the almost complete conformity of its mechanical properties to those of the perfect gases. Hence it was with very little hopes of a favorable result that M. Cailletet subjected this gas to the same tests which had produced liquefaction of all the others.

"In my early experiments," says he, "I recognized nothing that was peculiar; but, as often happens in the experimental sciences, the habit of observing phenomena at last leads us to recognize peculiarities where before they were quite unnoticed. This was what happened in the case of hydrogen. On repeating my experiments to-day, December 31st, in the presence and with the assistance of Messrs. Berthelot, H. Sainte-Claire-Deville, and Mascart, I succeeded in observing signs of the liquefaction of hydrogen, which to these expert witnesses appeared to be unquestionable.

"The experiment was repeated many times. Hydrogen placed under a pressure of 280 atmospheres, and then released, becomes transformed into an extremely fine and subtile mist, suspended in the tube throughout its entire length, and then suddenly disappearing. The production of this mist, despite its extreme subtilty, appeared to be indisputable to all the scientific men who witnessed this experiment, and who carefully repeated it again and again, under such conditions as to leave no doubt as to the fact."

Air.—"Having liquefied nitrogen and oxygen, the liquefaction of atmospheric air was *ipso facto* demonstrated. Nevertheless, I concluded to make this a matter of direct experiment; and here, as might have been expected, I was perfectly successful. I need not say that the air had been first dried and deprived of every trace of carbonic acid. In this way," adds M. Cailletet, "was demonstrated the correctness of the views held by the founder of modern chemistry, Lavoisier, as to the possibility of reducing air to the state of *liquidity*, by producing liquids endowed with new and unknown properties."

[1] *Comptes Rendus de l'Académie des Sciences*, December 24, 1877.

Plainly, the power of producing liquid air opens to applied science new horizons. There is no need to prove that, from the purely scientific and philosophical point of view, M. Cailletet's experiments are of supreme importance.

We will conclude this article with a description of the little lecture-room or laboratory apparatus, constructed by M. Ducretet, to show how, according to Cailletet's process, gases are liquefied. It is a copy of the essential parts of the apparatus at Châtillon-sur-Seine. The bell-glass is modified. The screw-press, too, is represented here by a more portable pump. The accompanying figure, which

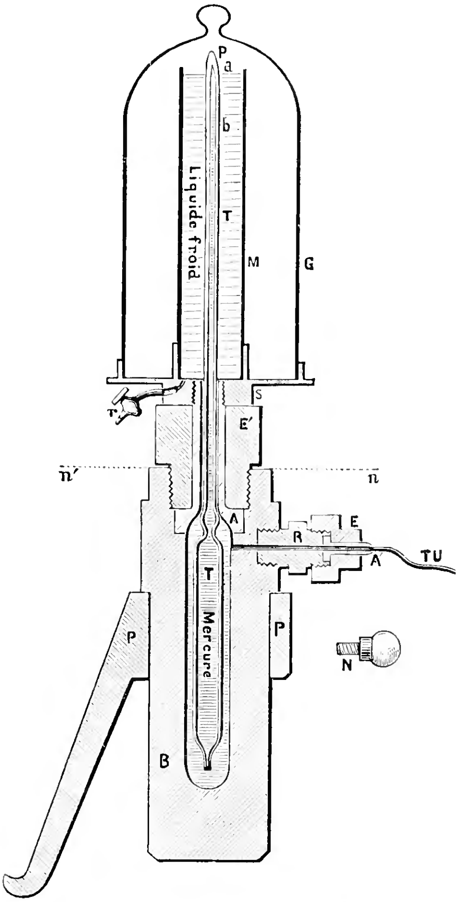

FIG. 3.—SMALL APPARATUS FOR LIQUEFYING GASES.

represents the apparatus in section, will enable us to give a more detailed description of the system devised by M. Cailletet.

T T is a glass tube, containing the gas to be compressed; a current of the gas has passed through it, so as to expel all the atmospheric air. For this purpose it is first placed in an horizontal position; then, after it has been filled with the gas destined for the experiment, the tube is closed at its extremity p at a lamp, while the other extremity is closed by the finger and introduced vertically into the iron apparatus, as shown in the figure. It dips into a cylindrical reservoir of mercury. The upper part of the tube is surrounded with a glass cylinder, *M*, filled with a freezing mixture, as in the larger apparatus. The whole is then covered over with a bell-glass, *G*. The tube *TU* connects with a compression-pump, worked by hand, and provided with a manometer, which shows the degree of pressure. The water compressed by the pump acts on the surface of the mercury as seen in the figure. This mercury is thus forced into the tube *T T*, diminishes the space $a\ b$, occupied by the gas, and soon bears on its top little drops of compressed gas, which unite to form a small quantity of liquid, b.

The principal parts of the apparatus are *B*, a box of wrought-iron, with very strong walls; *EE'*, nuts which can be screwed off in order to adjust the apparatus before the experiment begins; *A*, ajutage; *P P*, two of the three very strong legs supporting the apparatus; *S*, support of the bell-glass *G* and the cylinder *M*; *N*, supplementary screw used to stop the mouth of the passage *R*, while the mercury is being poured into the apparatus.

We would remark that the enlarged lower end of the tube *T* is subject to an equal pressure within and without, and cannot break. It is only the upper portion of the tube that has to withstand the internal pressure, but its walls are very strong.

The experiment may be projected on a screen by the aid of a Drummond light. The apparatus is very simple, and liquefies a great number of gases. One can with the naked eye observe all the phases of liquefaction, and this without any danger. Hence this instrument is destined to render great service in research and in instruction, whether in colleges or in the lecture-room.—*La Nature.*

CORRESPONDENCE.

To the Editor of the Popular Science Monthly.

SIR: As a student of Herbert Spencer's Philosophy, I have waited impatiently the advent of his "Principles of Sociology," and particularly so of late, as I am greatly interested in the work of an American writer on a kindred subject. I refer to Mr. Lewis H. Morgan's "Ancient Society," lately published by Henry Holt & Co. It is to a comparison of the views of these writers on the origin of the monogamian family that I wish to invite your attention.

In Mr. Morgan's studies of consanguinity and affinity he found certain systems prevailing which could only be explained by the existence of certain forms of marriage, and of the family which produced them. These forms he has named the "Consanguine," the "Punaluan," and the "Monogamian." As before stated, it is the origin of the latter form only that I propose to discuss at present. According to Mr. Morgan, the monogamian family is comparatively modern, and came into existence with the growth of the idea of property. He says (page 477): "The growth of property and the desire for its transmission to children was, in reality, the moving power which brought in monogamy to insure legitimate heirs, and to limit their number to the actual progeny of the married pair." He maintains that exclusive cohabitation, in the sense that we understand it, was not practised until mankind had created property in masses, which they desired should pass into the hands of their offspring, and that the marriage of single pairs previous to this did not constitute monogamy, but formed what he terms the "Syndyasmian or Pairing Family," which differed from monogamy in several essential particulars, chief of which was the fact that "the marriage relation continued during the pleasure of the parties, and no longer," and, so far as the male was concerned, "the absence of an exclusive cohabitation." In reading Mr. Spencer's article on the "Evolution of the Family," it occurred to me that Mr. Morgan's theory answered his question, "Are different forms of domestic arrangement associated with the militant system of organization and the industrial system of organization?" even better than his own. Mr. Spencer remarks that, "on examining the facts more closely, we discern general connections between the militant type and polygyny, and between the industrial type and monogamy." He then calls attention to the truth that "the contrast between the militant and the industrial is properly between a state in which life is occupied in conflict with other beings, brute and human, and a state in which life is occupied in peaceful labor—energies spent in destruction instead of energies spent in production." Now it is obvious that the latter state is the one in which the growth of the idea of property and the desire to transmit it to offspring would surely be generated, and that if, as is alleged by Mr. Morgan, monogamy owed its origin to the growth of these ideas, then necessarily monogamy and industrialness would surely be connected, and that this is the case, Mr. Spencer thinks unquestioned. He says: "That advance from the primitive predatory type to the highest industrial type has gone along with advance from prevalent polygyny to exclusive monogamy, is unquestionable; and that the decrease of militancy and increase of industrialness have been the essential cause of this change in the type of family, is shown by the fact that this change has occurred where such other supposable causes as culture, religious creed, etc., have not come into play."

It seems to me that, in applying the term monogamy to all forms of the pairing family, from the highest to the lowest, Mr. Spencer is in error. He should, like Mr. Morgan, limit it to that form in which exclusive cohabitation is the law for both man and woman. He should deal with monogamy as an *institution*. In so dealing with it, we see that it has arisen, as Mr. Spencer has taught us, like all other institutions, by the action of environing agencies on existing social conditions, and that the principal agency in the present case is the growth of the idea of property.

R. M.

"THE LAW OF CONTINUITY."

To the Editor of the Popular Science Monthly.

IN reply to Mr. Launcelot's letter in the MONTHLY for February, I would draw attention to the *Journal of the Chemical Society*, volume viii., page 51, where the late Prof. Graham records certain experiments. He found that sulphuric acid continued to evolve heat when mixed even with the fiftieth equivalent of water that was added to it, so that there seemed to be no distinct limit to chemical affinity. He concludes, "There is reason to believe that chemical affinity passes in its lowest degree into the attraction of aggregation."

As to Mr. Launcelot's paragraph, wherein he states that many metals, other than gold, have been reduced to translucent tenuity, your note makes any answer from me unnecessary. GEORGE ILES.

MONTREAL, *January* 22, 1878.

EDITOR'S TABLE.

THE PROGRESS OF AMERICAN BIOLOGY.

WE publish this month the first half of the able and interesting address delivered by Prof. Marsh, before the American Association, at Nashville, last August, on the "Introduction and Succession of Vertebrate Life in America," and which is the first complete edition that has appeared in any periodical. The paper is, from its nature, somewhat technical, but the author could not help that, as, in dealing with newly-discovered forms of life, he is compelled to use new terms a little freely, and to make his account complete he includes some lists of genera, which will be of great service to biological students, and should not frighten off unscientific readers, who will find much to interest them in the general treatment of the subject. There is nothing more remarkable in our time than the activity of its scientific thought, and the importance of the new results that are being reached in all the spheres of investigation. Of this, we have a striking illustration in the fact that four months was sufficient almost to antiquate Prof. Marsh's address, and make it necessary to post it up to the beginning of the present year, by notes from the author, stating what new things have been discovered since its delivery. Among these are mentioned a new species of fossil fish (*Ceratodus*), that has recently attracted much scientific attention, and is significant as the first found in the Mesozoic formations of this country. A number of new Jurassic reptiles, some of enormous size, and a new genus (*Epihippus*), a missing Eocene link in the genealogy of the horse, have also come to light. The interesting point here is, that these are all forms that the evolutionist was expecting from our marvelous Rocky Mountain region, and they show how rapidly the biological evidence of this theory is accumulating. The whole address is indeed a weighty contribution to the literature of this doctrine, as, besides the mere record of ancient life which it affords, the genealogies of many groups of animals are now traced for the first time. It is well known that Prof. Marsh, by his skill, enterprise, and assiduity, has made the field of the exploration of the Western fossil-beds very much his own; and in this address, which first attempts a summary statement of what is known of the extinct vertebrate life of this continent, he necessarily includes his own results. Among its leading features there is a discussion of the migrations of extinct mammals, and strong evidence is presented (in opposition to previous opinion upon the subject) that North America is really the oldest continent, from which South America, as well as Asia and Europe, derive many of their animals. The author's observations have led him also to conclude that there is at present no evidence that any of the supposed bird-tracks of the Connecticut River sandstone were made by birds, but were probably all made by reptiles. In discussing the unsettled question among geologists as to the line between the Cretaceous and Tertiary rocks in the West, Prof. Marsh puts forward a new principle or law as to the value of different kinds of fossils in determining geological age. His investigations show that the higher the grade of life, the better is the evidence they yield; plants, for example, being poor witnesses in such a case, and the higher vertebrates the best. Geologists will be interested in the researches of the author, the results of which are also given, into the origin and succession of the Tertiary fresh-water lakes of the Rocky Mountain region; a subject upon which but little accurate information has been hitherto attainable. The portion of the paper printed in the present MONTHLY includes the fishes, amphibians, reptiles, and birds; and the second part will be devoted to the mammals, which will be discussed more in detail. Prof. Marsh has kindly prepared for us a geological section of the earth's crust, revised so as to illustrate the present aspect of the subject of the introduction and succession of vertebrate life on this continent, and which the reader will find valuable for reference in studying the address.

SOME TEACHINGS OF THE TELEPHONE.

WE commend to those who persist in ventilating the ancient prejudice against the material medium of which all things around us are constituted, as "dead matter," "gross matter," "brute matter," etc., a little meditation on the remarkable powers manifested by the telephone.

In another part of the MONTHLY will be found an excellent explanation of the mechanism and mode of working of this remarkable contrivance. But, to appreciate its deeper meaning, we must recall some of the characteristics of sound and the conditions of the production of voice. The brain, the spinal centres, the nerves, and the muscles, have all to be coördinated in that expulsion of air through the apparatus of speech which results in the utterance of words. The vocal cords are thrown into vibration by the air-current which sets up wave-motions that are transmitted in all directions. To appreciate what here goes on in this light, invisible medium, we must strive to keep in mind the behavior of the air-particles. In the propagation of sound, a stream of thrills is shot out from its source, at the rate of about eleven hundred feet per second, and the series of air-waves is simply a succession of condensations and rarefactions of the elastic medium, in which the aërial particles successively take up and pass on the motions of the original impulse. According to the extent and complexity of these molecular motions is the intensity and quality of the noise. The size of the waves varies with the pitch of the sound; the first A of the bass in a piano producing air-waves about forty feet in length, while the waves of the last A of the treble are not quite four inches long. But these sound-waves are far more complex than at first seems, so that the motion of the air-particles involves something else than a mere backward-and-forward movement. A stretched string, vibrating its whole length, gives its fundamental tone, but while it thus swings as a whole, its different parts are thrown into separate and quicker vibrations, which are executed in harmonic ratio—2, 3, 4, 5, 6, 7, or 8 times—during the vibration of the whole string. These over-vibrations produce what are called overtones, which are, so to speak, drowned in the fundamental note, but which, nevertheless, serve to give it a peculiar character. It is thus that sounds from all sources acquire distinguishing marks, by which they are identified. It is by the effects of these frills, or fringes, of the larger waves, that different musical instruments, and different human voices, are distinguished from each other. The infinite varieties of sound are thus due to the subtile capacity of complex motion possessed by the air-particles. They always move exactly in the same way in the production of the same effects, and differently in yielding different effects. If we could see the dance of the air-particles when music is executed, it would be a picture of mathematical exactness, and infinite complication, that has no analogy in anything we observe. It has always been regarded as one of the mysterious miracles of vital structure how the little membranous drum of the human ear can take up so perfectly this rapid stream of intricate motions in the air, which are all so exactly reproduced by the layer of adjacent particles striking upon the membrane, that thousands of tympanums will be all affected precisely alike, while the nerves transmit the thrills to the brain, awakening the same musical sensations and sentiments in the consciousness of as many people as can be brought within hearing. This chain of effects is wonderful, indeed; but we are now confronted with the fact, more impressively than ever, that it is no prerogative of the living organism to respond to these subtile and exquisite changes in the air; the inert, dead matter of which we hear so much—mere cold iron—will do exactly the same thing.

When we begin to use a telephone for the first time, there is a sense of oddity, almost of foolishness, in the experiment. The dignity of talking consists in having a listener, and there seems a kind of absurdity in addressing a piece of iron, but we must raise our respect for the metal, for it is anything but deaf. The diaphragm of the telephone, the thin iron plate, is as sensitive as the living tympanum to all the delicate refinements of sound. Nor does it depend upon the thinness of the metallic sheet, for a piece of thick boiler-plate will take up and transmit the motions of the air-particles in all the grades of their subtilty. And not only will it do the same thing as the tympanum, but it will do vastly more: the gross, dead metal proves, in fact, to be a hundred times more alive than the living mechanism of speech and audition. This is no exaggeration. In quickness, in accuracy, and even in grasp, there is a perfection of sensitive capacity in the metal, with which the organic instrument cannot compare. We speak of the proverbial "quickness of thought," but the telephone thinks quicker than the nervous mechanism. Let a word be pronounced for a person to repeat, and the telephone will hear and speak it a hundred miles away in a tenth part of the time that the listener would need to utter it. Give a man a series of half a dozen notes to repeat, and he cannot do it accurately to save his life; but the iron plate takes them up, transmits them to another plate hundreds of miles off, which sings them forth instantaneously with absolute precision. The human machine can hear, and reproduce, in its poor way, only a single series of notes, while the iron ear of the telephone will take up whole chords and trains of music, and, sending them by lightning through the wire, its iron tongue will emit them in perfect relations of harmony. The correlations and transformations of impulse are besides much more extended in the telephone than in the living structure. The volitional mandate from the brain incites nervous discharges, expended in producing muscular contractions that impel the air across the vibrating cords, where it is thrown into waves. But in the case of the telephone, the air-waves are spent in producing mechanical vibrations of the metal; the secreate magnetic disturbances, which excite electrical action in the wire, and this again gives rise to magnetic changes that are still further converted into the tremors of the distant diaphragm, and these finally reappear as new trains ot air-waves that affect the listener, while the whole intermediate series of changes is executed in a fraction of the time that is required by the nervous combinations of speech. And not only does the telephone beat the living machine out of sight in speed, accuracy, compass of results, and multiplicity of dynamical changes, but it distances it also in the simplification of its resources. The same bit of dead metal serves equally for both ear and tongue; the offices of the diaphragm are interchangeable, and the machine works backward and forward with exactly the same facility.

The lesson here taught is, that we are to elevate our conceptions of the powers of matter. Science is making constantly fresh revelations of its potencies and capacities, and we are probably still only upon the threshold of this world of wonders.

CONCERNING THE BELIEF IN HELL.

A LIVELY discussion has recently been carried on by the pulpit and the press as to whether there is a future state of eternal torment. Two or three eminent orthodox clergymen spoke out in rather strong denunciation of the idea, and this was followed by an epidemic of controversy. Certain people seem to have been perplexed as to what is meant by so free a handling of a solemn old subject. We think it simply means that people have been thinking about it until expression is a relief, and that many have reached conclusions that they are glad to have a chance of ventilating. There has been, thanks to the influence of science, a pretty rapid liberalizing of theological opinion during the past generation; and this discussion about hell is an instructive indication of the advance that has been made.

The question of the existence of a veritable hell is, of course, a theological one, which we cheerfully leave to those interested, but the topic has also a scientific side. The rise and course of the *idea*, or what may be called the natural history of the belief in hell, is a subject quite within the sphere of scientific inquiry. It is legitimate to ask as to how the notion originated, as to its antiquity, the extent to which it has been entertained, the forms it has assumed, and the changes it has undergone, and from this point of view it of course involves the principle of evolution. We cannot go into so large a discussion here, but as this is an aspect of the subject not much dwelt upon, a few suggestions regarding it may not be inappropriate.

In the first place, it is necessary to rise above that narrowness of view which regards the doctrine of hell as especially a Christian doctrine, or as the monopoly of any particular religion. On the contrary, it is as ancient and universal as the systems of religious faith that have overspread the world. The oldest religions of which we have any knowledge—Hindoo, Egyptian, and the various Oriental systems of worship—all affirm the doctrine of a future life, with accompanying hells for the torture of condemned souls. We certainly cannot assume that all these systems are true, and of divine origin; but if not, then the question forces itself upon us, how they came by this belief. The old, historic religious systems involved advanced and complicated creeds and rituals, and if they were not real divine revelations in this elaborated shape, we are compelled to regard them as having had a natural development out of lower and cruder forms of superstition. To explain these religions—as to explain the earliest political institutions—we must go behind them. There is a prehistoric, rudimentary theology of the primitive man, the quality of which has to be deduced from his low, infantine condition of mind, interpreted by what we observe among the inferior types of mankind at the present time.

It is certain that early men, in profound ignorance of the surrounding world and of their own natures, must have grossly misinterpreted outward appearances and their internal experiences, and analysis of the conditions has abundantly shown how these primitive misunderstandings led inevitably to manifold superstitions. Herbert

Spencer, in his "Principles of Sociology," recently published, has carefully traced out this working of the primitive mind, and explained how the early men, by their crude misconceptions of natural things, were gradually led to the belief in a ghost-realm of being appended to the existing order. The idea of a life after death, so universally entertained among races of the lowest grades of intelligence, is accounted for, and is only to be accounted for, in this way. Through experiences of sleep, dreams, and loss and return of consciousness at irregular times as in swoon, catalepsy, trance, and various forms of insensibility, there grew up the idea of a double nature—of a part that goes away leaving the body lifeless, and returns again to revivify it; and thus originated the theory of immaterial ghosts and spirits. At death the ghost departed, but not to return and reanimate the body in the usual way; it went to inhabit another place. Thus arose the conception of a separate and future life, which, at first, could not have been supposed to differ much from that of the present order of things. No doubt what is said of the Fijians, that after death "they plant, live in families, fight, and, in short, do much as people in this world," represents the common beginnings of belief upon this subject. Yet the hope of better things could not fail to come soon into play, as indicated by the belief of the Creeks, that after death they go where "game is plenty, and goods very cheap; where corn grows all the year round, and the springs of pure water are never dried up." Von Tschudi tells us that in Peru "a small bag with cocoa, maize, quinua, etc., is laid beside the dead that they might have wherewithal to sow the fields in the other world." The condition of the future life, where the ghosts go to dwell, is believed to be so similar to that which they have left that it is almost universal among savages to bury food, weapons, implements, ornaments, clothing, and whatever they may be likely to want, with the bodies of their dead friends. Even dogs and cattle are slain, and women and servants immolated, that they may accompany and minister to the departed.

But this bald conception of a future life, as a kind of literal continuance of present materialities, could not last. As knowledge accumulated the conception grew incongruous, and underwent important modifications, so that similarity gradually passed into contrast. The intimacy of the intercourse supposed to be carried on between the two worlds decreased; the future world was conceived of as more remote, and as having other occupations and gratifications more consonant with developing ideas of the present life. Rude conceptions regarding good and evil could not fail to be early involved with considerations of man's futurity. Good and evil are inextricably mixed up in this world, which seems always to have been regarded as a faulty arrangement, and, as there was little hope of rectifying it here, the future life came to be regarded as compensatory to the present. But the problem was solved, not by the absorption and disappearance of evil, but by supposing good and bad to be mechanically separated; and, as good and bad means good people and bad people, the belief arose that in the future world they would be divided off, the good being all collected in a good place, and the bad ones all turned into a bad place.

This idea of using the next world to redress the imperfections and wrongs of this grew up early and survives still, and it has exerted a prodigious influence in human affairs. As the grosser superstitions were gradually developed into systematic religions, a priestly class arose, and religious beliefs were embodied in definite creeds. Fundamental among these was the belief in heaven as a place of happiness, and of hell as a place of penal torment for the wicked.

To one or other of these places, it was held, all men are bound to go after death; but to which depended — and here the office of the priesthood assumed a terrible importance, for they knew all about it, and had the keys. It is impossible to conceive any other idea of such tremendous power for dominating mankind as this! It raised the priesthood and ecclesiastical institutions into despotic ascendency, brought it into unholy alliance with civil despotisms, and became the mighty means of plundering the people, crushing out their liberties, darkening their hopes, and cursing their lives. So productive an agency of unscrupulous ambition could not fail to be assiduously cultivated, and the conception of hell, the most potent element in the case by its appeal to fear, was elaborated with the utmost ingenuity. Language was exhausted in depicting the terrors of the infernal regions and the agonies of the damned. We by no means say that these ideas were mere priestly inventions, but only that they grew up under the powerful guidance of a class consecrated to their exposition, and incited by the most powerful worldly motives to strengthen their influence. In order to enforce belief, to compel obedience to ecclesiastical requirements, to coerce civil submission, and to extort money, people were threatened with the horrors of hell, which were pictured with all the vividness of rhetorical and poetic fanaticism. As the hierarchical spirit grew in strength, and became a tyrannical rule, obedience to its minutest rites was enforced by the most appalling intimidations. To neglect some trivial ceremony was sufficient to incur damnation. Alger says, in his "History of the Doctrine of a Future Life:" "The Brahmanic priest tells of a man who, for neglecting to meditate on the mystic monosyllable Om before praying, was thrown down into hell, on an iron floor, and cleaved with an axe, then stirred in a caldron of molten lead till covered all over with the sweated foam of torture, like a grain of rice in an oven, and then fastened, with head downward and feet upward, to a chariot of fire, and urged onward with a red-hot goad."

In noticing the causes of the extent, influence, and perpetuity of this sombre belief, we must not forget that the future life, being beyond experience and inaccessible to reason, offers an attractive play-ground for the unbridled imagination. It opens an infinite realm for sensuous imagery and creative invention, stirs the deepest feelings, and concerns itself with the mystery of human destiny. It accordingly offers a favorite topic for poetic treatment, and this is more especially true of the darker aspects of the future world, poets having ever taken with avidity to delineations of hell. From Hesiod to Pollok, pagans and Christians have vied with each other in their poetical representations of the tortures and terrors of the infernal state. The mythological form of the doctrine figures largely in the great epics of Greece and Rome; the Italian "Inferno" pictures the Christian hell with terrible intensity, and the grand poem of the English language, "Paradise Lost," has hell at the root of its plot, and hell's master for its hero. Homer, Virgil, Dante, and Milton, working through poems of immortal genius that have fascinated mankind, some of them through thousands of years, and others through centuries, have thus combined to familiarize countless millions of people with the conception, and to stamp it deep in the literature of all countries.

Yet the doctrine of hell is now growing obsolete. Originating in ages of savagery and low barbarism, and developed in periods of fierce intolerance, sanguinary persecutions, cruel civil codes, and vindictive punishments, it harmonized with the severities and violence of society, and undoubtedly had use as a means of the harsh discipline of men when they were moved only by the lowest motives. But, with the advance of knowledge, and the cultivation of the humaner sentiments, the doctrine has become anomalous and out of harmony with the advance of human nature. Hence, though still a cardinal tenet of orthodoxy, it is now generally entertained in a vague and loose way, and with reservations and protests that virtually destroy it. Only revival preachers of the Moody type still affirm the literal "lake of fire and brimstone," and it is certain that the doctrine in any shape recurs much less prominently in current preaching than it did a generation or two ago. Sober-minded clergymen have got in the way of neglecting it, except now and then when rehearsing the creed, or, as at present, under the spur of controversy, or when rallied about the decay of the old theology. The hell of Jonathan Edwards is gone. That sturdy theologian wrote: "The world will probably be converted into a great lake, or liquid globe of fire—a vast ocean of fire in which the wicked shall be overwhelmed, which will always be in tempest, in which they shall be tossed to and fro, having no rest day or night, vast waves or billows of fire continually rolling over their heads, of which they shall forever be full of a quick sense within and without: their heads, their eyes, their tongues, their feet, their loins, and their vitals, shall forever be full of a glowing, melting fire fierce enough to melt the very rocks and elements; and also they shall eternally be full of the most quick and lively sense to feel the torments; not for one minute, nor for one day, nor for one age, nor for two ages, nor for a hundred ages, nor for ten thousands of millions of ages, one after another, but for ever and ever without any end at all, and never, never be delivered."[1]

This is sufficiently explicit, but no man of the rank of its author talks in such a strain nowadays. In the current pulpit utterance there is a perfect chaos of discordant speculation, open repudiation, tacit disavowal, and ingenious refining away, but no stern and sturdy defense of it, in the old form and spirit, from any source that commands respect. The doctrine of hell is still conserved in popular creeds, but, if not eliminated, it will be pretty certain to carry the creeds with it into the limbo of abandoned superstitions.

[1] Edwards's Works, vol. viii., p. 166.

LITERARY NOTICES.

Pessimism: A History and a Criticism. By James Sully, M. A. London: C. Keegan Paul & Co., 1877. Pp. 470.

Mr. Sully, who is already well known for his investigations of æsthetic feeling from the psychological point of view, here undertakes to give us an account of the modern pessimistic philosophy which has spread so widely of late years in Germany, and also thoroughly to criticise its basis, its procedure, and its results. He begins with an analysis of the two antithetical frames of thought among the unphilosophic public which he aptly designates as "unreasoned optimism and pessimism." By the first of these terms Mr. Sully understands that joyous and vigorous view of life which belongs to moments of exaltation, or to the constitutionally happy; by the opposite expression he means the gloomy standpoint which we all naturally assume in periods of grief or depression. Passing on from these primitive and unsystematic beliefs, each the transitory expression of a fleeting emotional tone, our author traces the growth of a more deliberately pessimistic creed through the literature of Hebrew and classical antiquity, the middle ages, and the modern world. Next, he attacks the various forms of "reasoned optimism and pessimism," the conscious attempts to appraise the worth of the universe as absolutely good or bad. The origin of evil is shown to be the main problem which the optimistic Israelitish religion set itself to solve; while the pessimistic tendencies of Aryan thought in India, reaching its furthest development in Buddhism, are well pointed out. Through Greece and Rome, Mr. Sully proceeds to the optimistic philosophers of the last century, who endeavored, by metaphysical subtilty, to argue the existence of evil out of the universe. Of this school, Leibnitz, Shaftesbury, and Pope, may be taken as the leaders. The French *éclaircissement* brought a new idea to the front, that of human perfectibility, personified in Condorcet and Godwin. It was hoped that, after all, evil might not be inherent in the nature of things, but might prove a mere excrescence, due to the social errors of mankind. This creed found its most eloquent exponent in the poet Shelley; and, extravagant as were its first enthusiastic developments, Mr. Sully justly traces to its influence the modern belief in progress as an actual fact, present and prospective. In the social amelioration promised by the apostles of evolution, and especially by Mr. Herbert Spencer, our author rightly sees "the one vital type of optimism in our age." The kernel of the work is reached when we come to the survey of Schopenhauer's philosophy, and the account of his disciple, Hartmann, whose system is very fully analyzed. Their deliberate conviction, arrived at by an ostentatiously logical and stringent method, consists in the belief that "life is a uselessly interrupting episode in the blissful repose of the non-existent." With the careful exposition of their teaching, the historical portion of Mr. Sully's volume closes. The larger and critical division consists of a systematic dialectic against the whole argument of German pessimism, as represented by these its greatest lights. Into this part of his work, which is lengthy, and closely reasoned, we can only briefly follow him. Mr. Sully begins by clearly setting forth the problem in dispute. He then attacks the superstructure of Hartmann from its metaphysical basis, which he shows to be verbal, illusory, and self-contradictory. Its scientific basis is next examined from the physical and the psychological standpoints; and from both it is found to be wanting. Finally, the author sums up his own view in three somewhat lengthy chapters, which exhibit him as holding a middle course between the two extremes. While he rejects the untenable theory of the absolute optimists, he cannot agree that any groundwork for pessimism as a reasoned principle exists in the facts under consideration. His own platform is summed up in the single expression *meliorism*, suggested to him by George Eliot. In this creed he finds an incitement to practical effort which falls in with the natural longings of humanity and the teachings of modern evolutionism, but which is wanting either to the satisfied theological optimist or to the blankly-despondent German pessimist. In the hopes of our common humanity we have a refuge alike from the selfish acquiescence of the pietist and the petty troubles of individual existence.

As a whole, the work exhibits all Mr. Sully's characteristics in their fullest form. It is rather long-winded, a trifle dull, and somewhat apt to stray from the plain paths of common-sense into the hazy realm of metaphysics and casuistical subtilty. But, on the other hand, it is full of varied and accurate learning, judicial impartiality, and studied moderation. Great pains have been taken to bring it up to date in every respect, some works being actually noticed or quoted which must have appeared while the volume was passing through the press. And as an exhaustive account of all that has been written or thought upon its subject at all periods, ancient or modern, it may be thoroughly recommended alike to the psychological student and to the general reader.

The Ancient Life-History of the Earth. A Comprehensive Outline of the Principles and Leading Facts of Palæontological Science. By H. Alleyne Nicholson, M. D., D. Sc., Professor of Natural History in the University of St. Andrew's. D. Appleton & Co. Pp. 407. Price, $2.00.

The subject of this book is one of growing scientific interest. Only within the present century has it been revealed that the earth has been laden with life for untold ages, until its crust has become a vast tomb, and even thick and extensive rock-strata are made up of the skeletons of creatures of extreme minuteness. The present life of the globe is but the last term in an almost infinite series of generations, that have so varied in form and character, as we go back in time, that they serve to mark off the geological epochs.

A group of absorbing questions now clusters around this great fact of the ancient life-history of the earth, and there is much concern among multitudes of thoughtful people to acquire some clear and correct ideas upon the subject. Fierce controversies have sprung up in relation to it, which are liable so to vitiate the statements of conflicting parties, that many are at a loss to know what representations they can trust, and how to get at the unquestioned facts. To all persons in this state of mind, Dr. Nicholson's work will be especially welcome, as it is a clear, succinct, and dispassionate account of the present state of palæontological knowledge, or of its descriptive parts independent of the contested theories to which it has given rise. His book is, moreover, compendious in form, and moderate in cost, to a degree that is quite unusual in a work so profusely and elegantly illustrated. Its preparation has involved great and careful labor, and the artists have done it excellent justice in the skill and fidelity of their pictorial representations. We know of no other volume that will so well meet the wants of a large class of readers at the present time. An excellent feature of the book is its copious bibliography or literature of reference appended to the leading chapters. In the appendix there is a tabular view of the chief divisions of the animal kingdom, followed by an ample glossary of technical terms, and a very full index.

An American Girl, and her Four Years in a Boys' College. By Sola. New York: D. Appleton & Co. Pp. 269. Price, $1.50.

This book records the experiences of a young lady who got a craze to go to college, and when a certain collegiate institution took off the embargo upon feminine opportunity, and admitted girls to the regular course of study, she argued her mother into consent, and entered the establishment. She has adventures, mishaps, exploits, and a lively time generally, both in doors and out. The book is written with considerable spirit, and conveys a very good idea of college-life, in its feminine aspect. The writer is somewhat critical of many things, but believes profoundly in women going to men's colleges. In the sequel, she gets married to one of the students, the circumstances of love-making, while in college, being duly presented; but what possible or conceivable bearing the course of study pursued had upon the prospective life of the woman, who passed from the valedictory platform to the hymeneal altar, appeareth not in this book of "An American Girl."

Money. By Francis A. Walker. New York: Henry Holt & Co. Pp. 550. Price, $4.

It is no disparagement to a book of this kind to state that it covers no new ground: efforts after originality in the treatment of subjects of this class are seldom successful or profitable. It is high, but in this case well-deserved, praise to be able to say that it is impartial in its statements, judicial in its conclusions, and full, clear, and exact, in its explanations — the presentation, as a whole, of the much-vexed question of money being popular and comprehensible.

The book will be a valuable one, because, among other reasons, the author has allowed himself space in which to classify his subject fully, and to elaborate details in a way to bring out likenesses and differences that the casual reader is likely to overlook.

There are three general divisions: Part I., "Metallic Money," under which head the function and distribution of money, the production of the precious metals, their coinage and circulation, are considered. Chapters XII., "The Concurrent Circulation of Two Metals," and XIII., "The Battle of the Standards," are of great present interest. They constitute a full and exceedingly fair presentation of the opposed views of the bi-metalists and the mono-metalists. The author emphasizes the fact, often lost sight of, that the question is one into which political considerations enter so largely, that it will be difficult, if not impossible, to settle it on strictly economic principles. Indeed, throughout the book the important influence of legislation, habit, sentiment, and other the like factors, upon economic affairs is more fully recognized than is usual in such treatises. Part II. is devoted to "Inconvertible Paper-Money." Its theory is stated and historically illustrated. The chief danger of its use is seldom better stated than in the following paragraph: "The danger of over-issue is one which never ceases to threaten an inconvertible paper-money. The path winds even along the verge of a precipice. Vigilance must never be relaxed. The prudence and self-restraint of years count for nothing, or count for but little, against any new onset of popular passion, or in the face of a sudden exigency of the Government. From this danger a people receiving into circulation an inconvertible paper-money can never escape. A single weak or reckless administration, one day of commercial panic, a mere rumor of invasion, may hurl trade and production down the abyss."

This and Part III., on "Convertible Paper-Money," are able discussions, and timely, for we fear they are over-sanguine who think that the day of our danger from paper inflation is past.

Mr. Walker discards altogether the word currency, for reasons which he gives fully, and which are not without force. He also substitutes the term "common denominator of exchange" for "measure of value," in defining one of the functions of money—a change which we indorse without reservation. There is a copious index, and the book is in all respects well gotten up.

Money and Legal Tender in the United States. By H. R. Linderman, Director of the Mint. New York: G. P. Putnam's Sons. Pp. 173. Price, $1.25.

There is given to the public in this little book a brief but comprehensive history of American coinage, by a man thoroughly conversant with his subject, and competent to point out clearly the lessons to be drawn from our experience.

The various laws regulating the coinage and the workings of the mint are given. The terms used in treating of bullion, coinage, and money, are defined. A short chapter states what constitutes a legal tender.

Accounts are given of the paper-currency since 1863, of fractional notes, coin-certificates, funding operations, etc.

Beginning with page 100 is a discussion of the proposition to remonetize silver. It is a straightforward, common-sense statement of the question, stripped of illusions and technicalities, that we should be glad to see widely circulated.

In the appendix are conveniently tabulated useful statistics concerning the production of silver, its use, movements, and prices, the ratio between it and gold, the coinage of the United States mints, etc.

It would be hard to find a book better adapted to clear away the fogs, which just now beset the subject of currencies and standards, than this volume of Dr. Linderman's, if the public could only be induced to read it.

An Epitome of the Positive Philosophy and Religion explanatory of the Society of Humanity in the City of New York, together with the Constitution and Regulations of that Society; to which is added an Important Letter of Harriet Martineau in regard to her Religious Convictions. Second edition. Pp. 59. Published by the Society of Humanity, 141 Eighth Street, New York.

This pamphlet will interest many as an exposition, in brief, of the religious basis of positivism. A society has been formed in New York devoted to these ideas, and this is its platform or confession of faith, various points of which are elucidated, and numerous authorities quoted, who have expressed sentiments in sympathy with the ideas here presented. It is an earnest and well-written document, evidently by a thorough-going adherent of the system, and is by no means strictly confined to the considerations of religious questions. It contains some new schemes or charts, presenting classifications and methodical arrangements of scientific and philosophical ideas that are filled out with a symmetrical completeness which seems to leave no room for improvement. The blank squares are all filled up so that the system looks finished, and there seems to be a perfect correspondence between the geometrical spacings of the map and the divisions of human knowledge. These tabular arrangements are, however, undoubtedly not designed to be final, but to be open to future revision, and they are of a very suggestive nature. Into the theological questions raised by this *brochure* we cannot now enter, but may note the manifest humility of the new sect, as there is not a name to be found of anybody connected with it, or of the authorship or publication of the manifesto, or of any human personality, representative of the "society." This is somewhat remarkable, as the propagandists of the new faith of Positivism are somewhat notorious for their free handling of personalities with whom they differ; and it seems still more surprising when we remember that the religious polity of positivism is so full of the apotheosis of individuals, and has such a copious calendar of saints, and makes men the objects of its worship.

Gerrit Smith: A Biography. By Octavius Brooks Frothingham. New York: G. P. Putnam's Sons. Pp. 381.

Whether this work is to be regarded as a success will depend upon the ideal formed of what a true biography ought to be. If we accept the Boswellian standard, which makes biographical excellence to consist in the copiousness of gossip, trivial particulars, and idle tattle about its subject, Mr. Frothingham's volume must be pronounced a failure. Such details are usually not only worthless, if true, but, originating in a spirit of adulation, they are generally so partial and false as to be of little use for any serious purpose. Moreover, the cast of mind that can produce such books is pretty certain to be wanting in the insight, the analytic capacity, and the critical judgment, necessary to form a true estimate of character.

Mr. Frothingham's book has not been made on this model. Though strictly a biography, that is, the description of a life, and though freely delineating those circumstances, incidents, peculiarities, sayings, and habitual actions, which mark and define the personality he is dealing with, yet all such details are made subordinate to the purpose of so unfolding and representing the nature of the man that readers may form their own judgment respecting his greatness. Thus regarded, the book is able, eminently successful, and worthy of its subject. Gerrit Smith was a most admirable man, a noble-hearted philanthropist, who put his great fortune at the service of society, and devoted his life to the skillful management of his immense wealth, that he might dispense it for beneficent ends. He was a radical and thorough-going reformer, taking deep interest in all projects of moral amelioration, such as peace, temperance, antislavery, and other philanthropic schemes, for which he worked with vigor, and which he aided liberally with his means. He was also from youth an uncompromising democrat, living plainly, carrying out his theories of practical equality, and never betrayed into the aristocratic ostentation which he might have indulged on an imposing scale. The radicalism of his nature, moreover, asserted itself strongly in his religious experience. Beginning as a devoted Christian of the orthodox stamp, he held steadily to the practical observances of a pious life, but gradually freed himself from the trammels of theology, and, at length, emerged as a liberal Christian of the extremest sort. Christianity was with him a purely practical affair, a carrying out of the principles of human brotherhood, and the extending of sympathy and help to all who needed them. Doctrinal matters were therefore held lightly, and he told somebody late in life that he had not yet made up his mind whether he had a soul or not. In a variety of respects his character and position were unique, and his career altogether forms a study of special interest to those concerned with the philosophy of charities and benevolence.

Transcendentalism, with Preludes on Current Events. By Joseph Cook. J. R. Osgood & Co. Pp. 305. Price, $1.50.

This book emanates from the same mind that wrote the "Biology," and is, probably, of similar quality. Osgood well knows the length of his customers' ears, and puts in the "applause" all the same.

PUBLICATIONS RECEIVED.

Cerebral Hyperæmia. By W. A. Hammond, M.D. New York: Putnam's Sons. Pp. 108. $1.

The Nabob. By A. Daudet. Boston: Estes & Lauriat. Pp. 456. $1.50.

Foundations. By J. Gandard. New York: Van Nostrand. Pp. 104. 50 cents.

Democracy in Europe. By Sir T. E. May. New York: W. J. Widdleton. 2 vols., pp. 495 and 568. $5.

Comparative Psychology. By J. Bascom. New York: Putnam's Sons. Pp. 296. $1.50.

State Regulation of Vice. By A. M. Powell. New York: Wood & Holbrook. Pp. 127. $1.

Journal of the Academy of Natural Sciences of Philadelphia. Vol. VIII., Part III. (New Series).

Bulletin of the Minnesota Academy of Natural Sciences. Minneapolis: Young & Winn print. Pp. 126. 50 cents.

Annual Report of the Pennsylvania Training School for Feeble-minded Children. West Chester, Pa.; Hickman print. Pp. 35.

Proceedings of the Association of Medical Officers of Institutions for Idiots. Philadelphia: Lippincott & Co. Pp. 35.

The Young Scientist. Monthly. Pp. 12. 50 cents per year.

Magazine of American History. January, 1878. New York: Barnes & Co. Pp. 64. With steel-plate Portrait.

Report of the New Jersey Commissioners of

Fisheries. Trenton: Naar, Day & Naar print. Pp. 63.

Report of Trustees of West Pennsylvania Institution for Deaf and Dumb. Pittsburg: Stevenson, Foster & Co. print. Pp. 32.

Is the Human Eye changing its Form? By Dr. E. G. Loring. New York: The Author. Pp. 25.

The Steppes of Southern Russia. By Th. Belt. Pp. 20.

A New Type of Steam-Engine. By R. H. Thurston. From *Journal of the Franklin Institute*. Philadelphia: Kildare print. Pp. 35.

Medical Education in the United States. By N. S. Davis, M. D. Washington: Government Printing-Office. Pp. 60.

Reports of Curators of Wesleyan University Museum. Middletown, Conn.: Pelton & King print. Pp. 30.

Pneumono-Dynamics. By G. M. Garland, M.D. New York: Hurd & Houghton. Pp. 155.

Bulletin of the American Geographical Society, No. 4. New York: The Society. Pp. 105.

Public Health. By G. P. Conn, M. D. Concord, N. H.: Republican Press Association print. Pp. 17.

Convergent Strabismus. By S. Theobald, M. D. Baltimore: Foster print. Pp. 10.

Pseudocyesis and Pregnancy. By J. W. Underhill, M. D. New York: Wood & Co. Pp. 18.

Reports of Examinations of the New York Insurance and Banking Departments. New York: Green print. Pp. 30.

Dietetics of Infants. By T. Moore, M. D. Philadelphia: Sherman & Co. print. Pp. 14.

Report of Director of Harvard College Observatory. By Prof. E. C. Pickering. Cambridge: Wilson & Son print. Pp. 36.

New Double Stars. By S. W. Burnham. From "Notices of Royal Astronomical Society." Pp. 3.

Album Leaves. By G. Houghton. Boston: Estes & Lauriat. Pp. 34. 35 cents.

Notes on Matters of Physical Astronomy. By L. Trouvelot. From "Proceedings of the American Academy of Arts and Sciences."

POPULAR MISCELLANY.

The Last of the Gases.—The last of the gases that had never been condensed to liquids—oxygen, hydrogen, and nitrogen—have at length yielded to pertinacious experiment, and, under the joint influence of greater degrees of cold and pressure than had ever before been employed, have been reduced to the liquid form. This great experimental exploit has been performed by two chemists independently, and almost simultaneously — Raoul Pictet, of Geneva, and M. L. Cailletet, of Paris, by different processes. Pictet condensed oxygen, which was first announced; but Cailletet had already done it, and he also liquefied nitrogen, hydrogen, and the air. We give a representation of his apparatus, and an account of his processes, and shall give fuller statements of the results as they are more fully announced.

Stanley's Trip down the Congo.—The exploration of the Congo River from Nyangwe to the sea, by Henry M. Stanley, must be esteemed one of the most important achievements in the whole history of African discovery. He set out on November 5, 1876, from Nyangwe (latitude 4° 20′ south, longitude 26° 40′ east), at the head of a numerous band of native followers, marching northward by land forty miles, till he again came to the river—known here as the Ugarowa, or the Lualaba. Putting his men in canoes, and himself embarking on the portable Lady Alice, he commenced his long journey of alternate boating and portaging which lasted for nine months. The party soon began to experience the hostility of the native tribes, who again and again attacked them from the banks of the stream or in canoes. On December 6th seventy-two of Mr. Stanley's men were down with small-pox, which rendered defense all the more difficult; he seized a town, and there housed his sick and wounded, but for two days and nights he and his party had to repel the fierce attacks of the natives. Soon he was boating down the river again, his force on January 4th numbering 146 men. In latitude 0° 32′ 36″ south is a series of cataracts, and Stanley's men had to cut a road through the forest and drag their canoes round the falls, the natives constantly harassing them in the mean time. Just below these cataracts the river widens enormously, receiving several considerable affluents; its course, too, becomes westerly, though still tending toward the north till it reaches latitude 1° 40′ north, longitude 23° east, when it takes a southwesterly direction to the sea. One of the great tributaries of the Congo below the cataracts is the Aruwini, supposed to be the Welle of Schweinfurth. Here, on Stanley's map, is the legend "The Cannibal Region," and a little to the south "The Region of Dwarfs." At one place the expedition was attacked by the cannibals in fifty-four canoes with paddles eight feet long, spear-headed and pointed with iron blades. Stanley's breech-loaders soon forced the enemy to retreat in confusion. After receiving, in latitude 0°

20′ south, longitude 19° 40′ east, the waters of a great river, Ikelembo, otherwise the Kasai, coming from the south, and a little below, another river from the north, the Congo flows southwesterly in a mighty stream, till at the mouth of the Kwango it is compressed between two ranges of hills. The rapids commence 180 miles above Yellala Falls, there being a series of sixty-two cataracts; these it took the party five months to pass. Mr. Stanley reached the coast on August 11th with the ragged and half-starved remnant of his followers, having followed the river for about 1,800 miles. They were received on board a British naval vessel, and the natives carried back to Zanzibar. Mr. Stanley himself has returned to England.

German Handicraft.—A correspondent of the *Manufacturer's Review*, now visiting Germany, cites numerous facts confirming the criticisms passed by Prof. Reuleaux upon the quality of the work done by German artisans. Last winter, this writer occupied a room richly furnished and decorated, but hardly a day passed without some accident happening. The ornaments were all glued on, and one day it was the cornice of a wardrobe, another the slat of the dressing-table, that fell off. Not a single lock in the bureau would hold a drawer closed. On a windy night a match was extinguished by a gust of air coming through the *double windows*. This case was typical. "Whenever," says the author, "I had occasion to call in an artisan, the job was badly done, or delayed, or bungled. I never had a suit of clothes or a pair of boots that fitted." His experience extended over all Germany, both north and south, in small villages and towns up to 25,000 inhabitants, and it was everywhere the same. The best specimens of German manufacture are exported, as the home market requires cheap goods. Now, as the author remarks, Germany is preëminently the land of technical education, and the question naturally arises, "Is this the fruit of the system, and is the system itself a failure?" Various answers have been given: "It has been pointed out that as domestic industry has no use for them, a large number of the skilled, technically educated artisans and workmen emigrate to where their services are better appreciated, and that they are to be found in the workshops of Paris, London, and New York, occupying leading and well-paid positions. There is undoubtedly a great deal of truth in that, but it is also evident that it fails to cover the case; the cause must be deeper. It has been asserted, by men who certainly ought to know, that the instruction in German technical schools is too purely theoretic and scientific, and too little practical; that the professors, able men though they be, often have no practical knowledge of the arts of which they expound the underlying principles. It is evident that in this way the students, instead of being trained, are spoiled for their work. To illustrate, you need simply look at some of our American agricultural colleges; the professors may be excellent chemists, physicists, botanists, and zoölogists, but how many of them know practically anything about farming? It is thus that the question I have discussed has a practical bearing upon our own institutions. We are beginning to introduce technical schools everywhere, and we must guard against the danger mooted."

The Whitney Glacier. — While visiting the Pacific slope, on business of the United States Entomological Commission, Mr. A. S. Packard, Jr., ascended Mount Shasta, in Northern California, and studied the Whitney Glacier, one of the three glaciers on its flanks. The Whitney Glacier is about three miles long, and extends from the summit of Shasta peak down to or quite near the line of trees. The surface is white and clean near the top. Ice cascades and crevasses begin very near the upper termination. On the upper portion on the east side, under a perpendicular wall of rock, is a lateral moraine; and a little farther down, where the glacier abuts against the crater-cone of Mount Shasta, is a lateral moraine on the west side. The terminal moraine covers the bottom of the glacier, and connects the two lateral moraines. The end of the glacier, instead of being free of detritus, pushing the mass before it, as in most European glaciers, runs under the terminal moraine for a considerable distance, the ice here and there projecting above the surface of the moraine. At and beyond the end of the present terminal moraine lies the former extension of it, constituting naked plains; and below the still more ancient moraine, showing the former size of the glacier, and comprised of a series of well-wooded hills. A muddy stream runs north from the end of the glacier.

Sensitiveness of the Leaves of the Common Teasel. — On closely examining the glandular hairs of the leaves of the common teasel, Mr. Francis Darwin observed protruding from them translucent, highly-refracting threads, capable of spontaneous movement. These filaments were found to consist of protoplasm, containing a large amount of resinous matter. They not only possess the power of spontaneous movement, but can also be made to contract violently under the influence of sundry reagents, of temperature, electricity, or simple mechanical irritation. In nutritive fluids the movements are very remarkable. Thus, in an infusion of meat, the filaments became rounded or sausage-shaped, or very long and bulky; sometimes they coalesced with one another, or again became completely detached and floated freely in the fluid. The movements resemble the "aggregation movements" observed in the tentacles of the *Drosera*. Mr. Darwin is of the opinion that these anomalous structures are connected both with the production of resin and the absorption of nitrogenous matter. In the adult teasel the leaves form, by their union in pairs across the stem, large cups, in which water collects, and in which insects are caught. The decomposing bodies of these insects form with the water a strongly-nutritive fluid, which is absorbed by the gland-hairs and their filaments.

Gas as a Domestic Fuel.—Gas as a fuel for domestic use possesses many noteworthy advantages over all other kinds of fuel, and there is, apparently, nothing to hinder its universal substitution in place of grosser fuels, save its greater cost. By using a gas-apparatus, we may do away with dust, smoke, ashes, cinders, and kindling-material, save time and labor, and escape many vexations. For summer use, gas-stoves possess special advantages even on the ground of economy. "It is desirable," says the *American Gaslight Journal*, "to keep as cool during the heated term as is consistent with the pecuniary and mechanical means at our command; therefore, we should have our artificial heat so arranged as to be used only when desired for active work, and employed no longer than is necessary. With a good apparatus, the gas actually used for cooking and performing all necessary fuel-labor, during the warm season, costs no more than the coal and kindling used for the same purposes, and we get the comfort, saving of time, convenience, and sanitary influence, thrown gratuitously into the trade." The case is different when it is proposed to employ gas for the purpose of warming houses. "It is," the *Journal* admits, "more expensive to run a gas-stove for a given amount of heat than it is to run a coal-stove for the same. Hence, when the heat is to be continuous, the coal-stove has the advantage so far as cost is concerned." Our contemporary then suggests to the gas companies the advisability of setting up in houses of gas-consumers a special metre connected with the heating and cooking apparatus, and of selling gas for these purposes at half-price, so as to encourage the use of gas in this way.

Impure Water fatal to Fish-Breeding.—Mr. Seth Green takes advantage of an accident which occurred lately at the State fish-ponds, to caution people against drawing off the water of old mill-ponds, except they do it very slowly, especially in warm weather. "Last week," he writes to *Forest and Stream*, "the State ponds at Caledonia came near losing all their breeding-fish. The head of the stream is about one mile above the ponds. Half of the water comes out of the ground at the head of the stream, and a dam was put across the creek sixty years ago, about forty rods from the spring, making a pond of several acres. It is full of moss and all sorts of animalcula. Last week the owner of the pond opened the gates, and let the water down with a rush. It killed all the trout in the stream for a half-mile below, and if it had not been for many large springs coming in on both sides of the creek, all the trout in the stream and ponds would have been killed, and it would take many years to restock the ponds as they now are." The different kinds of fish now in these ponds are California salmon, Kennebec salmon, brook-trout, salmon-trout, grayling, a hybrid of California salmon and brook-trout, also a hybrid between salmon-trout and white-fish.

Graves of the Mound-Builders. — On opening a sepulchral mound on Coup's Creek, Macoupin County, Illinois, four skeletons were found sitting two-and-two, with the arms crossed, and the knees of one pair pressing sharply against the backs of the other. The grave was six feet in length by three in width, and search was made for other remains. Nothing, however, was found, except four large marine-shells, identified as of the Linnæan species *Busycon perversum.* The position of each of these shells in relation to the skeletons was the same: the smaller end of one had been placed in the right hand of each, while the larger portion rested in the hollow above the left hip. But what will appear most singular in this remarkable find is the fact that each shell contained what seemed to be the bones of an infant. "Within each of the shells," writes Mr. John Ford, in the "Proceedings" of the Academy of Natural Sciences of Philadelphia, "there had been packed what appeared to be the bones of a child; the skull, which evidently had been crushed before burial, protruding beyond the aperture. Of course, any hypothesis regarding the purpose of this peculiar rite must necessarily be of a conjectural character; nevertheless, it was difficult to resist the conclusion that these infants were sacrificial offerings to the spirits of the dead, whom the living desired to honor."

Non-Poisonous Coloring for Preserved Vegetables.—A patented process, for giving to cooked and preserved vegetables a green color, without the employment of copper or any other poisonous substance, is described as follows: First, the green leaves of some such plant as spinach, or sorrel, are scalded for a few minutes with boiling water, and drained; they are then triturated with knives or other cutting instruments. Next the triturated mass is heated with an equal weight of caustic soda solution marking 12.5° Beaumé, the mixture being boiled till the leaves are dissolved. From the product prepare a "lacker" by precipitating alum with this alkaline solution of chlorophyl, and then draw off and wash the precipitate in abundance of water, and finally press out the excess of water. To prepare the lacker for use, about thirty pounds of it is put in a basin with about fifteen pounds of soluble phosphates, especially phosphates of soda, potash, or ammonia, or of acid phosphates, or alkaline citrates, or double tartrates, and water is added until the liquor marks 2° to 5° Beaumé. To communicate the green color of this chlorophyl preparation to cooked or preserved vegetables, the latter have only to be immersed for a few minutes in the solution at a temperature of 212° Fahr. The effect of the operation is to impart to the products treated a fine, permanent green color, due to the absorption and fixation of an excess of chlorophyl.

Compressed Air in Coal-Mining.—An English journal gives an account of certain experiments recently made at Wigan to show how compressed air may be substituted for fiery explosives in coal-mining. A "cartridge," or reservoir, was placed in a shot-hole, after the manner of a charge of powder, and rammed or plugged in the same way. This chamber is in connection with a powerful air-pump, adapted expressly for the purpose, and, by simply turning a wheel, the collier can "fire his shot" without the least danger of setting fire to the inflammable gases. Mr. Marsh's (the inventor's) machine is capable of exerting a pressure of over 12,000 pounds to the square inch, and this force can be produced by two men turning the wheel in less than three minutes from the time of ramming the cartridge. The Wigan experiments show that very large quantities of coal can be brought down at a very much less expenditure of force. The first cartridge "fired" was burst at a pressure of 7,500 pounds to the square inch, the pressure being registered by a gauge. The coal was fractured, but not brought down; and a second cartridge was inserted, and burst at a pressure of 8,250 pounds to the square inch, completely loosening the coal and breaking up about eight tons. The whole force of the shot was probably not exerted on the seam, as the ramming was blown out. The machine is described as very handy and compact, and easily used, while the cost, beyond the first outlay, is absolutely *nil.*

The Heliotype Process.—For some years an eminent publishing-house in Boston has been engaged in the production of "heliotype" copies of famous works of art, and the public is now more or less familiar with the products of the "heliotype" process. But what that process is we have nowhere seen explained till recently a writer in the *Tribune* gave a very intelligible account of its *modus operandi.* In what follows we propose to give in brief the main points of the author's explanation: First a photographic negative is made in the ordinary manner; but the "positive" plate is peculiar. The basis of its composition is gelatine, with a mixture of bichromate of potash and chrome alum. This mixture is dissolved in hot water, and the solution is then poured on a plate of glass or metal, and left to dry. When dry it is about as thick as ordinary parchment, and is stripped from the plate and placed in contact with the previously-prepared negative; the two are then exposed to the light. The bichromate of potash makes the gelatine plate sensitive to light, and wherever the light touches it the plate becomes leathery or water-proof. The result of the exposure to light is, therefore, that a portion of the gelatine plate—the image—is water-proofed, while the remainder is absorbent of water. Now, we know what a repulsion exists between water and greasy substances of every kind—for instance, printer's ink. It follows that, if we moisten the gelatine plate, the unchanged parts will absorb the water, and, if ink is then rolled over it, it will adhere only in the altered parts. By so applying ink, the sheet of gelatine is converted into a "positive" plate from which copies can be taken on a printing-press. This plate, strange to say, is very durable, and is capable of yielding, with fair treatment, several thousand impressions. Of course, the sheet of gelatine must have a solid base given to it, to hold it firmly on the bed of the press while printing. This is accomplished by uniting it under water with a metallic plate, exhausting the air between the two surfaces, and attaching them by atmospheric pressure.

Epidemics and Ablution.—A short time ago we published some remarks of Dr. Hebra, of Vienna, depreciatory of the value of frequent bathing. A diametrically opposite opinion is held by the eminent hygienic reformer, Edwin Chadwick, C. B., who cites facts to prove that skin-cleanliness, or in other words frequent ablution of the whole person, is a powerful preservative against all infectious and contagious diseases. He asserts that in children's institutions the death-rate and cases of sickness have been reduced one-third by regular head-to-foot ablutions with tepid water. Experienced trained nurses, regularly attending scarlatina-patients, give themselves regular head-to-foot ablutions twice a day, and a change of clothes once a day. Medical men of experience, who serve amid plagues and the most terrible epidemics, do the like. Mr. Chadwick adds: "If I had again to serve as a member of a general board, and had to exercise authority in providing defenses against epidemics, I would propose regulations for the immediate and general 'tubbing' of the population, and have it seen to as sedulously as vaccination for protection against small-pox." To show the influence of skin-cleanliness on the assimilation of food, Mr. Chadwick relates the following incident: "A friend of mine," he writes, "in command of a brigade in Spain, was hemmed in, and his men were put on very short rations; and to amuse them—it being summer-time—he encouraged them to bathe daily in a river close by, and he marked, as a result he had not expected, that his men were in as good strength as the unwashed soldiers on their full rations." Similar results are observable in the inmates of well-kept prisons.

New Process of Embalming.—A new and inexpensive method of embalming has been invented by Dr. Lowell, of Brooklyn. The preservative fluid he employs is a solution of zinc chloride which is injected into the body either by an artery or a vein. The apparatus required consists of a porcelain-lined vessel, which is elevated to such a height that the solution may be injected into the cadaver after the manner of a gravity-syringe. For the passage of the preservative fluid from this receptacle into the vein of the cadaver, glass and rubber tubing is all that is required. Dr. Lowell writes: "The injection may be made by either artery or vein. . . . I prefer the brachial artery above the elbow as the point for introduction of the glass tube, for the primary incision is slighter, and consequently divides smaller and fewer veins than when I expose the femoral artery. I use the gravity method, and introduce about five gallons of the antiseptic fluid. The effects are eminently satisfactory. The color of the integument is improved." A body treated in this way was transported from New York to Richmond last summer without odor, disfigurement, or external sign of decay.

NOTES.

The Count de Saporta has discovered in the Silurian rocks of Angers the remains of ferns—the first evidence so far found in Europe of the existence of terrestrial vegetation during Silurian times. In the American Silurian formation Prof. Leo Lesquereux had already found fern-remains.

Prof. William Dwight Whitney, of Yale College, has been named a member of the French Academy of Inscriptions and Belles-Lettres.

An interesting law case lately came before a London magistrate, namely, the violation by a gas company of the act of Parliament which fixes the maximum of impurity permissible in illuminating gas. The company defendant were sued to recover *eight penalties* of £50 each for having on eight days supplied gas of less purity than the act allows. The court ordered a warrant to issue for the full amount of penalties claimed.

We have to record the first instance that has come under our notice of a house-owner being arrested and held to account in New York City for neglecting duly to provide against the entrance of poisonous sewer-gases into his tenements. In January, an agent of the Board of Health sued out a warrant against a house-owner who had offended in this way, and the accused was bound over for examination. The Health Board is to be commended for its action in this case, and encouraged to go on with the good work.

Died at Paris, December 20th, Henri Daniel Ruhmkorff, aged about seventy-five years. He was by birth a Hanoverian, but came to Paris at a very early age, and there spent the remainder of his life. He was first a porter in a physical laboratory, where he acquired a taste for electrical experiments. He soon opened a little shop for making physical apparatus. His famous magneto-electric "coil" was produced in 1851; in 1858 he received for it the first prize of 50,000 francs at the French Exhibition of electrical apparatus.

Mr. E. A. Barber, in the *American Naturalist*, notes a singular rite formerly practised by the Seminoles at the "christening" of their male children. At the age of fourteen the boy was scratched or incised with a sharp flint six times on each arm and leg, the length of the incisions being about a foot. If the lad flinched or cried out, he received an insignificant name; but if he bore the pain manfully, he received a high-sounding title, and was destined to become a great man in the tribe.

The statistics of rainfall at San Francisco for the past twenty-five years or more are contradictory of the theory according to which the amount of rainfall is in direct proportion to the number of spots on the sun. It has been shown by Mr. J. S. Hittell that during the four years from 1865 to 1869 there was at San Francisco a total fall of 118 inches—the greatest quantity ever noted there for an equal period—and yet those four years were "in the minimum portion of the sun-spot cycle." The table of annual rainfall given by Mr. Hittell is in fact, as far as it goes, an evidence that there is no periodicity either of maximum or minimum rainfall at San Francisco.

The advantages of crying and groaning in pain are set forth by a French physician, who holds that these modes of expression are Nature's own methods of subduing the keenness of physical suffering. He would have men freely avail themselves of this means of numbing their sensibility during surgical operations. Crying in children should not be repressed, for, according to this authority, such repression may result in very serious consequences, as St. Vitus's dance, epileptic fits, etc.

A baker in Paris having used, for heating his oven, painted wood from old houses which had been torn down in opening a new street, many persons who ate the bread were seized with violent symptoms of lead-poisoning. The heat converted the paint into pulverulent oxide of lead, which adhered to the moist surface of the loaves. The men who brushed these loaves were the first to suffer, and then all who ate the crust experienced with more or less intensity the agonies of "painters' colic." A police regulation has been issued forbidding the use by bakers of wood from old houses.

P. ANGELO SECCHI.

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EVOLUTION OF CEREMONIAL GOVERNMENT.

By HERBERT SPENCER.

III. MUTILATIONS.

FACILITY of exposition will be gained by approaching indirectly the facts and conclusions here to be set forth.

As described by Burton, the ancient ceremony of infeftment in Scotland was completed thus: "He [superior's attorney] would stoop down, and, lifting a stone and a handful of earth, hand these over to the new vassal's attorney, thereby conferring upon him 'real, actual, and corporeal' possession of the fief." Among a distant, slightly-civilized people, a parallel form occurs. On selling his cultivated plot, a Khond, having invoked the village deity to bear witness to the sale, "then delivers a handful of soil to the purchaser." From cases where the transfer of lands for a consideration is thus expressed, we may pass to cases where lands are by a similar form surrendered to show political submission. When the Athenians applied to Persia for help against the Spartans, after the attack of Cleomenes, a confession of subordination was demanded in return for the protection asked; and the confession was made by sending earth and water. A like act has a like meaning in Feejee: "The *soro* with a basket of earth . . . is generally connected with war, and is presented by the weaker party, indicating the yielding up of their land to the conquerors." And similarly in India: When, some ten years ago, Tu-wên-hsin sent his "Panthay" mission to England, "they carried with them pieces of rock hewed from the four corners of the [Tali] mountain as the most formal expression of his desire to become feudatory to the British crown."

This giving of a part instead of the whole, where the whole cannot be mechanically handed over, may be called a symbolic ceremony;

though, even apart from any further interpretation, we may say that it approaches as nearly to actual transfer as the nature of the case permits. We are not, however, obliged to regard this ceremony as one artificially devised; but we may affiliate it upon a ceremony of a simpler kind which at once elucidates it, and is elucidated by it. I refer to giving up a part of the body as implying a surrender of the whole. In Feejee, tributaries approaching their masters were told by a messenger that "they must all cut off their *tobe* (locks of hair that are left like tails). . . . They all docked their tails." Still, it may be replied that this act, too, is a symbolic act—an act artificially devised rather than naturally derived. If we carry our inquiry a step back, however, we shall find a clew to its natural derivation.

First, let us remember the honor which accrues from accumulated trophies; so that, among the Shoshones, for instance, "he who takes the most scalps gains the most glory." Let us join with this Bancroft's statement respecting the treatment of prisoners by the Chichimecs, that "often were they scalped while yet alive, and the bloody trophy placed upon the heads of their tormentors." And now let us ask what will happen if the scalped enemy survives and is taken possession of by his captor. The captor preserves the scalp as an addition to his other trophies; the vanquished enemy becomes his slave; and he is shown to be a slave by the loss of his scalp. Here, then, are the beginnings of a custom that may become established when social conditions make it advantageous to keep conquered foes as servants instead of eating them. The conservative savage will change his custom as little as possible. While the new practice of enslaving the captured grows up, there will continue the old practice of cutting from their bodies such parts as serve for trophies without impairing their usefulness; and it will thereafter result that the marks left will be marks of subjugation. Gradually as the receipt of such marks becomes by use identified with bondage, not only will those taken in war be marked, but also those born to them; until at length the bearing of the mark shows subordination in general.

That submission to mutilation may eventually grow into the sealing of an agreement to be bondsmen, is shown us by Hebrew history: "Then Nahash the Ammonite came up, and encamped against Jabesh-gilead: and all the men of Jabesh said unto Nahash, Make a covenant with us, and we will serve thee. And Nahash the Ammonite answered them, On this condition will I make a covenant with you, that I may thrust out all your right eyes." They agreed to be subjects, and the mutilation (not in this case consented to, however) was to mark their subjection. And while mutilations thus serve, like the brands a farmer puts on his sheep, to show first private ownership, and afterward political ownership, they also serve as perpetual reminders of the ruler's power; so keeping alive the dread that brings obedience. This fact we see in the statement that when the second Basil deprived fifteen thousand Bulgarian captives of sight, "the nation was awed by this terrible example."

Just adding that the bearing of a mutilation, thus becoming the mark of a subject race, survives as a token of submission when the trophy-taking which originated it has disappeared, let us now note the different kinds of mutilations, and the ways in which they severally enter into the three forms of control—political, religious, and social.

When the Araucanians on going to war send messengers summoning confederate tribes, these messengers carry certain arrows as their credentials; and, "if hostilities are actually commenced, the finger or (as Alçedo will have it) the hand of a slain enemy is joined to the arrows"—another instance added to those already given, in which hands cut off are brought home to show victory.

We have proof that in some cases living vanquished men, made handless by this kind of trophy-taking, are brought back from battle. King Osymandyas reduced the revolted Bactrians; and "on the second wall" of the monument to him "the prisoners are brought forward: they are without their hands and members." But, though a conquered enemy may have one of his hands taken as a trophy without much endangering his life, loss of a hand so greatly diminishes his value as a slave that some other trophy is naturally preferred.

The like cannot, however, be said of a finger. That fingers are sometimes carried home as trophies we have seen; and that conquered enemies, mutilated by loss of fingers, are sometimes allowed to live as slaves, the Bible yields proof. In Judges i. 6, 7, we read: "Adoni-bezek [the Canaanite] fled; and they pursued after him, and caught him, and cut off his thumbs and his great-toes. And Adoni-bezek said, Threescore and ten kings, having their thumbs and their great-toes cut off, gathered their meat under my table: as I have done, so God hath requited me." Hence, then, the fact that fingers are, in various places, cut off and offered in propitiation of living rulers, in propitiation of dead rulers, and in propitiation of dead relatives. The sanguinary Feejeeans, extreme in their loyalty to cannibal despots, yield sundry illustrations. Describing the sequence of an alleged insult, Williams says: "A messenger was . . . . sent to the chief of the offender to demand an explanation, which was forthwith given, together with the fingers of four persons, to appease the angry chieftain." Again, on the occasion of a chief's death, "orders were issued that one hundred fingers should be cut off; but only sixty were amputated, one woman losing her life in consequence." And once more: a child's hand "was covered with blood, which flowed from the stump where, shortly before, his little-finger had been cut off, as a token of affection for his deceased father." This propitiation of the dead by offering amputated fingers occurs elsewhere. When, among the Charruas, the head of the family died, "the daughters, widow, and married sisters, were obliged to have each one joint from the finger cut off; and this was repeated for every relation of the like character who died: the primary amputation being from the little-finger." By the Mandans, the usual mode of expressing grief on the death of a relation "was to lose two joints of the little-fingers, or sometimes the other fingers." A like custom was found among the Dakotas, and various other American tribes. Sacrificed in this way to the ghost of the dead relative or the dead chief, to express that subjection which would have pacified him while alive, the amputated finger becomes, in other cases, a sacrifice to the expanded ghost or god. During his initiation, the young Mandan warrior, "holding up the little-finger of his left hand to the Great Spirit, he expresses to him, in a speech of a few words, his willingness to give it as a sacrifice; when he lays it on the dried buffalo-skull, where the other chops it off near the hand with a blow of the hatchet." According to Mariner, the natives of Tonga cut off a portion of the little-finger as a sacrifice to the gods for the recovery of a superior sick relative.

Expressing originally submission to powerful beings alive and dead, this mutilation in some cases becomes, apparently, a mark of domestic subordination. The Australians have a custom of cutting off the last joint of the little-finger of females; and a Hottentot "widow, who marries a second time, must have the top joint of a finger cut off, and loses another joint for the third, and so on for each time that she enters into wedlock."

As showing the way in which these propitiatory mutilations of the hands are made so as to interfere least with usefulness, it may be noted that habitually they begin with the last joint of the little-finger, and affect the more important parts of the hand only if they recur. And we may join with this the fact that where, by amputating the hand, there is repeated in full the original mutilation of slain enemies, it is where the usefulness of the subject person is not a consideration, but where the treatment of the external enemy is extended to the internal enemy—the criminal. The Hebrews made the loss of a hand a punishment for one kind of offense, as shown in Deuteronomy xxv. 11, 12. Of a Japanese political transgressor it is said, "His hands were ordered to be struck off, which in Japan is the very extremity of dishonor." In mediæval Europe hands were cut off for various offenses; and, among sundry penal mutilations enacted by William the Conqueror, loss of a hand is one.

Recent accounts from the East prove that some vanquished men deprived of their noses by their conquerors, either while obviously alive or when supposed to be dead, survive; and those who do so remain identifiable thereafter as conquered men. Consequently, the loss of a nose may become the mark of a slave; and, in some cases, it does this. Concerning certain ancient Central Americans, Herrera tells us that they challenged neighboring peoples when "they wanted slaves; if the other party did not accept of the challenge, they ravaged their country and cut off the noses of the slaves." And, describing a war that went on during his captivity in Ashantee, Ramseyer says the Ashantees spared one prisoner, "whose head was shaved, nose and ears cut off, and himself made to carry the king's drum."

Along with loss of nose occurs, in the last case, loss of ears, which naturally comes next to be dealt with. This is similarly interpretable as having originated from trophy-taking, and having in some cases survived; if not as a mark of ordinary slavery, still, as a mark of that other slavery which is often a punishment for crime. In ancient Mexico "he who told a lie to the particular prejudice of another had a part of his lip cut off, and sometimes his ears." Among the Honduras people a thief had his goods confiscated, "and, if the theft was very great, they cut off his ears and hands." One of the laws of an adjacent ancient people, the Miztecs, directed the "cutting off of an adulterer's ears, nose, or lips;" and by some of the Zapotecas, "women convicted of adultery had their ears and noses cut off."

But though absence of ears seems more generally to have marked a criminal than to have marked a vanquished enemy who, surviving the taking of his ears as trophies, had become a slave, we may suspect that it once did, among some peoples, mark an enslaved captive; and that, by mitigation, it gave rise to the method of marking a slave prescribed of old among the Hebrews, and which still continues in the East with a modified meaning. In Exodus xxi. 5, 6, we read that if, after his six years' service, a purchased slave does not wish to be free, his master shall "bring him to the door, or unto the door-post, and his master shall bore his ear through with an awl, and he shall serve him forever." Commenting on this ceremony, Knobel says: "In the modern East, the symbol of piercing the ears is mentioned as the mark of those who are dedicated. . . . It expresses the belonging to somebody." And since, where there grows up unqualified despotism, private slavery is joined with public slavery, and the accepted theory is that all subjects are the property of the ruler, we may suspect that there hence results in some cases the universality of this mutilation. "All the Burmese," says Sangermano, "without exception have the custom of boring their ears. The day when the operation is performed is kept as a festival; for this custom holds, in their estimation, something of the rank that baptism has in ours."

As bearing indirectly upon mutilations of this class, I may add the curious fact named by Forsyth, that the Gond holds "his ears in his hands in token of submission."

Jaws can be taken as trophies only from those whose lives are taken. There are the teeth, however; some of these may be extracted from the jaws as trophies without seriously decreasing the usefulness of the prisoner. Hence another form of mutilation.

We have seen that teeth are worn as trophies in Ashantee and in South America. Now, if teeth are taken as trophies from captives who are preserved as slaves, loss of them must become a mark of subjection. Of facts directly showing that a propitiatory ceremony hence arises I can name but one. Among mutilations submitted to on the death of a king or chief in the Sandwich Islands, Ellis names knocking out one of the front teeth; an alternative being cutting the ears. The implication is tolerably clear; and when we further read in Cook that the Sandwich-Islanders knock out from one to four of the front teeth—when we see that the whole population becomes marked by these repeated mutilations undergone to propitiate the ghosts of dead rulers—when we infer that in propitiation of a much-dreaded ruler deified after death, not only those who knew him may submit to this loss, but also their children subsequently born—we see how the practice, becoming established, may survive as a sacred custom when its meaning is lost. For, concluding that the practice has this sacramental nature, there are the further reasons derived from the fixing of the age for the operation, and from the character of the operator. Angas tells us that in New South Wales it is the Koradger men or priests who perform the ceremony of knocking out the teeth; and of a semi-domesticated Australian Haygarth writes that he said one day, "with a look of importance, that he must go away for a few days, as he had grown up to man's estate, and 'it was high time that he should have his teeth knocked out.'" Various African races, as the Batoka, the Dor, etc., similarly lose two or more of their front teeth; and habitually the loss of them is an obligatory rite. But the best evidence (which I have found since setting down the above) is furnished by the ancient Peruvians. A tradition among certain of them was that the conqueror Huayna Ccapac, finding them disobedient, "made a law that they and their descendants should have three of their front teeth pulled out in each jaw." Another tradition, given by Cieza, naturally derivable from the last, was that this pulling out of teeth by fathers from their young children was "a service very acceptable to their gods." And then, as happens with other mutilations of which the meaning has dropped out of memory, the improvement of the appearance was in some parts the assigned motive.

It should be added that, in this case as in most cases, the mutilation assumes modified forms. "The Damaras knock out a wedge-shaped gap between their two front teeth;" "the natives in the neighborhood of Sierra Leone file or chip the teeth;" and various other tribes have allied usages.

As the transition from eating conquered enemies to making slaves of them mitigates trophy-taking so as to avoid causing death; and, as the tendency is to modify the injury inflicted, so that it shall in the least degree diminish the slave's usefulness; and as, with the rise of a class born in slavery, the mark which the slave bears no longer showing that he was taken in war, does not imply a victory achieved by his owner—there eventually remains no need for the mark to be one involving a serious mutilation. Hence it is inferable that mutilations of the least injurious and least painful kinds will become the commonest. Such, at any rate, seems a reasonable explanation of the fact that cutting off of hair for propitiatory purposes is the most prevalent of all mutilations.

Already we have seen the probable origin of the custom among the Feejeeans that tributaries had to make a propitiatory sacrifice of their locks on approaching their great chiefs; and there is evidence that a kindred sacrifice made in homage was demanded of old in Britain. In the Arthurian legends, which, unhistoric as they may be, yield good evidence respecting the manners of the times from which they descend, we read (in Mr. Cox's abridgment): "Then went Arthur to Caerleon; and thither came messengers from King Ryons, who said: 'Eleven kings have done me homage, and with their beards I have trimmed a mantle. Send me now thy beard, for there lacks yet one to the finishing of my mantle.'"

Some reasons exist for the belief that taking an enslaved captive's hair began with the smallest practicable divergence from taking the dead enemy's scalp; for the part of the hair in some cases given in propitiation, and in other cases worn subject to a master's ownership, answers in position to the scalp-lock. The hair yielded up by the tributary Feejeeans was the *tobe*, a kind of pigtail—the implication being that this could be demanded by, and therefore belonged to, the superior. Moreover, among the Calmucks, when one pulls another by the pigtail, or actually tears it out, this is regarded as a punishable offense, because the pigtail is thought to belong to the chief, or to be a sign of subjection to him. If it is the short hair on the top of the head that has been subjected to such treatment, it does not constitute a punishable offense, because this is considered the man's own hair and not that of the chief. And then I may add the statement of Williams, that the Tartar conquerors of China ordered the Chinese "to adopt the national Tartar mode of shaving the front of the head, and braiding the hair in a long cue, as a sign of submission." Another fact presently to be given joins with these in suggesting that a vanquished man, not killed, but kept as a slave, was allowed to wear his scalp-lock on sufferance, the theory being that the victor might at any time demand it.

Be this as it may, however, the widely-prevalent custom of taking the hair of the slain, either with or without a part of the skin, has nearly everywhere resulted in the association between short hair and slavery. This association existed among both Greeks and Romans:

"The slaves had their hair cut short as a mark of servitude." We find it thus throughout America. "Socially the slave is despised, his hair is cut short," says Bancroft of the Nootkas. "The privilege of wearing long hair was rigorously denied" to Carib slaves and captives, says Edwards. The slavery that punished criminality was similarly marked. In Nicaragua "a thief had his hair cut off, and became a slave to the person that had been robbed till he was satisfied." And this badge of slavery was otherwise inflicted as a punishment. By the Central Americans a suspected adulterer "was stripped and his hair was cut (a great disgrace)." One ancient Mexican penalty "was to have the hair cut at some public place." And during mediæval times in Europe cutting of hair was enacted as a punishment. Of course there follows a correlative distinction: long hair becomes honorable. If among the Chibchas "the greatest affront that could be put on a man or a woman was to have their hair cropped;" the assimilation to slaves in appearance was the obvious reason, the honorableness of long hair being an implication. "The Itzaex Indians," says Fancourt, "wore their hair as long as it would grow; indeed, it is a most difficult thing to bring the Indians to cut their hair." Long hair is a mark of distinction among the Tongans, and none are permitted to wear it but the principal people. Similarly with the New Caledonians and various others of the uncivilized, and similarly with semi-civilized Orientals, "the Ottoman princes have their beard shaved off, to show that they are dependent on the favor of the reigning emperor." By the Greeks, "in manhood, . . . the hair was worn longer," and "a certain political significancy was attached to the hair." In Northern Europe, too, "among the Franks . . . . the serfs wore the hair less long and less carefully dressed than freemen," and the freemen less long than the nobles: "The long hair of the Frank kings is sacred. . . . It is for them a mark and honorable prerogative of the royal race." Clothair and Childebert, wishing to divide their brother's kingdom, consulted respecting their nephews, "whether to cut off their hair so as to reduce them to the rank of subjects, or to kill them." I may add the extreme case of the Japanese mikado: "Neither his hair, beard, nor nails are ever [avowedly] cut, that his sacred person may not be mutilated," such cutting as occurs being done while he is supposed to sleep.

A parallel marking of divine rank may be noted in passing. Length of hair being significant of terrestrial dignity, becomes significant, too, of celestial dignity. The gods of various peoples, and especially the great gods, are distinguished by their flowing beards and long locks.

Domestic subordination, too, in many cases goes along with short hair; in low social states women commonly bear this badge of slavery. Turner tells us that in Samoa the women wore the hair short; the men wore it long. Among other Malayo-Polynesians, as the Tahitians and New-Zealanders, the like contrast occurs. Similarly with the Negrito races. "In New Caledonia the chiefs and influential men wear their hair long, and tie it up in a semi-conical form on the top of their head. The women all crop theirs close to the very ears." And cropped heads in like manner distinguish the women of Tanna, of Lifu, of Vate, and also the Tasmanian women. A kindred mode of signifying filial subordination may be added. Yielding up of hair once formed part of the ceremony of adoption in Europe. "Charles Martel sent Pepin, his son, to Luithprand, King of the Lombards, that he might cut his first locks, and by this ceremony hold for the future the place of his father;" and Clovis, to make peace with him, became the adopted son of Alaric, by offering his beard to be cut by him.

While coming thus to imply subjection to living persons, this mutilation simultaneously came to imply subjection to dead persons. How the yielding up of hair to the dead is originally akin to the yielding up of a trophy is well shown by the Dakotas: "The men shave the hair off their heads, except a small tuft on the top [the scalp-lock], which they suffer to grow and wear in plaits over the shoulders; the loss of it is the usual sacrifice at the death of near relations:" that is, they go as near as may be to surrendering their scalps to the dead. The meaning is again seen in the account given of the Caribs: "As their hair thus constituted their chief pride, it was an unequivocal proof of the sincerity of their sorrow, when, on the death of a relation or friend, they cut it short like their slaves and captives." Everywhere among the uncivilized, kindred forms occur. Nor was it otherwise with the ancient historic races. By the Hebrews making "baldness upon their heads" was practised as a funeral rite, as was also shaving off "the corner of their beard." Similarly by Greeks and Romans, "the hair was cut close in mourning." In Greece the meaning of this mutilation was recognized. Potter remarks: "We find Electra in Euripides finding fault with Helena for sparing her locks, and thereby defrauding the dead; and he cites the statement that this sacrifice of hair (sometimes laid upon the grave) was "partly to render the ghost of the deceased person propitious." A significant addition must be made: "For a recent death, the mourner's head was shaved; for an offering to the long-dead, a single lock was cut off."

Naturally if, from propitiation of the dead, some of whom become deities, there grows up religious propitiation, the offering of hair may be expected to reappear as a religious ceremony; and we find that it does so. Already, in the just-named fact that, besides hair sacrificed at a Greek funeral, similar though smaller sacrifices were made afterward, we see the rise of that recurring propitiation characterizing worship of a deity. And when we further read that among the Greeks "on the death of any very popular personage, as a general, it sometimes happened that all the army cut off their hair," we are shown a step toward that propitiation by unrelated members of the community at large, which, when it becomes established, is a trait of religious worship. Hence certain Greek ceremonies. "The cutting off of the hair, which was always done when a boy became an ἔφηβος, was a solemn act, attended with religious ceremonies. A libation was first offered to Hercules, . . . and the hair after being cut off was dedicated to some deity, usually a river-god." So, too, at the first time of shaving among the Romans, "the hair cut off on such occasions was consecrated to some god."

Sacrifice of hair was an act of worship with the Hebrews also. We are told of "fourscore men, having their beards shaven, and their clothes rent, and having cut themselves, with offerings and incense in their hand, to bring them to the house of the Lord;" and Krehl gives sundry kindred facts concerning the Arabians.

Curious modifications of the practice occurred in Peru. Small sacrifices of hair were continual. "Another offering," writes D'Acosta, is "pulling out the eyelashes or eyebrows and presenting them to the sun, the hills, the combles, the winds, or whatever they are in fear of. . . . On entering the temples, or when they were already within them, they put their hands to their eyebrows as if they would pull out the hairs, and then made a motion as if they were blowing them toward the idol"—a good instance of the abridgment which ceremonies habitually undergo. Lastly, when, in presence of a national calamity, extreme propitiation of a deity is to be made, we sometimes find even the ruler sacrificing his hair. During an eruption of the great volcano in Hawaii, all other offerings having failed to appease the anger of the gods, "the king Kamehameha cut off part of his own hair, which was considered sacred, and threw it into the torrent [of lava], as the most valuable offering."

One further development remains: this kind of sacrifice becomes in some cases a social propitiation. Wreaths of their own hair plaited were bestowed upon others as marks of consideration by the Tahitians. In France, in the fifth and sixth centuries, it was usual to pluck out a few hairs from the beard on approaching a superior, and present them; and this usage was occasionally adopted as a mark of condescension by a ruler, as when Clovis, gratified by the visit of the Bishop of Toulouse, gave him a hair from his beard, and was imitated in so doing by his followers. Afterward the usage had its meaning obscured by abridgment: in the times of chivalry one mode of showing respect was to tug at the mustache.

Already, when treating of trophies, and when finding that those of the phallic class, major and minor, had the same meanings as the rest, the way was opened to explain the mutilations next to be dealt with. We have seen that, when the vanquished were not killed but preserved as slaves, it became imperative that the taking of trophies from them should neither endanger life nor be highly injurious; and that hence, instead of jaws, teeth were taken; instead of hands, fingers; instead of scalps, hair. Similarly, in this case, the fatal mutilation disappearing left only such allied mutilation as did not seriously, or at all, decrease the value of the enslaved enemy.

That castration was initiated by trophy-taking I find no direct proof; but there is direct proof that prisoners have in some cases been treated in the way that trophy-taking of the implied kind would entail. Of Theobald, Marquis of Spoleto, we read in Gibbon that "his captives . . . . were castrated without mercy;" and, for thinking that there was once an enforced sacrifice of the kind indicated made to a conqueror, there is the further reason that we find a parallel sacrifice made to a deity. At the annual festivals of the Phrygian goddess Amma [Agdistis], "it was the custom for the young men to make themselves eunuchs with a sharp shell, crying out at the same time, 'Take this, Agdistis!'" There was a like practice among the Phœnicians; and Brinton names a severe self-mutilation of the ancient Mexican priests which seems to have included this. Coming in the way shown to imply subordination, this usage, like many ceremonial usages, has in some cases survived where its meaning is lost. The Hottentots enforce semi-castration at about eight or nine years of age; and a kindred custom exists among the Australians.

Naturally, of this class of mutilations, the less serious is the more prevalent. Circumcision occurs among unallied races in all parts of the world—among the Malayo-Polynesians in Tahiti, in Tonga, in Madagascar; among the Negritos of New Caledonia and Feejee; among African peoples, both of the coast and the interior, from Northern Abyssinia to Southern Caffre-land; in America, among some Mexican peoples, the Yucatanese, and the people of San Salvador; and we meet with it again in Australia. Even apart from the fact that their monuments prove it to have been practised by the Egyptians from their earliest recorded times, and even apart from the reasons for believing that it prevailed among the Arabian peoples at large, these proofs that circumcision is not limited to region or race sufficiently dispose of the current theological interpretation. They sufficiently dispose, too, of another interpretation not uncommonly given; for a general survey of the facts shows us that, while the usage does not prevail among the most cleanly races in the world, it is common among the most uncleanly races. Contrariwise, the facts taken in the mass are congruous with the general theory thus far verified.

It was shown that among the Abyssinians down to recent times the trophy taken by circumcision from an enemy's dead body is presented by each warrior to his chief, and how all such trophies taken after a battle are eventually presented to the king. If the vanquished enemies, instead of being killed, are made slaves, and if the warriors who have vanquished them continue to present the usual proofs of their prowess, there must arise the circumcision of living captives, who thereby become marked as subjugated persons. A further result is obvious. As the chief and the king are propitiated by bringing them these trophies taken from their foes, and, as the primitive belief is that a dead man's ghost is pleased by whatever pleased the man when alive, there will naturally follow a presentation of such trophies to the ghost of the departed ruler. And then where in a highly-militant society governed by an absolute despot, divine by descent and nature, who, owning the entire population, requires them all to bear this badge of servitude, and who, dying, has his dreaded ghost anxiously propitiated, we may expect that the offering of these trophies taken from enslaved enemies to the king will develop into the offering of like trophies taken from each generation of male citizens to the god in acknowledgment of their slavery to him. Hence, when Movers tells us that among the Phœnicians circumcision was "a sign of consecration to Saturn," and when proof is given that of old the people of San Salvador circumcised "in the Jewish manner, offering the blood to an idol," we are shown just the results to be anticipated as eventually arising.

That this interpretation applies to the custom as made known to us in the Bible, there is clear evidence. We have already seen that the ancient Hebrews, like the modern Abyssinians, practised the form of trophy-taking which necessitates this mutilation of the dead enemy; and, as in the one case, so in the other, it follows that the vanquished enemy, not slain, but made prisoner, will by this mutilation be marked as a subject person. That circumcision was among the Hebrews the stamp of subjection, all the evidence proves. On learning that among existing Bedouins, as Mr. Palgrave shows, the only conception of God is that of a powerful living ruler, the sealing by circumcision of the covenant between God and Abraham becomes a comprehensible ceremony. There is furnished an explanation of the fact that, in consideration of a territory to be received, this mutilation, submitted to by Abraham, implied that "the Lord" was "to be *a* god unto" him; as also the fact that the mark was to be borne not by him and his descendants exclusively, as favored individuals, but also by slaves not of his blood. And, on remembering that in primitive beliefs the returning double of the dead potentate is believed to be indistinguishable from the living potentate, we get an interpretation of the otherwise strange tradition narrated in Exodus concerning God's anger with Moses for not circumcising his son: "And it came to pass by the way in the inn that the Lord met Moses, and sought to kill him. Then Zipporah took a sharp stone, and cut off the foreskin of her son, and cast it at his feet." That circumcision among the Jews was a mark of subordination to Jahveh is further implied by the facts that under the foreign ruler Antiochus, who brought in foreign gods, circumcision was forbidden, and those who, persevering in it, refused obedience to these foreign gods, were slain; while contrariwise Mattathias and his friends, loyal to the god of their fathers, and rebelling against foreign rule and worship, are said to have gone "round about, and pulled down the altars: and what children soever they found within the coast of Israel uncircumcised those they circumcised valiantly." Moreover Hyrcanus, having subdued the Idumeans, made them submit to circumcision as a condition of remaining in their country; and Aristobulus similarly imposed the mark on the conquered people of Iturea.

Quite congruous are certain converse facts. Mariner states that Tooitonga (the great divine chief of Tonga) is not circumcised, as all other men are: being unsubordinated, he does not bear the badge of subordination. And with this I may join a case in which whole tribes belonging to a race ordinarily practising circumcision are uncircumcised where they are unsubordinated. Naming certain Berbers in Morocco as thus distinguished, Rohlfs says: "These uncircumcised tribes inhabit the Rif Mountains. . . . All the Rif mountaineers eat wild-boar, in spite of the Koran law."

Besides mutilations entailing some loss of flesh, bone, skin, or hair, there are mutilations which do not imply a deduction—at least not a permanent one. Of these we may take, first, one which sacrifices a liquid part of the body, though not a solid part.

Bleeding as a mutilation has an origin akin to the origins of other mutilations. Did we not find that some uncivilized tribes, as the Samoyeds, drink the warm blood of animals—did we not find among existing cannibals, such as the Feejeeans, proofs that savages drink the blood of still-living human victims—it would seem incredible that from taking the blood of a vanquished enemy was derived the ceremony of offering blood to a ghost, and to a god. But when to accounts of horrors like these we join accounts of kindred ones which savages commit, such as that among the Amaponda Caffres "it is usual for the ruling chief, on his accession to the government, to be washed in the blood of a near relative, generally a brother, who is put to death on the occasion;" and when we infer that, before the rise of civilization, the sanguinary tastes and usages now exceptional were probably general, we may suspect that from the drinking of blood by conquering cannibals there arose some kinds of blood-offerings—at any rate, those of blood taken from immolated victims. Possibly some offerings of blood from the bodies of living persons are to be thus accounted for; but those which are not are explicable as sequences of the widely-prevalent practice of establishing a sacred bond of mutual obligation between living persons by partaking of each other's blood—the derived conception being that those who give some of their blood to the ghost of the man just dead and lingering near effect with it a union which on the one side implies submission, and on the other side friendliness.

On this hypothesis we have a reason for the great prevalence of self-bleeding as a funeral-rite, not among existing savages only, but among ancient and partially-civilized peoples—the Jews, the Greeks, the Huns, the Turks. We are shown how there arise kindred rites as permanent propitiations of those more dreaded ghosts which become gods—such offerings of blood (now taken from slain victims, now from their own bodies, and now from their newly-born infants) as those which the Mexicans gave the idols of their cannibal deities; such offerings as were implied by the self-gashings of the priests of Baal; and such as were sometimes made even in propitiating Jahveh—as by the fourscore men who came from Shechem, Shiloh, and Samaria. Moreover, the instances of bloodletting as a complimentary act in social intercourse cease to be inexplicable. During a Samoan marriage-ceremony the friends of the bride, to testify their respect, "took up stones and beat themselves until their heads were bruised and bleeding." In his account of the Central Americans, Martyr says, "When the Indians of Potonchan receive new friends, . . . as a proof of friendship, they, in the sight of the friend, draw some blood . . . . from the tongue, hand, or arm, or from some other part."

Here, however, my purpose in naming these offerings of blood under the head of mutilations is not so much to show their kinship of origin as to prepare the way for explaining the mutilations which result from them.

Gashings and tearings of the flesh make wounds which leave scars. If the blood-offerings which entail them are made by relatives to the departed spirit of an ordinary person, these scars are not likely to have any permanent significance; but, if they are made in propitiation of some deceased chief, not by his relatives alone, but by unrelated members of the tribe who stood in awe of him and fear his ghost, then like other mutilations they become signs of subjection. The Huns who "at the burial of Attila cut their faces with hollow wounds," in common with the Turks who did the like at royal funerals, thus inflicted on themselves marks which thereafter distinguished them as servants of their respective rulers. So, too, did the Lacedæmonians, who, "when their king died, had a barbarous custom of meeting in vast numbers, where men, women, and slaves, all mixed together, tore the flesh from their foreheads with pins and needles . . . . to gratify the ghosts of the dead." Customs of this kind would sometimes have further results. With the apotheosis of some notable king whose conquests gave him the character of founder of the nation, such marks, borne not by his contemporary followers only, but imposed by them on their children, might become national marks.

That the scars caused by propitiatory bloodletting at funerals do become recognized as binding to the dead those who bear them, and do develop in the way alleged, we have tolerably good evidence. The command in Leviticus, "Ye shall not make any cuttings in your flesh for the dead, nor print any marks upon you," shows us the usage in that stage at which the scar left by sacrifice of blood is still a sign partly of family subordination and partly of other subordination. And the traditions of the Scandinavians show us a stage at which it betokens allegiance either to an unspecified supernatural being, or to a deceased ruler who has become a god. Odin, "when he was near his death, made himself be marked with the point of a spear;" and Niort "before he died made himself be marked for Odin with the spear-point."

That scars on the surface of the body, thus coming to express loyalty to a deceased father or a deceased ruler, or a god derived from him, initiate, among other disfigurements, those we class as tattooing, is a probable inference. Lacerations, and the traces they leave, are certain to take different forms in different places. The Andaman-Islanders "tattoo by incising the skin with small pieces of glass, without inserting coloring-matter, the cicatrix being whiter than the sound skin." Some natives of Australia have ridges raised on this or that part of the body, while others brand themselves. In Tanna the people make elevated scars on their arms and chests. And Burton, in his "Abeokuta," says: "The skin-patterns were of every variety, from the diminutive prick to the great gash and the large, boil-like lumps. . . . In this country every tribe, sub-tribe, and even family, has its blazon, whose infinite diversifications may be compared with the lines and ordinaries of European heraldry—a volume would not suffice to explain all the marks in detail." Naturally, among the various skin-mutilations originating in the way alleged, many will, under the promptings of vanity, take on a character more or less ornamental; and the use of them for decoration will often survive when their meaning has been lost.

Hypothesis apart, we have proof that these marks made by cutting gashes, or puncturing lines, or raising welts, or otherwise, are in many cases tribal marks—as they would, of course become if they were originally made when binding themselves by blood to the dead founder of the tribe. A clear exhibition of the feeling implied by the bearing of marks is contained in a statement Bancroft makes respecting the Cuebas of Central America: "If the son of a chief declined to use the distinctive badge of his house, he could, when he became chief, choose any new device he might fancy. A son who did not adopt his father's totem was always hateful to him during his lifetime." And if the refusal to adopt the family-mark where it is painted on the body is thus regarded as a kind of disloyalty, equally will it be so when the mark is one that has arisen from modified lacerations; and such refusal will be tantamount to rebellion where the mark signifies descent from, and submission to, some great father of the race. Hence, then, the meaning of such facts as the following: "All these Indians," says Cieza of the ancient Peruvians, "wear certain marks by which they are known, and which were used by their ancestors. . . . Both sexes of the Sandwich-Islanders have a particular mark (tattooed) which seems to indicate the district in which, or the chief under whom, they lived." Of the Uaupes, "one tribe, the Tucános, are distinguished from the rest by three vertical blue lines on the chin."

That a special form of tattooing becomes a tribal mark in the way suggested, we have, indeed, some direct evidence. Among sundry mutilations undergone as funeral-rites, at the death of a chief among the Sandwich-Islanders, such as knocking out teeth, cutting the ears, cutting hair, etc., one is tattooing a spot on the tongue. Here we see this mutilation acquiring the signification of allegiance to a ruler who has died; and then when the deceased ruler, unusually distinguished, is apotheosized, the tattoo-mark becomes the sign of obedience to him as a deity. "With several Eastern nations," says Grimm, "it was a custom to mark one's self by a burned or incised sign as adherent to a certain worship. . . . Philo complains of his country-people in this respect." It was thus with the Hebrews. Bearing in mind the above-quoted interdict against marking themselves for the dead, we shall see the meaning of the words in Deuteronomy—"They have corrupted themselves, the spot is not the spot of his children: they are a perverse and crooked generation." And that such contrasted spots as are here referred to were understood in later times to imply the service of different deities is suggested by passages in Revelation, where an angel is described as ordering delay "till we have sealed the servants of our God in their foreheads," and where "an hundred and forty and four thousand, having his Father's name written in their foreheads," are described as standing on Mount Sion, while an angel proclaims that, "if any man worship the beast and his image, and receive his mark in his forehead, or in his hand, the same shall drink of the wine of the wrath of God." Down to the present day in the East like marks have like meanings. Thomson, after specifying the method of tattooing, says: "This practice of marking religious tokens upon the hands and arms is almost universal among the Arabs of all sects and classes. Christian pilgrims to Jerusalem have the operation performed there, as the most holy place known to their religion." And still more definite is the statement of Kalisch, that "Christians in some parts of the East, and European sailors, were long in the habit of marking, by means of punctures and a black dye, their arms and other members of the body with the sign of the crucifix or the image of the Virgin; the Mohammedans mark them with the name of Allah." So that down to our own time among advanced races we trace in these skin-mutilations meanings like those avowedly given to them in ancient Mexico, where, when a child was dedicated to Quetzalcohuatl, "the priest made a slight cut with a knife on its breast, as a sign that it belonged to the cult and service of the god," and, like those still avowedly given to them by negroes in Angola, where in many regions every child as soon as born is tattooed on the belly, in order thereby to dedicate it to a certain fetich.

A significant group of evidences must be added. We have seen that, where cropped hair implies servitude, long hair becomes an honorable distinction; that, shorn beards being marks of subordination, unshorn beards are marks of supremacy; and that, occasionally, in opposition to circumcision, as associated with subjection, there is absence of it along with the highest power. Here we have a parallel antithesis. The great divine chief of the Tongans is unlike all other men in Tonga, not only as being uncircumcised, but also as being untattooed. Elsewhere classes are sometimes thus distinguished. Burton says of the people of Banza Nokkoi, on the Congo, that those who are tattooed "are generally slaves." And in this relation there may be significance in the statement of Boyle that "the Kyans, Pakatans, and Kennowits, alone in Borneo practise tattooing, and these are the three aboriginal races least esteemed for bravery." Not, however, that distinctions implied by tattooing and its absence are at all regular: we here meet with anomalies. Though in some places showing social inferiority, tattooing in other places is a trait of the superior. While in Feejee only the women are tattooed—while in Tahiti there is tattooing of both men and women, in the Sandwich Islands the men are more tattooed than the women. Sometimes the presence of this skin-mutilation is evidence of high rank. "In the province of Panuco, the noblemen were easily to be distinguished, as they had their bodies tattooed." But the occurrence of anomalies is not surprising. During the perpetual overrunnings of race by race, it must sometimes have happened that, an untattooed race having been conquered by one which practised tattooing, the presence of these markings became associated with social supremacy. Moreover, since, along with dispersions of tribes and obscurings of their traditions, the meanings of mutilations will often die, while they themselves survive, there may not unnaturally occur developments of them for purposes of display, tending to reverse their original significance; as seems implied by the statement of Angas that "tattooing is a class distinction among the New-Zealanders; the faces of slaves have not the spiral tattooing;" or that of Dobrizhoffer, that "every Abiponian woman you see has a different pattern on her face. Those that are most painted and pricked you may know to be of high rank and noble birth."

But a further cause exists for this conflict of meanings. There remains to be named a species of skin-mutilation having another origin and different implication.

Besides scars resulting from lacerations made in propitiation of dead relatives, dead chiefs, and deities, there are scars resulting from wounds received in battle. The presence of many such implies many conflicts with enemies; and hence, all the world over, they are held in honor and displayed with pride. The sentiment associated with them among ourselves in past times is indicated in Shakespeare by sundry references to "such as boasting show their scars." Lafeu says, "A scar nobly got, or a noble scar, is a good livery of honor;" and Henry V. foretells of an old soldier that "then will he strip his sleeve and show his scars."

Animated as are savages in still higher degrees than civilized by the feelings thus indicated—having no other kind of honor than that derived from the reputation for bravery—what may be expected to result? Will not the anxiety to bear honorable scars sometimes lead to the artificial making of scars? We have evidence that it does. Lichtenstein tells us that the priest among the Bechuanas makes a long cut in the skin from the thigh to the knee of each warrior who has slain some of the enemy in battle. There is a kindred usage among the Bachapin Caffres. Among the Damaras, "for every wild animal that a young man destroys, his father makes four small incisions on the front of the son's body as marks of honor and distinction." And then Tuckey, speaking of certain Congo people who make scars, says that this is "principally done with the idea of rendering themselves agreeable to the women:" a motive which is intelligible if such scars originally passed for scars got in war, and implying bravery. American races yield some evidence of like meaning. We read that "the Itzaex Indians [in Yucatan] have handsome faces, though some of them were marked with lines as a sign of courage." Facts furnished by other American tribes suggest that the infliction of torture on entering maturity originated from the habit of making scars artificially in imitation of scars bequeathed by battle. If self-injury to avoid service in war has in all times been frequent among those lacking courage, we may reasonably infer that among the more courageous, who have received no wounds, self-injury might be not unfrequent, where there was gained by it that character for bravery desired above everything. Though at first secret and exceptional, the reputation achieved might make it gradually more common and at length general; until, finally, public opinion, vented against those who did not follow it, made the usage peremptory. When we read in Dobrizhoffer that, among the Abipones, "boys of seven years old pierce their little arms in imitation of their parents, and display plenty of wounds," we are shown the rise of a feeling, and a consequent practice, which, growing, may end in a system of initiatory tortures at manhood. Hence, when of the Arawaks Schomburgk tells us that after a Mariquarri dance the blood will be running down their swollen calves, and strips of skin and muscle hang down the mangled limbs, we may suspect that in this and kindred self-mutilations we see an outcome of the ambition to bear honorable scars. Though, when the scars, being borne by all, are no longer distinctive, discipline in endurance comes to be the reason given for inflicting them, this cannot well have been the original reason; since primitive men, improvident in all ways, are very unlikely to have deliberately devised and instituted a usage with a view to a foreseen distant benefit: the assumption of anything like a legislative act is inadmissible.

However this may be, we have here a second origin for certain kinds of mutilations. And hence a probable reason why markings on the skin, though generally badges of subordination, become in some cases honorable distinctions and occasionally signs of rank.

Something must be added concerning a secondary motive for mutilation; parallel to, or sequent upon, a secondary motive for taking trophies.

In the last chapter we inferred that, prompted by his belief that the spirit pervades all parts of the corpse, the savage preserves relics of dead enemies partly in the expectation that he will be enabled thereby to coerce their spirits—if not himself, still by the help of the medicine-man. He has a parallel reason for preserving a part cut from one whom he has enslaved: both he and the slave think that he so obtains a power to inflict injury. When we find that the sorcerer's first step is to procure some hair or nail-parings of his victim, or else some piece of his dress pervaded by that odor which is identified with his spirit, it appears to be a necessary corollary that the master who keeps by him the tooth of a slave, a joint of his finger, or even a lock of his hair, thereby retains a power of delivering him over to the necromancer, who may bring on him one or other fearful evil—torture by demons, disease, death.

Thus it seems possible that, where the part cut off is preserved, mutilation has a secondary governmental effect. The subjugated man is made obedient by a dread akin to that which Caliban expresses of Prospero's magically-inflicted torments.

The evidence that bodily mutilation of the living has been a sequence of trophy-taking from the dead, is thus at once abundant and varied. As the taking of the trophy implies victory carried even to the death, the derived practice of cutting off a part from the living prisoner comes to imply subjugation; and eventually the voluntary surrender of such a part expresses submission, and becomes a propitiatory ceremony because it does this.

Hands are cut off from dead enemies; and, answering to this, besides some identical mutilations of criminals, we have the cutting-off of fingers or portions of fingers, to pacify living chiefs, deceased persons, and gods. Noses are among the trophies taken from slain foes; and we have loss of noses inflicted on prisoners, on slaves, on transgressors of certain kinds. Ears are brought back from the battle-field; and occasionally they are cut off from prisoners, criminals, or slaves; while there are people among whom pierced ears mark the servant or the subject. Jaws and teeth, too, are trophies; and teeth, in some cases knocked out in propitiation of a dead chief, are, in various other cases, knocked out by a priest as a quasi-religious ceremony. Most prevalent and complete is the evidence furnished by mutilation of the hair. Scalps are taken from killed enemies, and sometimes their hair is used to decorate a victor's dress; and then come various sequences. Here the enslaved have their heads cropped; here scalp-locks are worn subject to a chief's ownership, and these are demanded in sign of submission; while, elsewhere, men are shorn of their beards to ornament the robe of a superior: unshorn hair being thus rendered a mark of rank. Among numerous peoples, hair is sacrificed to propitiate the ghosts of relatives; whole tribes cut it on the deaths of their chiefs or kings; it is yielded up to express subjection to deities; occasionally it is offered to a living superior in token of respect; and this complimentary offering is extended to others. Similarly with genital mutilations, there is a like taking of parts from slain enemies and from living prisoners; and there is a presentation of them to kings and to gods. Nor is it otherwise with mutilations of another class. Self-bleeding, initiated partly, perhaps, by cannibalism, but more extensively by the mutual giving of blood in pledge of loyalty, enters into several ceremonies expressing subordination: we find it occurring in propitiation of ghosts and of gods, and occasionally as a compliment to living persons. Naturally it is the same with the resulting marks. Originally indefinite in form and place, but rendered definite by custom, and at length often decorative, these healed wounds, at first entailed only on relatives of deceased persons, then on all the followers of a man who was much feared while alive, so became marks expressive of subjection to a dead ruler, and eventually to a god: thus growing into tribal and national marks.

If, as we have seen, trophy-taking as a sequence of conquest enters as a factor into those governmental restraints which conquest initiates, it is to be inferred that the mutilations originated by trophy-taking will do the like. The evidence justifies this inference. Beginning as marks of personal slavery, and becoming marks of political and religious subordination, they play a part like that of oaths of fealty and pious self-dedications. Moreover, being public acknowledgments of submission to a ruler, visible or invisible, they enforce authority by making conspicuous to all eyes the extent of his sway. And where they signify class-subordination, as well as where they show the subjugation of criminals, they further strengthen the hands of the regulative agency.

If mutilations originate as alleged, we may expect to find some connection between the extent to which they are carried and the social type as simple or compound, militant or industrial. On grouping the facts as presented by fifty-two peoples, the connection emerges with as much clearness as can be expected. In the first place, since the development of mutilation as a custom goes with conquest, and resulting aggregation, it is inferable that simple societies, however savage, will be less characterized by it than the larger savage societies compounded out of them, and less than even the semi-civilized societies. This proves to be true. Of peoples who form simple societies that practise mutilation either not at all or in slight forms, I find, among races wholly unallied, eleven—Fuegians, Veddahs, Andamanese, Dyaks, Todas, Gonds, Santals, Bodo and Dhimals, Mishmis, Kamtchadales, Snake Indians; and these are characterized throughout either by absence of chieftainship, or by chieftainship of an unsettled kind. Meanwhile, of peoples who mutilate little or not at all, I find but two in the class of compound societies; of which one, the Kirghiz, is characterized by a wandering life that makes subordination difficult, and the other, the Iroquois, had a republican form of government. Of societies practising mutilations that are moderate, the simple are relatively fewer, and the compound relatively more numerous: of the one class there are ten—Tasmanians, Tannese, New Guinea people, Karens, Nagas, Ostiaks, Esquimaux, Chinooks, Comanches, Chippewyans; while of the other class there are five—New-Zealanders, East Africans, Khonds, Kukis, Calmucks. And of those it is to be remarked that in the one class the simple headship, and in the other class the compound headship, is unstable. On coming to the societies distinguished by severer mutilations, we find these relations reversed. Among the simple I can name but three—the New Caledonians (among whom, however, the severer mutilation is not general), the Bushmen (who are believed to have lapsed from a higher social state), and the Australians (who have, I believe, similarly lapsed); while, among the compound, twenty-one may be named—Feejeeans, Sandwich-Islanders, Tahitians, Tongans, Samoans, Javans, Sumatrans, Malagasy, Hottentots, Damaras, Bechuanas, Caffres, Congo people, coast negroes, inland negroes, Dahomans, Ashantees, Fulahs, Abyssinians, Arabs, Dakotas. Social consolidation being habitually effected by conquest, and compound and doubly-compound societies being, therefore, during early states, militant in their activities and types of structure, it follows that the connection of the custom of mutilation with the size of the society is indirect, while that with its type is direct. And this the facts show us. If we put side by side those societies which are most unlike in respect of the practice of mutilation, we find them to be those which are most unlike as being wholly unmilitant in organization, and wholly militant in organization. At the one extreme we have the Veddas, Todas, Bodo and Dhimals; while, at the other extreme, we have the Feejeeans, Abyssinians, ancient Mexicans.

Derived from trophy-taking, and developing with the development of the militant type, it is to be anticipated that mutilations decrease as fast as the societies consolidated by militancy become less militant, and disappear as the industrial type of structure evolves. That they do so European history at large may be assigned in proof. And it is significant that in our own society, now predominantly industrial, such slight mutilations as continue are connected with that regulative part of the organization which militancy has bequeathed: there survive only the now-meaningless tattooings of sailors, the branding of deserters, and the cropping of the heads of felons.

THE EUCALYPTUS IN THE FUTURE.

By Professor SAMUEL LOCKWOOD.

A LITERARY venture of our boyhood comes upon us like the aroma of tropical fruit eaten for the first time. An uncle had given his eight-year-old favorite a silver sixpence. Never before had the youngling possessed so much money in his own right. Soon the young capitalist found himself confronting the shop-window of the nearest stationer, where his eyes became riveted to a little book—"Life and Voyages of La Pérouse," price sixpence. The book was eagerly bought, and it proved an exciting *morceau*. This same Jean François de Galaup, Count de la Pérouse, when about thirty-seven years old, served in the American Revolution. In 1782 he led a small fleet into Hudson Bay, and destroyed the English trading-post. But Louis XVI. found that, while he had been helping to wrest the colonies from Great Britain, she was adding to herself new glory, and vast territories, by the discoveries of her great navigator, Captain Cook. So the French monarch dispatched La Pérouse, with two ships, on a mission of exploration in the Pacific. Neither the bold navigator nor any of his men saw home again. The last known of the expedition was from a letter written by La Pérouse at Botany Bay, February 7, 1788. Three years after, a French squadron was sent to search for the great *voyageur*, but in vain. With this expedition went as naturalist the famous botanist La Billardière. In Tasmania he found the most extraordinary arboreal flora he had ever seen. Especially wonderful for number and size was one tree, to which he gave the generic name *Eucalyptus*, meaning "well-covered," alluding to the singular form of the flower-bud, which has on it an operculum or cover not unlike the lid of a tiny sugar-bowl (see the object between the flower and the fruit at foot of Fig. 3). Thus the unexpanded flower-bud, being cup-like below and cone-like at top, was not dissimilar in form to the globular brass button formerly in vogue, and so the blue-gum received from this botanist the specific name *globulus*.

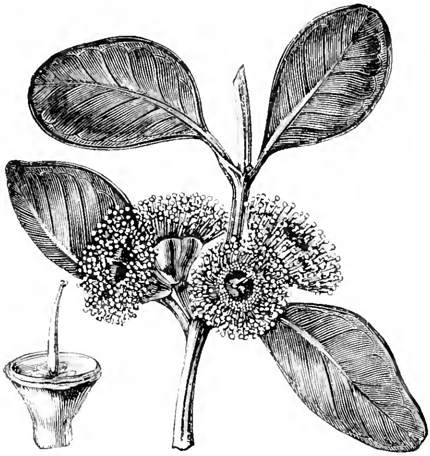

FIG. 1.—EUCALYPTUS PREISSIANA.

"One tree of the future—one of hope," says Prof. Flückiger, "may be recognized in *Eucalyptus globulus*." And the prophecy is advancing to fulfillment, for already the eucalypt is becoming a cosmopolitan tree. It was discovered by La Billardière on the south of the island of Tasmania, near Entrecastenaux Channel, May 6, 1792. But, though soon after known to science, not until 1856 was it known to the arboriculturists of the Old World. In that year M. Ramel sent seeds from Melbourne to Paris. In 1857, and again in 1860, larger supplies arrived, which, being distributed, found their way over a great part of the civilized world. Of the many varieties of eucalypts, the blue-gum, or *Eucalyptus globulus*, was the first to be introduced into Europe; hence, perhaps, it may yet appear that the best variety for acclimatization has not received proper attention. The *Eucalyptus globulus* is only found in Tasmania and Victoria, but where found it is really the monopolist of the woods. The forest area of Victoria, the most southern colony of Australia, contains 73,000 square miles of forest, of which 71,500 is almost wholly of eucalypts. And so great is the diversity of these trees among themselves, that some one hundred and fifty varieties are recognized. This gave marked interest to the exhibits of the Australian colonies and Tasmania in the Philadelphia Exposition. But to the student of human progress a noteworthy fact was, that this *Eucalyptus* figured in the contributions of nations to whom the seed even was unknown twenty years ago. Eucalyptus woods, leaves, oils, essences, gums, etc., formed items in the exhibits from the south and the north of Africa, the Cape Colony and Algeria; the Orange Free State, Southern Europe, notably France and Italy, Brazil, the pampas of South America, Mexico, California, Jamaica, and even India, could have competed. Hence it would be no fiction to pronounce to-day that the *Eucalyptus* is the cosmopolitan tree.

But our subject is interesting to three kinds of observers—the economist, or utilitarian, the botanist, and the geologist. Let us ask of each one a free-hand sketch.

The first, who is a matter-of-fact personage, adduces the *economic* uses of these gum-trees, as the Eucalypts are frequently called. When freshly cut the wood of these trees is soft, but so full is it of a resinous gum that it soon hardens, and becomes wellnigh imperishable. For ships, and docks, and jetties, it is invaluable. The terrible *Teredo navalis*, or ship-worm, lets it alone. It is proof also against that fearful scourge the termites, or white ant. Hence, in India, eucalyptus-wood is used for the sleepers of the railroads, where it defies the insects and the climate. So great is the variety of the eucalypts, that they are provident for nearly every purpose which wood can subserve. The ship-builder, wheelwright, carpenter, coach-maker, and cabinet-makers, are all supplied. Usually the eucalypts are evergreens, and hold tenaciously to their leaves. But they readily shed their bark, as a rule, and in such immense pieces can this be detached that the natives make a rude tent of a single piece. Of many species the bark is serviceable for paper-making. For size no trees can equal these Australian gums in the magnitude of the timber afforded. A plank sent from Victoria, and intended for the London Exhibition, but which arrived too late, sold for £100. It was a clear plank, over 223 feet long, two feet six inches wide, and three inches thick. But, though excellent timber, some of the species are of little worth for fuel. In these the wood burns with such difficulty that it is regarded as specially suited for shingles.

These gum-trees are the Titans of the race. In the deep ravines of Dandenong, in Victoria, a *Eucalyptus amygdalina* measured 420 feet; while another, on the Black Spur, measured 480 feet, thus overtopping greatly the Pyramid of Cheops and every human achievement, and even beating by 155 feet the famous *Sequoia gigantea* (Torrey) ("Keystone State"), the biggest of the "big trees" of the Calaveras grove. Mr. G. W. Robinson found a eucalypt, which, at the height of four feet from the ground, had a girth of 81 feet, or 27 feet diameter. It is notable, too, that for amount of timber per acre these gum-trees are unmatchable. We read that, in one of the densest parts of the Mount Macedon state forest, an acre of *Eucalyptus fissilis* contained forty-two large standing trees and twelve saplings. Many of the largest of these trees were from six to seven feet in diameter four feet from the ground, and were from 200 to 220 feet high. Nor do such altitudes necessarily indicate a very high antiquity. The rapidity of growth is wonderful. Saplings fifty feet high, and but ten years old, are not remarkable. It is declared that seed sown in Jamaica at an elevation of 5,000 feet, in 1870, had in 1876 attained a growth of fifty feet. We have with our own eyes witnessed throughout an entire summer a growth of an inch a day. No one understood so well as Baron von Müller the nature and capacities of the *Eucalyptus*. He more than all others has made the world acquainted with it. With him was a scientific faith that this was the world's tree of promise. In this tree of Australia he saw the means with which to obliterate from the hydrographic map the rainless zones, to clothe with wood the desolate ranges of Tunis, Algeria, and Morocco, and render habitable parts of the Great Sahara, by indefinitely expanding the oases, to restore fertility to the Holy Land, to give rain to the Asiatic plateau, or the desert of Atacama, and furnish timber and fuel to Natal and La Plata.

None better than the baron, however, knew that, while able to stand great heat, these rapidly-growing eucalypti cannot resist great cold, and without these home conditions we must not expect of them their home achievements. Even at home the tribe does its best with its semi-tropical members. And there is a great range of variety until we meet even the Alpine species, of slow growth and very modest altitude. Skill and patience may do much; but in our country, except in a few favored spots, little can be hoped of the semi-tropical varieties north of latitude 30°, until acclimatization shall have been effected.

But it is claimed for the eucalypts that their presence is hygienic, or sanatory, especially in malarial regions. That the *E. globulus* has earned by fair experiment its name of fever-tree, as a preventive, seems now to be settled. Its rapid growth must make it a great drainer of wet soils, while its marked terebinthine odor may have its influence, and it is highly probable that the liberation of this essence into the air stands connected with its generation of ozone. But, whatever the sanatory activities of the eucalypt may be, the fact is squarely settled that spots in Italy, uninhabitable because of malarial fever, have been rendered tolerable by the planting of *E. globulus*, and it is believed that a more plentiful planting would nearly if not quite remove the difficulty. A military post is mentioned in Algeria, in which the garrison had to be changed every five days, such was the virulence of the malaria. A plantation of eucalypts cleared the miasma nearly away, and rendered unnecessary the frequent changes of the garrison. In this case 60,000 trees were planted.

But the eucalyptus has not a few medicinal virtues. Its oils and essences are antiseptic. Diffused in the sick-room, they purify the air and generate ozone. Already they have taken their places in the materia medica as very important internal medicines. The leaves contain the essence *eucalyptol*, and a resinous solid containing a bitter principle not yet understood, and which seems to afford the antifebrile virtue; hence an extract from the leaves, either aqueous or alcoholic, is used as a febrifuge. As a tonic, water may be aromatized by a slight infusion of the leaves. A liquor similar to that of mastic can be produced, and the pharmacy gives instructions for making a tonic eucalyptal wine. Some of the species are tapped for the sap, and gum-tree cider is obtained; the leaves of others yield manna. The famous East India kino of commerce, obtained from the *Pterocarpus marsupium*, a lofty legume growing on the mountains of India, now finds a rival in the Botany Bay kino, the concrete juice of the brown gum-tree (*Eucalyptus resinifera*), of which it is said that a single tree is capable of furnishing 500 pounds of kino in a year. In a word, in the modern pharmacopœia, eucalyptus, with its many preparations, occupies considerable space. A very interesting instance of what the therapeutist calls "masking" is an application of the oil of eucalypt for the deodorizing and aromatizing of cod-liver oil, thus rendering palatable and even additionally tonic this repulsive medicine.

At the Intercolonial Exhibition of 1866, in Australia, Baron von Müller caused to be exhibited, as from the Phyto-Chemical Laboratory of Victoria, tannic acid, gallic acid, pure wood-spirits, pure acetic acid, distilled wood-vinegar, and other products, obtained from several species of eucalyptus. Mr. Bosisto, a chemist of Victoria, sent to the Philadelphia Exhibition the following products of the one species (*E. globulus*): Essential oil—a tonic, stimulant, antiseptic, anthelmintic; eucalyptol, for inhalation in bronchial or throat affections; eucalyptic acid; liquor of eucalyptus globulus—stimulant in ague or low fever; tincture of eucalyptus globulus—stimulant, tonic, antiperiodic; powder of eucalyptus globulus—antiseptic, cataplasma; cigarettes of eucalyptus globulus—disinfectant, employed in bronchial or asthmatic affections. But many mysteries are waiting solution in the laboratory of the pharmacist. New substances are to be discovered, and those already known will be better understood; all which revealings will be as new fruits on this tree of the future.

But let us hear the botanist's story. He says the thing has been a good deal of a bother to him; that he thought these gum-trees of Australia were pretty much like the animals there, specimens of Nature's jokes. Indeed, we find a recent authority saying, "Nine-tenths of the 8,000 species of plants in Australia are unknown elsewhere, and entirely unconnected with the forms of vegetation of any other division of the world." And then to think of the great variety of forms in this one genus, *Eucalyptus*. In one the leaves, six or seven inches long, are but a quarter of an inch wide, almost grass-like; while the leaves of the messmate, or *E. amygdalina*, are almond-shape, and nearly as wide as they are long. Those of *E. Preissiana* are bluntly rounded at the ends (Fig. 1), while the big-berry-gum-tree, *E. macrocarpa* (Fig. 2), has wide leaves with mucronate points. Compare these with the outline Fig. 3 of *E. globulus*, with its sickle-shaped leaves, ten inches long, in the specimen from which this was sketched. Alluding to the difficulty in defining the species, Woolls says, "Botanists, from Robert Brown to Baron Müller, have endeavored to reduce the varying forms to systematic arrangement," but without success. And a vast amount of acumen and ingenuity has been brought to the task; such as the consideration of the operculum or cap of the flower-bud, and the length of the pistil. Compare the long pistil in the seed-vessel of *E. Preissiana*, left side of Fig. 1, with the short one in the

FIG. 2.—EUCALYPTUS MACROCARPA.

flower of *E. Globulus*, in Fig. 3. The form of the anthers and the seed-vessels, and the texture of the bark, have all been taken as factors of the problem.

Owing to the bluish-green of its leaves, *E. globulus* is popularly known as the blue-gum tree. Abroad it is most known outside of its systematic name as the Tasmanian gum-tree, and Australian fever-tree. Among the settlers, gum-tree is the general name of the eucalypts. But, as might be expected of a genus so numerous in species, there are many trivial names, such as blue-gum, brown-gum, the red and the white mahogany, stringy-bark, and iron-bark, etc. The botanists reckon 150 varieties. These all belong to the great order *Myrtaceæ*, or myrtle-blooms. And a decidedly respectable relationship have these trees which shed "their medicinal gum," for they are close cousins to the well-known myrtle, the pomegranate, pimento, or allspice, cajeput, and clove. The flowers of this order are known in their structure as calycifloral. Perhaps this curious blending, or confusion, of the calyx and the corolla, is shown most interestingly in the flowers of these eucalypts. The calyx is really in two distinct parts, a woody cup below with an operculum or lid above. (*See* middle figure, bottom of cut 3.) When the flower is ready to open it pushes up, and thrusts off the calyx-cover, which falls to the earth, carrying with it the dubious corolla, which is intimately united to it on its inside. Thus, what is left is the lower part of the calyx, which is really a woody cup, with its pistillate organs in the centre. But, though a cup-like body, it has four rib-like markings on the outer side, which

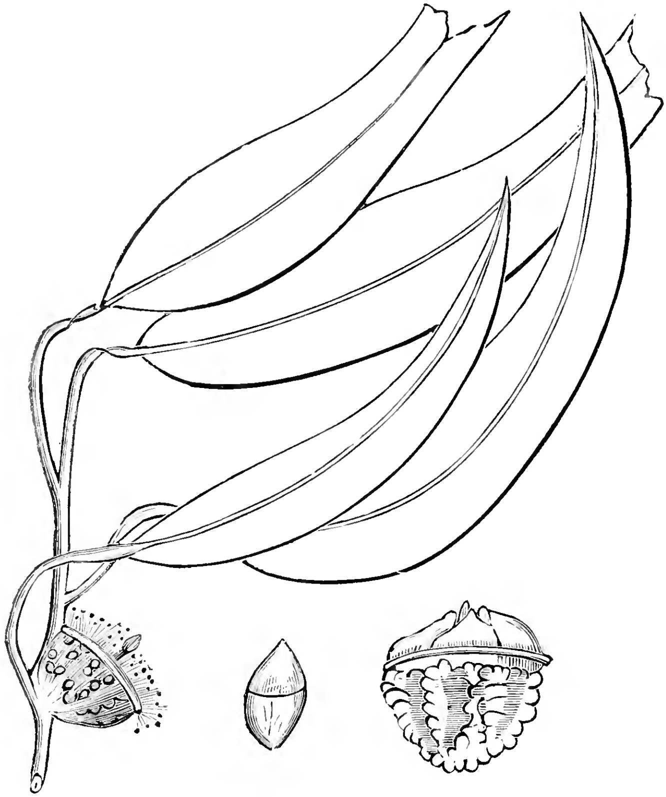

Fig. 3.—Eucalyptus Globulus: Adult Leaves, Flower, Bud, and Fruit.

plainly indicate the sepaloid divisions. Look at the fruit, or seed-capsule, which is given about the natural size at the bottom and to the right of Fig. 3. Bristling from the inner rim or edge of the calyx, stand the thread-like stamens, each with its golden anthers atop, making a showy display for what would otherwise be, from its extreme simplicity, a very unhandsome flower.

The growth of the young eucalypt affords some points of strange interest. There is the rapidity of growth of the three species which have been best tried, and which certainly will figure largely as the world's future timber-trees: *E. globulus*, the blue-gum; *E. gigantea*, the stringy-bark; and *E. amygdalina*, the messmate, or peppermint-tree.

The one best known in experiments at acclimatizing is the blue-gum. We have followed its growth from seeds planted by ourselves. Last October we saw in the back-yard of Dr. R. E. Kunzè, of this city, a eucalypt scarcely a year old, and over twelve feet in height. For four or five months it averaged an inch a day. Blue-gums but seven years from the seed have been known to reach a height of sixty-five feet, with a girth of stem near the ground of forty-five inches.

But, for all this rapidity of growth, the young eucalypt seems to be doggedly resolved that for some years at least it shall resemble its parent in no particular save one, namely, the aromatic odor of its leaves.

Suppose we compare Figs. 3 and 4, the one representing a young eucalypt, and the other an adult—that is, one old enough to bear flowers and seeds. Notice the stem of the young tree, Fig. 4, that it

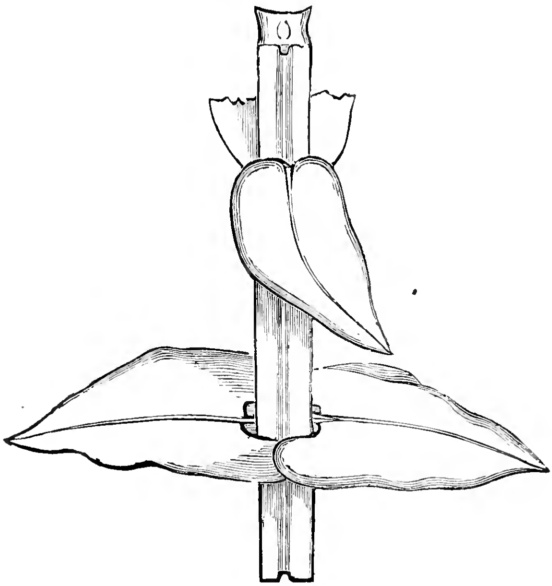

Fig. 4.—Eucalyptus Globulus: a Young Tree.

is square, or four-sided, like those of the labiates, or Mint family of plants. On each side of this square stem is a depression, within which the leaf is attached, which, technically, may be said to be amplexicaul, or embracing, as it half surrounds the stem, and this at some disadvantage, since the attachment is not at the angle, but flush upon the side of the stem. The leaf is sessile, having no appreciable petiole or foot-stalk. And the leaves are opposite, so that each pair is set at right angles, or crosswise to the pair next below it or next above it. And the leaves are cordate, or heart-shaped, being deeply notched at the base, so that the lobes of one leaf lap over or lie upon the lobes of the other, thus appearing at first sight, by deception, like the perfoliate leaves on the upper part of a honeysuckle. Each leaf, too, has its upper and its lower plane, the upper one being exposed to the sunlight, and the under one being kept in the shade. The two sides of the leaf differ physiologically, as the stomata, or breathing-organs, are on the under side of the leaf. The leaves, too, of the young eucalypt are bright, grassy green; they are also thin, and the tissue soft and somewhat succulent.

Now, not one of these particulars is carried into the maturity of the tree. Perhaps, in its enlarged arboreal wisdom, the big gum-tree eschews them all as the indiscretions of its youth. So the labiate character, or four-sidedness, gives place to a round stem. The leaves are now not amplexicaul, but stand well out from the branch-stems, and sometimes even hang suspended. They have now long petioles, or leaf-stems. In fact, as against the former sessile character of the leaf, the difference is almost forced to the point of exaggeration, since in *E. globulus* the long-lanceolate leaf seems really an extension and expansion of the petiole, or leaf-stalk. The leaves are no longer opposite, but alternate, nor are they heart-shaped, but long-lanceolate, and often even falcate, or scythe-shaped. Their color is now not grass-green, but bluish-green, and the points are tipped with red. The tissue, too, is changed, for the leaves are thick, and leathery, and dry. Nor has the leaf now its sunny side and its shady side distinct—that is, the blade has no upper or lower plane, but an upper and a lower edge, the one edge being set toward the sky and the other toward the earth, thus exposing both planes equally to the sunlight. To accomplish this eccentric adjustment of the leaf, the petiole actually twists itself, as if it really knew what it was about—with, however, seemingly some of that discomfort which attends on strained etiquette. Often the twist or contortion is so evident as to arrest the attention at once; and the amount of torsion is wonderful when it is mentioned that the petiole seems to delight in holding the scythe-shaped leaf with its concave edge uppermost (Fig. 3). It is surely curious to find in the leaves of the adult tree the texture so different from that of the leaves of its youth. But the leaf is now the seat of a much greater physiological change. The two planes of the leaf are now virtually alike—the same in texture and in organs. The ribs and veins are the same, alike prominent on each side, much as if the roof of a house should have its beams and rafters inside and out. And two series of stomata, or breathing-organs, now appear—one series for each side of the leaf. Here, we think, lies much of the secret of the great draining capacity of the eucalypts. Both sides of the leaf work equally. It is as the double-cylinder engine against the single one. It is asserted of the gum-tree that it can eliminate from a swampy soil eight times its own weight of water in twenty-four hours.

What, then, is the logic of these facts? Let us give the geologist the last word; for it may be that, from his habit of dealing with the floras and the faunas of the long ago, his generalization may be more profound than that of the mere systematic botanist.

What about the eccentricities of the young eucalypt? Our mentor here denies the eccentricity in the sense of freakiness. He sees in it a law of the Creator. The young eucalypt, he thinks, in its marvelous vigor of growth, is tending to, or striving after, the forms and conditions of the higher and more recent groups; but that, with something of its growth-vigor abated in the adult state, it reverts back to its legitimate ancestral type. But we may not be too knowing; and surely a devout science can well afford to admit with reverence that "His ways are past finding out."

And this delver in the earth after organic relics assures us that these eucalypts are an extremely ancient race, and that they were formerly wide-spread. He even finds them in the Eocene times, composing in part the great forests of Europe. These, he tells us, were the arboreal ancestors of the gum-trees of Australia; and he bids us note that, of the existing floras of the world, that of Australia has the highest antiquity. With this instance, as almost paralleled, we may adduce the "big trees" of California. There can be no doubt that these gigantic and graceful trees once covered a large area, extending into an antiquity scarcely less ancient than that of the eucalypts. Even snow-clad Greenland in that ancient time had its flowery age, and was a home for the princely sequoias. Now, what reduced them to but two species, and what pushed them over the mountains, and bade them be content with that small domain centred by the Calaveras grove? And what a change must earth have undergone, that Australia should be isolated from its once-continental alliance, and these noble eucalypts, the tallest Titans that the world has known, should be thus put upon their limits! The sequoias promise little, and seem doomed ere long to pass away. Beyond their beauty and scientific interest, their virtues are few. Not so with the eucalypts. Give them a fair showing of place and climate, and they will thrive and enrich their environment. This tree has the hardiness of the ancient; it also has virtues which will enlarge the comforts and lengthen the days of men. As when some beneficent art, once enjoyed by a former people, has been lost, and, long known only in tradition, has been rediscovered and revived, and men are again enlivened with hope, so is the possession by the modern world of this ancient tree.

INTRODUCTION AND SUCCESSION OF VERTEBRATE LIFE IN AMERICA.[1]

By Professor O. C. MARSH.

[CONCLUDED FROM MARCH NUMBER.]

IT remains now to consider the highest group of the animal kingdom, the class *Mammalia*, which includes man. Of the existence of this class before the Trias we have no evidence, either in this country or in the Old World, and it is a significant fact that, at essentially the same horizon in each hemisphere, similar low forms of mammals make their appearance. Although only a few incomplete specimens have been discovered, they are characteristic and well preserved, and all are apparently Marsupials, the lowest mammalian group which we know in this country, living or fossil. The American Triassic mammals are known at present only from two small lower jaws, on which is based the genus *Dromatherium*, supposed to be related to the insect-eating *Myrmecobius*, now living in Australia.

Although the Jura of Europe has yielded other similar mammals, we have as yet none of this class from that formation; while, from rocks of Cretaceous age, no mammals are known in any part of the world. This is especially to be regretted, as it is evidently to the Cretaceous that we must look for the first representatives of many of our present groups of mammals, as well as for indications of their more ancient lineage. That some discovery of this nature from the Cretaceous is near at hand, I cannot doubt, when I consider what the last few years have brought to light in the Eocene.

In the lowest Tertiary beds of this country a rich mammalian fauna suddenly makes its appearance, and, from that time through the age of mammals to the present, America has been constantly occupied by this type of life in the greatest diversity of form. Fortunately, a nearly continuous record of this life, as preserved, is now accessible to us, and insures great additions to our knowledge of the genealogy of mammals, and perhaps the solution of more profound problems. Before proceeding to discuss in detail American fossil *Mammalia*, it is important to define the divisions of time indicated in our Tertiary and Post-Tertiary deposits, as these in many cases mark successive stages in the development of the mammals.

The boundary-line between the Cretaceous and Tertiary in the region of the Rocky Mountains has been much in dispute during the last few years, mainly in consequence of the uncertain geological bearings of the fossil plants found near this horizon. The accompanying

[1] An address delivered before the American Association for the Advancement of Science, at Nashville, Tenn., August 30, 1877, by Prof. O. C. Marsh, Vice-President.

invertebrate fossils have thrown little light on the question, which is essentially whether the great Lignite series of the West is uppermost Cretaceous or lowest Eocene. The evidence of the numerous vertebrate remains is, in my judgment, decisive, and in favor of the former view.

This brings up an important point in paleontology, one to which my attention was drawn several years since, namely: the comparative value of different groups of fossils in marking geological time. In examining the subject with some care, I found that, for this purpose, plants, as their nature indicates, are most unsatisfactory witnesses; that invertebrate animals are much better; and that vertebrates afford the most reliable evidence of climatic and other geological changes. The subdivisions of the latter group, moreover, and in fact all forms of animal life, are of value in this respect, mainly according to the perfection of their organization or zoölogical rank. Fishes, for example, are but slightly affected by changes that would destroy reptiles or birds, and the higher mammals succumb under influences that the lower forms pass through in safety. The more special applications of this general law, and its value in geology, will readily suggest themselves.

The evidence offered by fossil remains is, in the light of this law, conclusive, that the line, if line there be, separating our Cretaceous from the Tertiary, must at present be drawn where the Dinosaurs and other Mesozoic vertebrates disappear, and are replaced by the mammals, henceforth the dominant type.[1]

The Tertiary of Western America comprises the most extensive series of deposits of this age known to geologists, and important breaks in both the rocks and the fossils separate it into three well-marked divisions. These natural divisions are not the exact equivalents of the Eocene, Miocene, and Pliocene of Europe, although usually so considered, and known by the same names; but, in general, the fauna of each appears to be older than that of its corresponding representative in the other hemisphere; an important fact, not hitherto recognized. This partial resemblance of our extinct faunas to others in regions widely separated, where the formations are doubtless somewhat different in geological age, is precisely what we might expect, if, as was probable, the main migrations took place from this continent. It is better at once to recognize this principle, rather than attempt to bring into exact parallelism formations that were not strictly contemporaneous.

The fresh-water Eocene deposits of our Western Territories, which are in the same region at least two miles in vertical thickness, may be separated into three distinct subdivisions. The lowest of these, resting unconformably on the Cretaceous, has been termed the Vermilion Creek, or Wahsatch, group. It contains a well-marked mammalian

[1] *See* Frontispiece Section, March number.

fauna, the largest and most characteristic genus of which is the ungulate *Coryphodon*, and hence I have called these deposits the Coryphodon beds. The middle Eocene strata, which have been termed the Green River and Bridger Series, may be designated as the Dinoceras beds, as the gigantic animals of this order are only found here. The uppermost Eocene, or the Uintah group, is especially well characterized by large mammals of the genus *Diplacodon*, and hence may be termed the Diplacodon beds. The fauna of each of these three subdivisions was essentially distinct, and the fossil remains of each were entombed in different and successive ancient lakes. It is important to remember that these Eocene lake-basins all lie between the Rocky Mountains on the east and the Wahsatch Range on the west, or along the high central plateau of the continent. As these mountain chains were elevated, the inclosed Cretaceous sea, cut off from the ocean, gradually freshened, and formed these extensive lakes, while the surrounding land was covered with a luxuriant tropical vegetation, and with many strange forms of animal life. As the upward movement of this region continued, these lake-basins, which for ages had been filling up, preserving in their sediments a faithful record of Eocene life-history, were slowly drained by the constant deepening of the outflowing rivers, and they have since remained essentially dry land.

The Miocene lake-basins are on the flanks of this region, where only land had been since the close of the Cretaceous. These basins contain three faunas, nearly or quite distinct. The lowest Miocene, which is only found east of the Rocky Mountains, alone contains the peculiar mammals known as the *Brontotheridæ*, and these deposits may be called the Brontotherium beds. The strata next above, which represent the middle Miocene, have as their most characteristic fossil the genus *Oreodon*, and are known as the Oreodon beds. The upper Miocene, which occurs in Oregon, is of great thickness, and from one of its most important fossils, *Miohippus*, may be designated as the Miohippus Series. The climate here during this period was warm temperate.

Above the Miocene, east of the Rocky Mountains and on the Pacific coast, the Pliocene is well developed, and is rich in vertebrate remains. The strata rest unconformably on the Miocene, and there is a well-marked faunal change at this point, modern types now first making their appearance. For these reasons, we are justified in separating the Miocene from the Pliocene at this break; although in Europe, where no marked break exists, the line seems to have been drawn at a somewhat higher horizon. Our Pliocene forms essentially a continuous series, although the upper beds may be distinguished from the lower by the presence of a true *Equus*, and some other existing genera. The Pliocene climate was similar to that of the Miocene. The Post-Pliocene beds contain many extinct mammals, and may thus be separated from recent deposits.

Returning now to our subject from this geological digression—which will hardly be deemed unprofitable, since I have given you in few words the results of a great deal of my own hard mountain work—let us consider the Tertiary mammals, as we know them from the remains already discovered, and attempt to trace the history of each order down to the present time. We have seen that a single small Marsupial, from the Trias, is the only mammal found in all the American rocks below the Eocene; and yet in beds of this age, immediately over the Chalk, fossil mammals of many different kinds abound.

The Marsupials, strange to say, are here few in number, and diminutive in size; and have as yet been identified only by fragmentary specimens, and most of them are too imperfect for accurate description. In the higher Eocene deposits, this group is more abundant, but still represented by small animals, most of them insectivorous, or carnivorous in habit, like the existing opossum. From the Miocene and Pliocene, no remains of Marsupials have been described. From the Post-Tertiary, only specimens nearly allied to those now living are known, and most of these were found in the caves of South America.

The Edentate[1] Mammals are evidently an American type, and on this continent attained a great development in numbers and size. No Eocene Edentates have been found here, and, although their discovery in this formation has been announced, the identification proves to have been erroneous. In the Miocene of the Pacific coast, a few fossils have been discovered which belong to animals of this group, and to the genus *Moropus.* There are two species, one about as large as a tapir, and the other nearly twice that size. This genus is the type of a distinct family, the *Moropodidæ.* In the lower Pliocene above, well-preserved remains of Edentates of very large size have been found at several widely-separated localities in Idaho and California. These belong to the genus *Morotherium*, of which two species are known. East of the Rocky Mountains, in the lower Pliocene of Nebraska, a large species apparently of the genus *Moropus* has been discovered. The horizon of these later fossils corresponds nearly with beds in Europe that have been called Miocene. In the Post-Pliocene of North America, gigantic Edentates were very numerous and widely distributed, but all disappeared with the close of that period. These forms were essentially huge sloths, and the more important genera were *Megatherium*, *Mylodon*, and *Megalonyx.* The genera *Megalocnus* and *Myomorphus* have been found only in Cuba.

In South America, during the Pliocene or Post-Pliocene, enormous Edentates were still more abundant, and their remains are usually in

[1] The Edentates are an order of Mammals, in which the teeth are imperfect or wanting. The teeth when present are without enamel, or true roots. This order includes the sloths, armadilloes, ant-eaters, etc.

such perfect preservation as to suggest a very recent period for their extinction. The Sloth tribe is represented by the huge *Mylodon*, *Megatherium*, *Megalonyx*, *Cœlodon*, *Ochotherium*, *Gnathopis*, *Lestodon*, *Scelidotherium*, and *Sphænodon;* and among the Armadilloes were *Chlamydotherium*, *Eurydon*, *Glyptodon*, *Heterodon*, *Pachytherium*, and *Schistopleurum*. *Glossotherium*, another extinct genus, is supposed to be allied to the Ant-Eaters.

It is frequently asserted, and very generally believed, that the large number of huge *Edentata* which lived in North America during the Post-Pliocene were the results of an extensive migration from South America soon after the elevation of the Isthmus of Panama, near the close of the Tertiary. No conclusive proof of such migration has been offered, and the evidence, it seems to me, so far as we now have it, is directly opposed to this view. No undoubted Tertiary Edentates have yet been discovered in South America, while we have at least two species in our Miocene, and, during the deposition of our lower Pliocene, large individuals of this group were not uncommon as far north as the forty-third parallel of latitude, on both sides of the Rocky Mountains. In view of these facts, and others which I shall lay before you, it seems more natural to conclude, from our present knowledge, that the migration, which no doubt took place, was from north to south. The Edentates, finding thus in South America a congenial home, flourished greatly for a time, and, although the larger forms are now all extinct, diminutive representatives of the group still inhabit the same region.

The *Cetacea*[1] first appear in the Eocene, as in Europe, and are comparatively abundant in deposits of this age on the Atlantic coast. The most interesting remains of this order, yet found, belong to the *Zeuglodontidæ*, which are carnivorous whales, and the only animals of the order with teeth implanted by two roots. The principal genera of this family are *Zeuglodon* and *Squalodon*, the former genus being represented by gigantic forms, some of which were seventy feet in length. The genus *Saurocetes*, which includes some small animals of this group, has been found in South America. The Dolphin family (*Delphinidæ*) are well represented in the Miocene, both on the Atlantic and Pacific coast. The best-known genus is *Priscodelphinus*, of which several species have been described. Several other generic names which have been applied to fragments need not here be enumerated. In none of the Tertiary species of this family were the cervical vertebræ anchylosed. The Sperm Whales (*Catodontidæ*) were also abundant throughout the Tertiary, and with them, in the earlier beds, various Ziphioid forms have been found. The toothless *Balænidæ* are only known with certainty as fossils from the later Tertiary and more recent deposits.

[1] *Cetacea*, an order of marine mammals which includes among its living representatives the whales, dolphins, porpoises, narwhal, etc.

The Sirenians,[1] which appear first in the Eocene of the Old World, occur in the Miocene of our eastern coast, and throughout the later Tertiary. The specimens described have all been referred to the genus *Manatus*, and seem closely related to our living species. In the Tertiary of Jamaica, a skull has been found which indicates a new genus, *Prorastomus*, also allied to the existing manatee. The genus *Rhytina*, once abundant on our Northwest coast, has recently become extinct.

The Ungulates[2] are the most abundant mammals in the Tertiary, and the most important, since they include a great variety of types, some of which we can trace through their various changes down to the modified forms that represent them to-day. Of the various divisions in this comprehensive group, the Perissodactyle, or odd-toed Ungulates, are evidently the oldest, and throughout the Eocene are the prevailing forms. Although all of the Perissodactyles of the earlier Tertiary are more or less generalized, they are still quite distinct from the Artiodactyles, even at the base of the Eocene. One family, however, the *Coryphodontidæ*, which is well represented at this horizon, both in America and Europe, although essentially Perissodactyle, possesses some characters which point to a primitive Ungulate type from which the present orders have been evolved. Among these characters are the diminutive brain, which in size and form approaches that of the reptiles, and also the five-toed feet, from which all the various forms of the mammalian foot have been derived. Of this family, only a single genus, *Coryphodon* (*Bathmodon*), is known, but there were several distinct species. They were the largest mammals of the lower Eocene, some exceeding in size the existing tapirs.

In the middle Eocene, west of the Rocky Mountains, a remarkable group of Ungulates makes its appearance. These animals nearly equaled the elephant in size, but had shorter limbs. The skull was armed with two or three pairs of horn-cores, and with enormous canine tusks. The brain was proportionally smaller than in any other land mammal. The feet had five toes, and resembled in their general structure those of *Coryphydon*, thus indicating some affinity with that genus. These mammals resemble in some respects the Perissodactyles, and in others the Proboscidians, yet differ so widely from any known Ungulates, recent or fossil, that they must be regarded as forming a distinct order, the *Dinocerata*. Only three genera are known, *Dinoceras*, *Tinoceras*, and *Uintatherium*, but quite a number of species have been described. During the later part of the middle Eocene these animals were very abundant for a short time, and then be-

[1] *Sirenia*, an order of aquatic mammals represented at present only by the manatee and dugong.

[2] *Ungulata*. As now used, this term is employed to designate that order of mammals which contains the *Artiodactyla*, or even-toed, and the *Perissodactyla*, or odd-toed, mammals with hoofs. It thus includes, among the former, the camels, giraffe, bovines, antelopes, deer, musks, swine, and hippopotami; and, among the latter, the horses, rhinoceroses, and tapirs.

came extinct, leaving apparently no successor, unless possibly we have in the Proboscidians their much-modified descendants. Their genetic connection with the Coryphodonts is much more probable, in view of what we now know of the two groups.

Besides these peculiar mammals, which are extinct, and mainly of interest to the biologist, there were others in the early Tertiary which remind us of those at present living around us. When a student in Germany some twelve years ago, I heard a world-renowned Professor of Zoölogy gravely inform his pupils that the horse was a gift of the Old World to the New, and was entirely unknown in America until introduced by the Spaniards. After the lecture I asked him whether no earlier remains of horses had been found on this continent, and was told in reply that the reports to that effect were too unsatisfactory to be presented as facts in science. This remark led me, on my return, to examine the subject myself, and I have since unearthed, with my own hands, not less than thirty distinct species of the horse tribe in the Tertiary deposits of the West alone; and it is now, I think, generally admitted that America is, after all, the true home of the horse.

I can offer you no better illustration than this of the advance vertebrate paleontology has made during the last decade, or of the important contributions to this progress which our Rocky Mountain region has supplied.

The oldest representative of the horse, at present known, is the diminutive *Eohippus*, from the lower Eocene. Several species have been found, all about the size of a fox. Like most of the early mammals, these Ungulates had forty-four teeth, the molars with short crowns, and quite distinct in form from the premolars. The ulna and the fibula were entire and distinct, and there were four well-developed toes, and a rudiment of another on the fore-feet, and three toes behind. In the structure of the feet, and in the teeth, the *Eohippus* indicates unmistakably that the direct ancestral line to the modern horse has already separated from the other Perissodactyles. In the next higher division of the Eocene, another genus, *Orohippus*, makes its appearance, replacing *Eohippus*, and showing a greater, although still distant, resemblance to the Equine type. The rudimentary first digit of the fore-foot has disappeared, and the last premolar has gone over to the molar series. *Orohippus* was but little larger than *Eohippus*, and in most other respects very similar. Several species have been found in the same horizon with *Dinoceras*, and others lived during the upper Eocene with *Diplacodon*, but none later.[1]

Near the base of the Miocene, in the Brontotherium beds, we find a third closely-allied genus, *Mesohippus*, which is about as large as a

[1] Since this address was delivered, I have found in the Diplacodon beds a new genus of Equines (*Epihippus*), which is larger than *Orohippus*, and has the same number of toes, but has two premolar teeth like the molars.—O. C. M.

sheep, and one stage nearer the horse. Three are only three toes and a rudimentary splint bone in the fore feet, and three toes behind. Two of the premolar teeth are quite like the molars. The ulna is no longer distinct, or the fibula entire, and other characters show clearly that the transition is advancing. In the upper Miocene, *Mesohippus* is not found, but in its place a fourth form, *Miohippus*, continues the line. This genus is near the *Anchitherium* of Europe, but presents several important differences. The three toes in each foot are more nearly of a size, and a rudiment of the fifth metacarpal bone is retained. All the known species of this genus are larger than those of *Mesohippus*, and none pass above the Miocene.

The genus *Protohippus*, of the lower Pliocene, is yet more equine, and some of its species equaled the ass in size. There are still three toes on each foot, but only the middle one, corresponding to the single toe of the horse, comes to the ground. This genus resembles most nearly the *Hipparion* of Europe. In the Pliocene, we have the last stage of the series before reaching the horse, in the genus *Pliohippus*, which has lost the small hooflets, and in other respects is very equine. Only in the upper Pliocene does the true *Equus* appear, and complete the genealogy of the horse, which in the Post-Tertiary roamed over the whole of North and South America, and soon after became extinct. This occurred long before the discovery of the continent by Europeans, and no satisfactory reason for the extinction has yet been given. Besides the characters I have mentioned, there are many others, in the skeleton, skull, teeth, and brain, of the forty or more intermediate species, which show that the transition from the Eocene *Eohippus* to the modern *Equus* has taken place in the order indicated; and I believe the specimens now at New Haven will demonstrate the fact to any anatomist. They certainly carried prompt conviction to the first of anatomists, who was the honored guest of the Association a year ago, whose genius had already indicated the later genealogy of the horse in Europe, and whose own researches so well qualified him to appreciate the evidence here laid before him. Did time permit, I might give you at least a probable explanation of this marvelous transition, but justice to the comrades of the horse in his long struggle for existence demands that some notice of their efforts should be placed on record.

Besides the horse and his congeners, the only existing Perissodactyles are the rhinoceros and tapir. The last is the oldest type, but the rhinoceros had near allies throughout the Tertiary; and, in view of the continuity of the equine line, it is well worth while to attempt to trace his pedigree. At the bottom of the Eocene, in our Western lake-basins, the tapiroid genus *Helaletes* is found, represented by numerous small mammals hardly larger than the diminutive horses of that day. In the following epoch of the Eocene, the closely-allied *Hyrachyus* was one of the most abundant animals. This genus was nearly related to the *Lophiodon* of Europe, and in its teeth and skeleton strongly resembled the living tapir, whose ancestry, to this point, seems to coincide with that of the rhinoceros we are considering. Strangely enough, the rhinoceros line, before it becomes distinct, separates into two branches. In the upper part of the Dinoceras beds we have the genus *Colonoceras*, which is really a *Hyrachyus* with a transverse pair of very rudimentary horn-cores on the nasal bones. In the lower Miocene west of the Rocky Mountains this line seems to pass on through the genus *Diceratherium*, and in the higher Miocene this genus is well represented. Some of the species nearly equaled in size the existing rhinoceros, which *Diceratherium* strongly resembled. The main difference between them is a most interesting one. The rudimentary horn-cores on the nasals, seen in *Colonoceras*, are in *Diceratherium* developed into strong bony supports for horns, which were placed transversely, as in the ruminants, and not on the median line, as in all existing forms of rhinoceros. In the Pliocene of the Pacific coast, a large rhinoceros has been discovered, which may be a descendant of *Diceratherium;* but, as the nasal bones have not been found, we must wait for further evidence on this point. Returning now to the other branch of the rhinoceros group, which left their remains mainly east of the Rocky Mountains, we find that all the known forms are hornless. The upper Eocene genus, *Amynodon*, is the oldest known rhinoceros, and by far the most generalized of the family. The premolars are all unlike the molars; the four canines are of large size, but the inner incisor in each jaw is lost in the fully adult animal. The nasals were without horns. There were four toes in front, and three behind. The genus *Hyracodon*, of the Miocene, which is essentially a rhinoceros, has a full set of incisor and canine teeth; and the molars are so nearly like those of its predecessor, *Hyrachyus*, that no one will question the transformation of the older into the newer type. *Hyracodon*, however, appears to be off the true line, for it has but three toes in front. In the higher Miocene beds, and possibly with *Hyracodon*, occurs a larger rhinoceros, which has been referred to the genus *Aceratherium*. This form has lost the canine and one incisor above, and two incisors below. In the Pliocene are several species closely related, and of large size. Above the Pliocene in America, no vestiges of the rhinoceros have been found; and our American forms, doubtless, became extinct at the close of this period.

The tapir is clearly an old American type; and we have seen that, in the Eocene, the genera *Helaletes* and *Hyrachyus* were so strongly tapiroid in their principal characters that the main line of descent probably passed through them. It is remarkable that the Miocene of the West, so greatly developed as it is on both sides of the Rocky Mountains, should have yielded but a few fragments of tapiroid mammals; and the same is true of the Pliocene of that region. In the Miocene of the Atlantic coast, too, only a few imperfect specimens have been found. These forms all apparently belong to the genus

Tapiravus, although most of them have been referred to *Lophiodon*—a lower Eocene type. In the Post-Tertiary, a true *Tapirus* was abundant; and its remains have been found in various parts of North America. The line of descent, although indistinct through the middle and upper Tertiary, was doubtless continuous in America; and several species exist at present from Mexico southward. It is worthy of notice that the species north of the Isthmus of Panama appear all to be generically distinct from those of South America.

In addition to these three Perissodactyle types, which, as the fittest, have alone survived, and whose lineage I have endeavored to trace, there were many others in early Tertiary times. Some of these disappeared with the close of the Eocene, while others continued, and assumed strange specialized shapes in the Miocene, before their decline and extinction. One series of the latter deserves especial mention, as it includes one of the most interesting families of our extinct animals. Among the large mammals in the lower Eocene is *Limnohyus*, a true Perissodactyle, but only known here from fragments of the skeleton. In the next higher beds, this genus is well represented, and with it is found a nearly allied form, *Palæosyops*. In the upper Eocene, both have left the field, and the genus *Diplacodon*, a very near relative, holds the supremacy. The line seems clear through these three genera, but on crossing the break into the Miocene, we have apparently, as next of kin, the huge *Brontotheridæ*. These strange beasts show in their dentition and some other characters the same transition steps beyond the *Diplacodon*, which that genus had made beyond *Palæosyops*. The *Brontotheridæ* were nearly as large as the elephant, but had much shorter limbs. The skull was elongated, and had a transverse pair of large horn-cores on the maxillaries, in front of the orbits, like the middle pair in *Dinoceras*. There were four toes in front and three behind, and the feet were similar to those of the rhinoceros. There are four genera in this group, *Brontotherium*; *Diconodon*; *Menodus* (*Titanotherium*); and *Megacerops*, which have been found only in the lowest Miocene, east of the Rocky Mountains.

In the higher Miocene beds of Oregon, an allied genus, *Chalicotherium*, makes its appearance. It is one stage further on in the transition, and perhaps a descendant of the *Brontotheridæ*; but here, so far as now known, the line disappears. It is a suggestive fact that this genus has now been found in Western America, China, India, Greece, Germany, and France, indicating thus, as I believe, the path by which many of our ancient mammals helped to people the so-called Old World.

The Artiodactyles,[1] or even-toed Ungulates, are the most abundant

[1] *Artiodactyla*, a sub-order of the *Ungulata*, in which the third and fourth digits are nearly equally developed, and their ungual phalanges are flattened on their contiguous sides, so that together they constitute a symmetrical form. The axis, or middle line, of the whole foot lies between the third and fourth digits.

of the larger mammals now living; and the group dates back at least to the lowest Eocene. Of the two well-marked divisions of this order, the Bunodonts[1] and the Selenodonts,[2] as happily defined by Kowalevsky, the former is the older type, which must have separated from the Perissodactyle line after the latter had become differentiated from the primitive Ungulate. In the Coryphodon beds of New Mexico occurs the oldest Artiodactyle yet found, but it is at present known only from fragmentary specimens. These remains are clearly Suilline in character, and belong to the genus *Eohyus*. In the beds above, and possibly even in the same horizon, the genus *Helohyus* is not uncommon, and several species are known. The molar teeth of this genus are very similar to those of the Eocene *Hyracotherium*, of Europe, which is supposed to be a Perissodactyle, while *Helohyus* certainly is not, but apparently a true lineal ancestor of the existing pigs. In every vigorous primitive type which was destined to survive many geological changes, there seems to have been a tendency to throw off lateral branches, which became highly specialized and soon died out, because they are unable to adapt themselves to new conditions. The narrow path of the persistent Suilline type, throughout the whole Tertiary, is strewed with the remains of such ambitious offshoots; while the typical pig, with an obstinacy never lost, has held on in spite of catastrophes and evolution, and still lives in America to-day. In the lower Eocene, we have in the genus *Parahyus* apparently one of these short-lived, specialized branches. It attained a much larger size than the true lineal forms, and the number of its teeth was reduced. In the Dinoceras beds, or middle Eocene, we have still, on or near the true line, *Helohyus*, which is the last of the series known from the American Eocene. All these early Suillines, with the possible exception of *Parahyus*, appear to have had at least four toes of usable size.

In the lower Miocene, we find the genus *Perchœrus*, seemingly a true Suilline, and with it remains of a larger form, *Elotherium*, are abundant. The latter genus occurs in Europe in nearly the same horizon, and the specimens known from each continent agree closely in general characters. The name *Pelonax* has been applied erroneously to some of the American forms; but the specimens on which it was based clearly belong to *Elotherium*. This genus affords another example of the aberrant Suilline offshoots, already mentioned. Some of the species were nearly as large as a rhinoceros, and in all there were but two serviceable toes; the outer digits, seen in living animals of this group, being represented only by small rudiments concealed beneath the skin. In the upper Miocene of Oregon, Suillines are abundant, and almost all belong to the genus *Thinohyus*, a near ally of

[1] *Bunodont* (hill-tooth); hence, teeth the crowns of which are composed of rounded tubercles.

[2] *Selenodont* (moon-tooth); teeth which have the crowns marked by crescents.

the modern peccary (*Dicotyles*), but having a greater number of teeth, and a few other distinguishing features. In the Pliocene, Suillines are still numerous, and all the American forms yet discovered are closely related to *Dicotyles.* The genus *Platygonus* is represented by several species, one of which was very abundant in the Post-Tertiary of North America, and is apparently the last example of a side branch, before the American Suillines culminate in existing peccaries. The feet in this species are more specialized than in the living forms, and approach some of the peculiar features of the ruminants; as, for example, a strong tendency to coalescence in the metapodial bones. The genus *Platygonus* became extinct in the Post-Tertiary, and the later and existing species are all true peccaries.

No authenticated remains of the genera *Sus*, *Porcus*, *Phacochœrus*, or the allied *Hippopotamus*, the Old World Suillines, have been found in America, although several announcements to that effect have been made.

In the series of generic forms between the lower Eocene *Eohyus* and the existing *Dicotyles*, which I have very briefly discussed, we have apparently the ancestral line ending in the typical American Suillines. Although the demonstration is not yet as complete as in the lineage of the horse, this is not owing to want of material, but rather to the fact that the actual changes which transformed the early Tertiary pig into the modern peccary were comparatively slight, so far as they are indicated in the skeletons preserved, while the lateral branches were so numerous as to confuse the line. It is clear, however, that from the close of the Cretaceous to the Post-Tertiary the Bunodont Artiodactyles were especially abundant on this continent, and only recently have approached extinction.

The Selenodont division of the Artiodactyles is a more interesting group and, so far as we now know, makes its first appearance in the upper Eocene of the West, although forms, apparently transitional, between it and the Bunodonts occur in the Dinoceras beds, or middle Eocene. These belong to the genus *Homacodon*, which is very nearly allied to *Helohyus*, and but a single step away from this genus toward the Selenodonts. By a fortunate discovery, a nearly complete skeleton of this rare intermediate form has been brought to light, and we are thus enabled to define its characters. Several species of *Homacodon* are known, all of small size. This primitive Selenodont had forty-four teeth, which formed a nearly continuous series.

The molar teeth are very similar to those of *Helohyus*, but the cones on the crowns have become partially triangular in outline, so that, when worn, the Selenodont pattern is clearly recognizable. The first and second upper molars, moreover, have three distinct posterior cusps, and two in front; a peculiar feature, which is seen also in the European genera *Dichobune* and *Cainotherium*. There were four toes on each foot, and the metapodial bones were distinct. The type species of this genus was about as large as a cat. With *Helohyus*, this genus forms a well-marked family, the *Helohyidæ*.

In the *Diplacodon* horizon of the upper Eocene, the Selenodont dentition is no longer doubtful, as it is seen in most of the *Artiodactyla* yet found in these beds. These animals are all small, and belong to at least three distinct genera. One of these, *Eomeryx*, closely resembles *Homacodon* in most of its skeleton, and has four toes, but its teeth show well-marked crescents, and a partial transition to the teeth of *Hyopotamus*, from the Eocene of Europe. With this genus is another, *Parameryx*, also closely allied to *Homacodon*, but apparently a straggler from the true line, as it has but three toes behind. The most pronounced Selenodont in the upper Eocene is the *Oromeryx*, which genus appears to be allied to the existing Deer family, or *Cervidæ*, and if so is the oldest known representative of the group. These facts are important, as it has been supposed, until very recently, that our Eocene contained no even-hoofed mammals.

In the lowest Miocene of the West, no true crescent-toothed *Artiodactyla* have as yet been identified, with the exception of a single species of *Hyopotamus;* but, in the overlying beds of the middle Miocene, remains of the *Oreodontidæ* occur in such vast numbers as to indicate that these animals must have lived in large herds around the borders of the lake-basins in which their remains have been entombed. These basins are now the denuded deserts so well termed *Mauvaises Terres* by the early French trappers. The least specialized, and apparently the oldest, genus of this group is *Agriochærus*, which so nearly resembles the older *Hyopotamus*, and the still more ancient *Eomeryx*, that we can hardly doubt that they all belonged to the same ancestral line. The typical Oreodonts are the genera *Oreodon* and *Eporeodon*, which have been aptly termed by Leidy ruminating hogs. They had forty-four teeth, and four well-developed toes on each foot. The true Oreodons, which were most numerous east of the Rocky Mountains, were about as large as the existing peccary, while *Eporeodon*, which was nearly twice this size, was very abundant in the Miocene of the Pacific slope.

In the succeeding Pliocene formation, on each side of the Rocky Mountains, the genus *Merychyus* is one of the prevailing forms, and continues the line on from the Miocene, where the true Oreodons became extinct. Beyond this, we have the genus *Merychochærus*, which is so nearly allied to the last that they would be united by many naturalists. With the close of the Pliocene, this series of peculiar ruminants abruptly terminates, no member surviving until the Post-Tertiary, so far as known.

A most interesting line, that leading to the camels and llamas, separates from the primitive Selenodont branch in the Eocene, probably through the genus *Parameryx*. In the Miocene, we find in *Pœbrotherium* and some nearly allied forms unmistakable indications that the Cameloid type of ruminant had already become partially specialized, although there is a complete series of incisor teeth, and the metapodial bones are distinct. In the Pliocene, the camel tribe was, next to the horses, the most abundant of the larger mammals. The line is continued through the genus *Procamelus*, and perhaps others, and in this formation the incisors first begin to diminish, and the metapodials to unite. In the Post-Tertiary we have a true *Auchenia*, represented by several species, and others in South America, where the alpacas and llamas still survive. From the Eocene almost to the present time, North America has been the home of vast numbers of the *Camelidæ*, and there can be little doubt that they originated here, and migrated to the Old World.

Returning once more to the upper Eocene, we find another line of descent starting from *Oromeryx*, which, as we have seen, had apparently then just become differentiated from the older Bunodont type. Throughout the middle and upper Miocene, this line is carried forward by the genus *Leptomeryx* and its near allies, which resemble so strongly the Pliocene *Cervidæ* that they may fairly be regarded as their probable progenitors. Possibly some of these forms may be related to the *Tragulidæ*, but at present the evidence is against it.

The deer family has representatives in the upper Miocene of Europe, which contains fossils strongly resembling the fauna of our lower Pliocene, a fact always to be borne in mind in comparing the horizon of any group in the two continents. Several species of *Cervidæ*, belonging to the genus *Cosoryx*, are known from the lower Pliocene of the West, and all have very small antlers, divided into a single pair of tynes. The statement recently published, that most of these antlers had been broken during the life of the animals, is unsupported by any evidence, and is erroneous. These primitive deer do not have the orbit closed behind, and they have all the four metapodial bones entire, although the second and fifth are very slender. In the upper Pliocene, a true *Cervus* of large size has been discovered. In the Post-Tertiary, *Cervus*, *Alces*, and *Tarandus*, have been met with, the latter far south of its present range. In the caves of South America, remains of *Cervus* have been found, and also two species of antelopes, one referred to a new genus, *Leptotherium*.

The hollow-horned ruminants, in this country, appear to date back no further than to the lower Pliocene, and here only two species of *Bison* have as yet been discovered. In the Post-Tertiary this genus was represented by numerous individuals and several species, some of large size. The musk-ox (*Ovibos*) was not uncommon during some parts of this epoch, and its remains are widely distributed.

No authentic fossil remains of true sheep, goats, or giraffes, have as yet been found on this continent.

The Proboscidians,[1] which are now separated from the typical

[1] *Proboscidea*, the mammalian order which contains the elephants, and extinct mastodon and mammoth.

Ungulates as a distinct order, make their first appearance in North America in the lower Pliocene, where several species of *Mastodon* have been found. This genus occurs, also, in the upper Pliocene, and in the Post-Tertiary; although some of the remains attributed to the latter are undoubtedly older. The Pliocene species all have a band of enamel on the tusks, and some other peculiarities observed in the oldest mastodons of Europe, which are from essentially the same horizon. Two species of this genus have been found in South America, in connection with the remains of extinct llamas and horses. The genus *Elephas* is a later form, and has not yet been identified in this country below the upper Pliocene, where one gigantic species was abundant. In the Post-Pliocene, remains of this genus are numerous. The hairy mammoth of the Old World (*Elephas primigenius*) was once abundant in Alaska, and great numbers of its bones are now preserved in the frozen cliffs of that region. This species does not appear to have extended east of the Rocky Mountains, or south of the Columbia River, but was replaced there by the American elephant, which preferred a milder climate. Remains of the latter have been met with in Canada, throughout the United States, and in Mexico. The last of the American mastodons and elephants became extinct in the Post-Tertiary.

The order *Toxodontia* includes two very peculiar genera, *Toxodon* and *Nesodon*, which have been found in the Post-Tertiary deposits of South America. These animals were of huge size, and possessed such mixed characters that their affinities are a matter of considerable doubt. They are thought to be related to the Ungulates, Rodents, and Edentates; but, as the feet are unknown, this cannot at present be decided.

Macrauchenia and *Homalodontotherium* are two other peculiar genera from South America, now extinct, the exact affinities of which are uncertain. *Anoplotherium* and *Palæotherium*, so abundant in Europe, have not been found in our North American Tertiary deposits, although reported from South America.

Perhaps the most remarkable mammals yet found in America are the *Tillodontia*, which are comparatively abundant in the lower and middle Eocene. These animals seem to combine the characters of several different groups, viz., the Carnivores, Ungulates, and Rodents. In the genus *Tillotherium*, the type of the order, and of the family *Tillotheridæ*, the skull resembles that of the bears; the molar teeth are of the ungulate type, while the large incisors are very similar to those of Rodents. The skeleton resembles that of the Carnivores, but the scaphoid and lunar bones are distinct, and there is a third trochanter on the femur. The feet are plantigrade, and each had five digits, all with long, pointed claws. In the allied genus *Stylinodon*, which belongs to a distinct family, the *Stylinodontidæ*, all the teeth were rootless. Some of these animals were as large as a tapir. The genus

Dryptodon has been found only in the *Coryphodon* beds of New Mexico, while *Tillotherium* and *Stylinodon* occur in the middle Eocene of Wyoming. *Anchippodus* probably belongs to this group, which may perhaps include some other forms that have been named from fragmentary specimens.

The Rodents are an ancient type, and their remains are not unfrequently disinterred in the strata of our lowest fresh-water Eocene. The earliest known forms are, apparently, all related to the squirrels; and the most common genus is *Sciuravus*, which continued throughout the Eocene. A nearly allied form, which may prove to be the same, is *Paramys*, the species of which are larger than those of the older type. In the Dinoceras beds, the genus *Colonomys* is found, and the specimens preserved point to the *Muridæ* as the nearest living allies. A peculiar genus, *Apatemys*, which also occurs in the middle Eocene, has gliriform incisors; but the molars resemble those of Insectivores. All the Eocene Rodents known are of small size, the largest being about as large as a rabbit.

In the middle and upper Miocene lake-basins of the West, Rodents abound, but all are of moderate size. The hares first appear in the Oreodon beds, and continue in considerable numbers through the rest of the Tertiary and Post-Tertiary, to the present day. In these beds, the most common forms belong to the *Leporidæ*, and mainly to the genus *Palæolagus*. The Squirrel family is represented by *Ischyromys*, the *Muridæ* by the genus *Eumys*, and the beavers by *Palæocastor*. In the upper Miocene of Oregon, most of the same genera are found; and with them some peculiar forms, very unlike anything now living. One of these is the genus *Allomys*, possibly related to the flying-squirrels, but having molar teeth somewhat like those of the Ungulates. In the Pliocene, east and west of the Rocky Mountains, Rodents continue abundant; but most of them belong to existing genera. Among these are *Castor*, *Hystrix*, *Cynomys*, *Geomys*, *Lepus*, and *Hesperomys*. In the Post-Tertiary, the gigantic beaver, *Castoroides*, was abundant throughout most of North America. *Hydrochærus* has been found in South Carolina. In the caves of the island of Anguilla, in the West Indies, remains of large extinct Rodents, belonging to the *Chinchillidæ*, have been discovered.

The early Tertiary Rodents known from South America are the genera *Megamys*, *Theridromys*, and a large species referred to *Arvicola*. In Brazil, the Pliocene Rodents found are referred to the existing genera, *Cavia*, *Kerodon*, *Lagostomus*, *Ctenomys*, *Hesperomys*, *Oxymycterus*, *Arvicola*, and *Lepus*. A new genus, *Cardiodus*, described from this horizon, is a true rodent; but the peculiar *Typotherium*, which has been referred to this order by some authorities, has perhaps other affinities. In the Post-Tertiary, the Rodents were very abundant in South America, as they are at present. The species are, in most instances, distinct from those now living, but the genera are nearly the same. The *Caviidæ* were especially numerous. *Cercolabes*, *Myopotamus*, and *Lagostomus*, are also found; and two extinct genera, *Phyllomys* and *Lonchophorus*.

The *Cheiroptera*, or bats, have not been found in this country below the middle Eocene, where two extinct genera, *Nyctilestes* and *Nyctitherium*, are each represented by numerous remains. These fossils all belong to small animals, and, so far as they have been investigated, show no characters of more than generic importance to distinguish them from the bats of to-day. No other members of this group are known from our Tertiary. In the Post-Tertiary, no extinct species of bats have been found in North America, but from the caves of Brazil quite a number have been reported. These all belong to genera still living in South America, and most of them to the family *Phyllostomidæ*.

The Insectivores[1] date back, in this country, at least to the middle Eocene. Here numerous remains occur, which have been described as belonging to this order, although it is possible that some of them were insect-eating Marsupials. The best-known genera are—*Hemiacodon*, *Centetodon*, *Talpavus*, and *Entomacodon*; all represented by animals of small size. In the Miocene, the bones of Insectivores are comparatively abundant, and the genera best determined are *Ictops* and *Leptictis*. A few specimens only have been found in the Pliocene and Post-Pliocene, most of them related to the moles. No extinct Insectivores are known from South America, and no member of the group exists there at present.

The *Carnivora*, or true flesh-eating animals, are an old type, well represented in the Eocene, and, as might be expected, these early forms are much less specialized than the living species. In the Coryphodon beds, the genus *Limnocyon*, allied to the *Pterodon* of the European Eocene, is abundant. Another genus, apparently distinct, is *Prototomus*, and several others have been named from fragmentary fossils. In the middle Eocene, Carnivores were still more numerous, and many genera have been discovered. One of these, *Limnofelis*, was nearly as large as a lion, and apparently allied to the cats, although the typical *Felidæ* seem not yet to have been differentiated. Another Carnivore, of nearly equal size, was *Orocyon*, which had short, massive jaws and broad teeth. *Dromocyon* and *Mesonyx* were large animals, allied to *Hyænodon*. The teeth were narrow, and the jaws long and slender. Among the smaller Carnivores were—*Vulpavus*, *Viverravus*, *Sinopa*, *Thinocyon*, and *Ziphacodon*.

In our Western Miocene, Carnivores are abundant, and make an approach to modern types. The *Felidæ* are well represented, the most interesting genus being *Machairodus*, which is not uncommon in the Oreodon beds on both sides of the Rocky Mountains. An

[1] *Insectivora*, that order of mammals which includes the existing moles, shrews, hedgehogs, etc.

allied genus is *Dinictis*, and several smaller cats are known from about the same horizon. The *Canidæ* are represented by *Amphicyon*, a European genus, and by several species of *Canis*, or a very nearly allied form. The peculiar genus *Hyænodon*, found also in Europe, and the type of a distinct family, is abundant in the Miocene east of the Rocky Mountains, but has not yet been found on the Pacific coast. In the Pliocene of both regions the *Canidæ* are numerous, and all apparently belong to the existing genus *Canis*. The genus *Machairodus* is still the dominant form of the cats, which are abundant, and for the most part belong to the genus *Felis*. The extinct *Leptarctus* is supposed to belong to the *Ursidæ*,[1] and, if so, is the oldest American representative of this family. In the Post-Pliocene, the extinct *Felidæ* include species nearly as large as a lion, and smaller forms very similar to those still living. Bears, raccoons, and weasels, have also been found.

In the Pliocene of South America, *Machairodus* represents the *Felidæ*, while the genera *Arctotherium* and *Hyænarctus* belong to the Bear family. Species of *Mustela* and *Canis* have also been found. In the caves of Brazil, the fauna of which is regarded as Post-Pliocene, one species of *Machairodus* is known, and one of *Synælurus*. *Canis* and *Icticyon*, still living in Brazil, and the extinct genus *Speothos*, represent the *Canidæ*. *Mephitis* and *Galictis*, among the weasels, were also present, and with them species of *Nasua* and *Arctotherium*.

We come now to the highest group of Mammals, the Primates, which includes the Lemurs, the Apes, and Man. This order has a great antiquity, and even at the base of the Eocene we find it represented by several genera belonging to the lower forms of the group. In considering these interesting fossils, it is important to have in mind that the Lemurs, which are usually regarded as Primates, although at the bottom of the scale, are found at the present day only in Madagascar and the adjacent regions of the globe. All the American monkeys, moreover, belong to one group, much above the Lemurs, while the Old World apes are higher still, and most nearly approach man.

In the lower Eocene of New Mexico we find a few representatives of the earliest known Primates, and among them are the genera *Lemuravus* and *Limnotherium*, each the type of a distinct family. These genera became very abundant in the middle Eocene of the West, and with them are found many others—all, however, included in the two families *Lemuravidæ* and *Limnotheridæ*. *Lemuravus* appears to have been most nearly allied to the Lemurs, and is the most generalized form of the Primates yet discovered. It had forty-four teeth, forming a continuous series above and below. The brain

[1] *Ursidæ*, the family including the bears, raccoons, etc.

was nearly smooth, and of moderate size. The skeleton most resembles that of the Lemurs. A nearly allied genus, belonging to the same family, is *Hyopsodus*. *Limnotherium* (*Tomitherium*) also is nearly related to the Lemurs, but shows some affinities with the South American marmosets. This genus had forty teeth. The brain was nearly smooth, and the cerebellum large, and placed mainly behind the cerebrum. The orbits are open behind, and the lachrymal foramen is outside the orbit. Other genera belonging to the *Limnotheridæ* are—*Notharctos*, *Hipposyus*, *Microsyops*, *Palæacodon*, *Thinolestes*, and *Telmatolestes*. Besides these, *Antiacodon* (*Anaptomorphus*), *Bathrodon*, and *Mesacodon*, should probably be placed in the same group. In the Diplacodon beds, or upper Eocene, no remains of Primates have yet been detected, although they will doubtless be found there. All the Eocene Primates known from American strata are low generalized forms, with characters in the teeth, skeleton, and feet, that suggest relationships with the Carnivores, and even with the Ungulates. These resemblances have led paleontologists to refer some imperfect specimens to both these orders.

In the Miocene lake-basins of the West, only a single species of the Primates has been identified with certainty. This was found in the Oreodon beds of Nebraska, and belongs to the genus *Laopithecus*, apparently related both to the *Limnotheridæ* and to some existing South American monkeys. In the Pliocene and Post-Pliocene of North America no remains of Primates have yet been found.

In the Post-Pliocene deposits of the Brazilian caves, remains of monkeys are numerous, and mainly belong to extinct species of *Callithrix*, *Cebus*, and *Jacchus*, all living South American genera. Only one extinct genus, *Protopithecus*, which embraced animals of large size, has been found in this peculiar fauna.

It is a noteworthy fact, that no traces of any Anthropoid apes, or indeed of any Old World monkeys, have yet been detected in America. Man, however, the highest of the Primates, has left his bones and his works from the arctic circle to Patagonia. Most of these specimens are clearly Post-Tertiary, although there is considerable evidence pointing to the existence of man in our Pliocene. All the remains yet discovered belong to the well-marked genus *Homo*, and apparently to a single species, at present represented by the American Indian.

In this rapid review of mammalian life in America, from its first known appearance in the Trias down to the present time, I have endeavored to state briefly the introduction and succession of the principal forms in each natural group. If time permitted, I might attempt the more difficult task of trying to indicate what relations these various groups may possibly bear to each other; what connection the ancient mammals of this continent have with the corresponding forms of the Old World; and, most important of all, what real progress mammalian life has here made since the beginning of the Eocene. As it is, I can only say, in summing up, that the Marsupials are clearly the remnants of a very ancient fauna, which occupied this continent millions of years ago, and from which the other mammals were doubtless all derived, although the direct evidence of the transformation is wanting.

Although the Marsupials are nearly related to the still lower Monotremes, now living in the Australian region, we have as yet no hint of the path by which these two groups became separated from the inferior vertebrates. Neither have we to-day much light as to the genetic connection existing between Marsupials and the placental Mammalia, although it is possible that the different orders of the latter had their origin each from a separate group of the Marsupials.

The presence, however, of undoubted Marsupials in our lower and middle Eocene, some of them related to the genus *Didelphys*, although remotely, is important evidence as to the introduction of these animals into America. Against this, their supposed absence in our Miocene and Pliocene can have but limited weight, when taken in connection with the fact that they flourished in the Post-Tertiary, and are still abundant. The evidence we now have is quite as strongly in favor of a migration of Marsupials from America to the Old World, as the reverse, which has been supposed by some naturalists. Possibly, as Huxley has suggested, both countries were peopled with these low mammals from a continent now submerged.

The Edentate mammals have long been a puzzle to zoölogists, and up to the present time no clew to their affinities with other groups seems to have been detected. A comparison of the peculiar Eocene mammals which I have called the *Tillodontia*, with the least specialized Edentates, brings to light many curious resemblances in the skull, teeth, skeleton, and feet. These suggest relationship, at least, and possibly we may yet find here the key to the Edentate genealogy. At present, the Tillodonts are all from the lower and middle Eocene, while *Moropus*, the oldest Edentate genus, is found in the middle Miocene, and one species in the lower Pliocene.

The Edentates have been usually regarded as an American type, but the few living forms in Africa, and the Tertiary species in Europe, the oldest known, have made the land of their nativity uncertain. I have already given you some reasons for believing that the Edentates had their first home in North America, and migrated thence to the southern portion of the continent. This movement could not have taken place in the Miocene period, as the Isthmus of Darien was then submerged; but, near the close of the Tertiary, the elevation of this region left a much broader strip of land than now exists there, and over this the Edentates and other mammals made their way, perhaps urged on by the increasing cold of the glacial winters. The evidence to-day is strongly in favor of such a southern migration. This, however, leaves the Old World Edentates, fossil and recent, unaccounted for; but I believe the solution of this problem is essentially the same, namely, a migration from North America. The Miocene representatives of this group, which I have recently obtained in Oregon, are older than any known in Europe, and, strangely enough, are more like the latter and the existing African types than like any of our living species. If, now, we bear in mind that an elevation of only 180 feet would close Behring's Straits, and give a road thirty miles wide from America to Asia, we can easily see how this migration might have taken place. That such a Tertiary bridge did exist, we have much independent testimony, and the known facts all point to extensive migrations of animals over it.

The *Cetacea* are connected with the marine Carnivores through the genus *Zeuglodon*, as Huxley has shown, and the points of resemblance are so marked that the affinity cannot be doubted. That the connection was a direct one, however, is hardly probable, since the diminutive brain, large number of simple teeth, and reduced limbs in the whales, all indicate them to be an old type, which doubtless branched off from the more primitive stock leading to the Carnivores. Our American extinct Cetaceans, when carefully investigated, promise to throw much light upon the pedigree of these strange mammals. As most of the known forms were probably marine, their distribution is of little service in determining their origin.

That the Sirenians are allied to the Ungulates is now generally admitted by anatomists, and the separation of the existing species in distant localities suggests that they are the remnants of an extensive group, once widely distributed. The large number of teeth in some forms, the reduced limbs, and other characters, point back to an ancestry near that of the earliest Ungulates. The gradual loss of teeth in the specialized members of this group, and in the Cetaceans, is quite parallel with the same change in Edentates, as well as in Pterodactyles and Birds.

The Ungulates are so distinct from other groups that they must be one of the oldest natural divisions of mammals, and they probably originated from some herbivorous marsupial. Their large size, and great numbers, during Tertiary and Post-Tertiary time, render them most valuable in tracing migrations induced by climate, as well as in showing the changes of structure which such a contest for existence may produce.

In the review of the extinct Ungulates, I have endeavored to show that quite a number of genera, usually supposed to belong originally to the Old World, are in reality true American types. Among these were the horse, rhinoceros, and tapir, all the existing odd-toed Ungulates, and, besides these, the camel, pig, and deer. All these I believe, and many others, went to Asia from our Northwest coast. It must, for the present, remain an open question whether we may not fairly claim the *Bovidæ*, and even the *Proboscidea*, since both occur in our strata at about the same horizon as on the other continent. On this point there is some confusion, at least in names. The Himalayan deposits called upper Miocene, and so rich in Proboscidians, indicate in their entire fauna that they are more recent than our Niobrara River beds, which, for apparently good reasons, we regard as lower Pliocene. The latter appear to be about the same horizon as the Pikermi deposits in Greece, also regarded as Miocene. Believing, however, that we have here a more complete Tertiary series, and a better standard for comparison of faunas, I have preferred to retain the names already applied to our divisions, until the strata of the two continents are more satisfactorily coördinated.

The extinct Rodents, Bats, and Insectivores of America, although offering many suggestive hints as to their relationship with other groups, and their various migrations, cannot now be fully discussed. There is little doubt, however, that the Rodents are a New World type, and, according to present evidence, they probably had their origin in North America. The resemblance in so many respects of this order to the Proboscidians is a striking fact, not yet explained by the imperfectly known genealogy of either group.

The Carnivores, too, I must pass by, except to call attention to a few special forms which accompanied the migrations of other groups. One of these is *Machairodus*, the sabre-toothed tiger, which flourished in our Miocene and Pliocene, and apparently followed the huge Edentates to South America, and the Ungulates across Asia to Europe. With this genus went *Hyænodon*, and some typical wolves and cats, but the bears probably came the other way with the antelopes. That the gazelle, giraffe, hippopotamus, hyena, and other African types, once abundant in Asia, did not come, is doubtless because the Miocene bridge was submerged before they reached it.

The Edentates, in their southern migration, were probably accompanied by the horse, tapir, and rhinoceros, although no remains of the last have yet been found south of Mexico. The mastodon, elephant, llama, deer, peccary, and other mammals, followed the same path. Why the mastodon, elephant, rhinoceros, and especially the horse, should have been selected with the huge Edentates for extinction, and the other Ungulates left, is at present a mystery, which their somewhat larger size hardly explains.

The relations of the American Primates, extinct and recent, to those of the other hemisphere, offer an inviting topic, but it is not within my present province to discuss them in their most suggestive phases. As we have here the oldest and most generalized members of the group, so far as now known, we may justly claim America for the birthplace of the order. That the development did not continue here until it culminated in man, was due to causes which at present we can only surmise, although the genealogy of other surviving groups gives some data toward a solution. Why the Old World apes, when differentiated, did not come to the land of their earlier ancestry, is readily explained by the then intervening oceans, which likewise were a barrier to the return of the horse and rhinoceros.

Man, however, came—doubtless first across Behring's Straits; and at his advent became part of our fauna, as a mammal and primate. In these relations alone it is my purpose here to treat him. The evidence, as it stands to-day, although not conclusive, seems to place the first appearance of man in this country in the Pliocene, and the best proof of this has been found on the Pacific coast. During several visits to that region, many facts were brought to my knowledge which render this more than probable. Man at this time was a savage, and was doubtless forced by the great volcanic outbreaks to continue his migration. This was at first to the south, since mountain-chains were barriers on the east. As the native horses of America were now all extinct, and as the early man did not bring the Old World animal with him, his migrations were slow. I believe, moreover, that his slow progress toward civilization was in no small degree due to this same cause, the absence of the horse.

It is far from my intention to add to the many theories extant in regard to the early civilizations in this country, and their connections with the primitive inhabitants, or the later Indians; but two or three facts have recently come to my knowledge which I think worth mentioning in this connection. On the Columbia River, I have found evidence of the former existence of inhabitants much superior to the Indians at present there, and of which no tradition remains. Among many stone carvings which I saw there, were a number of heads which so strongly resemble those of apes that the likeness at once suggests itself. Whence came these sculptures, and by whom were they made? Another fact that has interested me very much is the strong resemblance between the skulls of the typical mound-builders of the Mississippi Valley and those of the Pueblo Indians. I had long been familiar with the former; and, when I recently saw the latter, it required the positive assurance of a friend, who had himself collected them in New Mexico, to convince me that they were not from the mounds. A third fact, and I leave man to the archæologists, on whose province I am even now trenching. In a large collection of mound-builders' pottery, over a thousand specimens, which I have recently examined with some care, I found many pieces of elaborate workmanship so nearly like the ancient water-jars from Peru, that no one could fairly doubt that some intercourse had taken place between the widely-separated people that made them.

The oldest known remains of man on this continent differ in no important characters from the bones of the typical Indian, although in some minor details they indicate a much more primitive race. These early remains, some of which are true fossils, resemble much more closely the corresponding parts of the highest Old World apes, than do the latter our Tertiary Primates, or even the recent American monkeys. Various living and fossil forms of Old World Primates fill up essentially the latter gap. The lesser gap between the primitive man of America and the Anthropoid apes is partially closed by still lower forms of men, and doubtless also by higher apes, now extinct. Analogy, and many facts as well, indicate that this gap was smaller in the past. It certainly is becoming wider now with every generation, for the lowest races of men will soon become extinct, like the Tasmanians, and the highest apes cannot long survive. Hence the intermediate forms of the past, if any there were, become of still greater importance. For such missing links, we must look to the caves and later Tertiary of Africa, which I regard as now the most promising field for exploration in the Old World. America, even in the tropics, can promise no such inducements to ambitious explorers. We have, however, an equally important field, if less attractive, in the Cretaceous mammals, which must have left their remains somewhere on this continent. In these two directions, as I believe, lie the most important future discoveries in paleontology.

As a cause for many changes of structure in mammals during the Tertiary and Post-Tertiary, I regard as the most potent, *natural selection*, in the broad sense in which that term is now used by American evolutionists. Under this head I include not merely a Malthusian struggle for life among the animals themselves, but the equally important contest with the elements and all surrounding Nature. By changes in the environment, migrations are enforced, slowly in some cases, rapidly in others, and with change of locality must come adaptation to new conditions, or extinction. The life-history of Tertiary mammals illustrates this principle at every stage, and no other explanation meets the facts.

The real progress of mammalian life in America, from the beginning of the Tertiary to the present, is well illustrated by the brain-growth, in which we have the key to many other changes. The earliest known Tertiary mammals all had very small brains, and in some forms this organ was proportionally less than in certain reptiles. There was a gradual increase in the size of the brain during this period, and it is interesting to find that this growth was mainly confined to the cerebral hemispheres, or higher portion of the brain. In most groups of mammals, the brain has gradually become more convoluted, and thus increased in quality as well as quantity. In some, also, the cerebellum and olfactory lobes, the lower parts of the brain, have even diminished in size. In the long struggle for existence during Tertiary time, the big brains won, then as now; and the increasing power thus gained rendered useless many structures inherited from primitive ancestors, but no longer adapted to new conditions.

Another of the interesting changes in mammals during Tertiary time was in the teeth, which were gradually modified with other parts of the structure. The primitive form of tooth was clearly a cone, and all others are derived from this. All classes of Vertebrates below mammals, namely, fishes, amphibians, reptiles, and birds, have conical teeth, if any, or some simple modification of this form. The Edentates and Cetaceans with teeth retain this type, except the zeuglodonts, which approach the dentition of aquatic Carnivores. In the higher mammals, the incisors and canines retain the conical shape, and the premolars have only in part been transformed. The latter gradually change to the more complicated molar pattern, and hence are not reduced molars, but transition forms from the cone to more complex types. Most of the early Tertiary mammals had forty-four teeth, and in the oldest forms the premolars were all unlike the molars, while the crowns were short, covered with enamel, and without cement. Each stage of progress in the differentiation of the animal was, as a rule, marked by a change in the teeth; one of the most common being the transfer, in form at least, of a premolar to the molar series, and a gradual lengthening of the crown. Hence, it is often easy to decide from a fragment of a jaw to what horizon of the Tertiary it belongs. The fossil horses of this period, for example, gained a grinding-tooth for each toe they lost, one in each epoch. In the single-toed existing horses, all the premolars are like the molars, and the process is at an end. Other dental transformations are of equal interest, but this illustration must suffice.

The changes in the limbs and feet of mammals during the same period were quite as marked. The foot of the primitive mammal was, doubtless, plantigrade, and certainly five-toed. Many of the early Tertiary forms show this feature, which is still seen in some existing forms. This generalized foot became modified by a gradual loss of the outer toes, and increase in size of the central ones, the reduction proceeding according to systematic methods, differing in each group. Corresponding changes took place in the limb-bones. One result was a great increase in speed, as the power was applied so as to act only in the plane of motion. The best effect of this specialization is seen to-day in the horse and antelope, each representing a distinct group of Ungulates, with five-toed ancestors.

If the history of American mammals, as I have briefly sketched it, seems, as a whole, incomplete and unsatisfactory, we must remember that the genealogical tree of this class has its trunk and larger limbs concealed beneath the *débris* of Mesozoic time, while its roots doubtless strike so deeply into the Paleozoic that for the present they are lost. A decade or two hence we shall probably know something of the mammalian fauna of the Cretaceous, and the earlier lineage of our existing mammals can then be traced with more certainty.

The results I have presented to you are mainly derived from personal observation; and, since a large part of the higher vertebrate remains hitherto found in this country have passed through my hands, I am willing to assume full responsibility for my presentation of the subject.

For our present knowledge of the extinct Mammals, Birds, and Reptiles of North America, science is especially indebted to Leidy, whose careful, conscientious work has laid a secure foundation for our vertebrate paleontology. The energy of Cope has brought to notice many strange forms, and greatly enlarged our literature. Agassiz, Owen, Wyman, Baird, Hitchcock, Deane, Emmons, Lea, Allen, Gibbes, Jefferson, DeKay, and Harlan, deserve honorable mention in the history of this branch of science. The South American extinct Vertebrates have been described by Lund, Owen, Burmeister, Gervais, Huxley, Flower, Desmarest, Aymard, Pictet, and Nodot. Darwin and Wallace have likewise contributed valuable information on this subject, as they have on nearly all forms of life.

In this long history of ancient life I have said nothing of what Life itself really is—and for the best of reasons—because I know nothing. Here, at present, our ignorance is dense, and yet we need not despair. Light, Heat, Electricity, and Magnetism, Chemical Affinity, and Motion, are now considered different forms of the same force; and the opinion is rapidly gaining ground that Life, or vital force, is only another phase of the same power. Possibly the great mystery of Life may thus be solved, but, whether it be or not, a true faith in science knows no limit to its search for Truth.

THE WICKED WEASEL.

THERE are other enemies of game-life besides human poachers whose numbers must be kept within bounds to insure successful sport. The thirst of the weasel for blood is insatiable, and it is curious to watch the persistency with which he will hunt down the particular rabbit he has singled out for destruction. Through the winding subterranean galleries of the "buries" with their cross-passages, "blind" holes and "pop" holes (i. e., those which end in undisturbed soil, and those which are simply bored from one side of the bank to the other, being only used for temporary concealment), never once in the dark, close caverns losing sight or scent of his victim, he pursues it with a species of eager patience. It is generally a long chase. The rabbit makes a dash ahead, and a double or two, and then halts, usually at the mouth of a hole; perhaps to breathe.

By-and-by the weasel, baffled for a few minutes, comes up behind. Instantly the rabbit slips over the bank outside and down the ditch for a dozen yards, and there enters the "bury" again. The weasel follows, gliding up the bank with a motion not unlike that of the snake; for his body and neck are long and slender, and his legs short. Apparently he is not in haste, but rather lingers over the scent. This is repeated five or six times, till the whole length of the hedgerow has been traversed—sometimes up and down again. The chase may be easily observed by any one who will keep a little in the background. Although the bank be tenanted by fifty other rabbits, past whose hiding-place the weasel must go, yet they scarcely take any notice. One or two, whom he has approached too closely, bolt out and in again; but as a mass the furry population remain quiet, as if perfectly aware that they are not yet marked out for slaughter. At last, having exhausted the resources of the bank, the rabbit rushes across the field to a hedgerow, perhaps a hundred yards away. Here the wretched creature seems to find a difficulty in obtaining admittance. Hardly has he disappeared in a hole before he comes out again, as if the inhabitants of the place refused to give him shelter. For many animals have a strong tribal feeling, and their sympathy, like that of man in a savage state, is confined within their special settlement. With birds it is the same; rooks, for instance, will not allow a strange pair to build in their trees, but drive them off with relentless beak, tearing down the half-formed nest, and taking the materials to their own use. The sentiment, "If Jacob take a wife of the daughters of Heth, what good shall my life do me?" appears to animate the breasts of gregarious creatures of this kind. Rooks intermarry generation after generation; and if a black lover brings home a foreign bride, they are forced to build in a tree at some distance. Near large rookeries several such outlying colonies may be seen.

The rabbit, failing to find a cover, hides in the grass and dry rushes; but across the meadow, stealing along the furrow, comes the weasel; and, shift his place how he may, in the end, worn out and weary, bunny succumbs, and the sharp teeth meet in the neck behind the ear, severing the vein. Ofter in the end the rabbit runs to earth in a hole which is a *cul-de-sac*, with his back toward the pursuer. The weasel, unable to get at the poll, which is his desire, will mangle the hinder parts in a terrible manner—as will the civilized ferret under similar conditions. Now and then the rabbit, scratching and struggling, fills the hole in the rear with earth, and so at the last moment chokes off his assailant and finds safety almost in the death-agony. In the woods, once the rabbit is away from the "buries," the chase really does resemble a hunt; from furze-bush to bracken, from fern to rough grass, round and round, backward, doubling, to and fro, and all in vain. At such times, eager for blood, the weasel will run right across your path, almost close enough to be kicked. Pursue him in turn, and if there be no hedge or hole near, if you have him in the open, he will dart hither and thither right between your legs, uttering a sharp, short note of anger and alarm, something composed of a tiny bark and a scream. He is easily killed with a stick when you catch him in the open, for he is by no means swift; but if a hedge be near it is impossible to secure him.

Weasels frequently hunt in couples, and sometimes more than two will work together. We once saw five, and have heard of eight. The five we saw were working a sandy bank drilled with holes, from which the rabbits in wild alarm were darting in all directions. The weasels raced from hole to hole and along the sides of the bank exactly like a pack of hounds, and seemed intensely excited. Their manner of hunting resembles the motions of ants; these insects run a little way very swiftly, then stop, turn to the right or left, make a short *détour*, and afterward on again in a straight line. So the pack of weasels darted forward, stopped, went from side to side, and then on a yard or two, and repeated the process. To see their reddish heads thrust for a moment from the holes, then withdrawn to reappear at another, would have been amusing had it not been for the reflection that their frisky tricks would assuredly end in death. They ran their quarry out of the bank and into a wood, where we lost sight of them. The pack of eight was seen by a laborer returning down a woodland lane from work one afternoon. He told us he got in the ditch, half from curiosity to watch them, and half from fear—laughable as that may seem—for he had heard the old people tell stories of men in the days when the corn was kept for years in barns, and so bred hundreds of rats, being attacked by those vicious brutes. He said they made a noise, crying to each other—short, sharp, snappy sounds; but the pack of five we ourselves saw hunted in silence.

Often and often, when standing in a gateway, partly hidden by the bushes, watching the woodpecker on the ant-hills, of whose eggs, too, the partridges are so fond (so that a good ant year, in which their nests are prolific, is also a good partridge year), you may, if you are still, hear a slight, faint rustle in the hedge, and by-and-by a weasel will steal out. Seeing you he instantly pauses, elevates his head, and steadily gazes; move but your eyes, and he is back in the hedge; remain quiet, still looking straight before you as if you saw nothing, and he will presently recover confidence, and actually cross the gateway almost under you. This is the secret of observation: stillness, silence, and apparent indifference. In some instinctive way these wild creatures learn to distinguish when one is or is not intent upon them in a spirit of enmity; and, if very near, it is always the eye they watch. So long as you observe them, as it were, from the corner of the eyeball, sidewise, or look over their heads at something beyond, it is well. Turn your glance full upon them to get a better view, and they are gone. When waiting in a dry ditch with a gun on a warm autumn afternoon for a rabbit to come out, sometimes a bunny will suddenly appear at the mouth of a hole which your knee nearly touches. He stops dead, as if petrified with astonishment, sitting on his haunches. His full dark eye is on you with a gaze of intense curiosity; his nostrils work as if sniffing; his whiskers move; and every now and then he thumps with his hind-legs upon the earth with a low, dull thud. This is evidently a sign of great alarm, at the noise of which any other rabbit within hearing instantly disappears in the "bury." Yet there your friend sits and watches you as if spellbound, so long as you have the patience to move neither hand nor foot nor to turn your eye. Keep your glance on the frond of the fern just beyond him, and he will stay. The instant your eye meets his, or a finger stirs, he plunges out of sight. It is so also with birds. Walk across a meadow, swinging a stick, even humming, and the rooks calmly continue their search for grubs within thirty yards; stop to look at them, and they rise on the wing directly. So, too, the finches in the trees by the road-side. Let the wayfarer pass beneath the bough on which they are singing, and they will sing on, if he moves without apparent interest; should he pause to listen, their wings glisten in the sun as they fly.

Stoats, though not so numerous as weasels, probably do quite as much injury, being larger, swifter, stronger, and very bold, sometimes entering sheds close to dwelling-houses. The laboring-people—at least, the elder folk—declare that they have been known to suck the blood of infants left asleep in the cradle upon the floor, biting the child behind the ear. They hunt in couples also—seldom in larger numbers. We have seen three at work together, and with a single shot killed two out of the trio. In elegance of shape they surpass the weasel, and the color is brighter. Their range of destruction seems only limited by their strength; they attack anything they can manage.

The keeper looks upon weasel and stoat as bitter foes, to be ruthlessly exterminated with shot and gin. He lays to their charge deadly crimes of murder, the death of rabbits, hares, birds, the theft and destruction of his young broods, even occasional abstraction of a chicken close to his very door, despite the dogs chained there. They are not easily shot, being quick to take shelter at the sight of a dog, and, when hard hit with the pellets, frequently escaping, though perhaps to die. Both weasel and stoat, and especially the latter, will snap viciously at the dog that overtakes them, even when sore wounded, always aiming to fix their teeth in his nose, and fighting savagely to the last gasp. The keeper slays a wonderful number in the course of a year, yet they seem as plentiful as ever. He traps perhaps more than he shoots. It is not always safe to touch a stoat caught in a trap; he lies apparently dead, but lift him up, and instantly his teeth are in your hand, and it is said such wounds sometimes fester for months. Stoats are tough as leather; though severely nipped by the iron fangs of the gin, struck on the head with the butt of the gun, and seemingly quite lifeless, yet, if thrown on the grass and left, you will often find on returning to the place in a few hours time that the animal is gone. Warned by experiences of this kind, the keeper never picks up a stoat till "settled" with a stick or shot, and never leaves him till he is nailed to the shed. Stoats sometimes emit a disgusting odor when caught in a trap. The keeper has no mercy for such vermin, though he thinks some other of his enemies are even more destructive.—*Pall Mall Budget.*

THE DISSIPATION OF ENERGY.

BY GEORGE ILES.

SCARCELY had the grand truth been well demonstrated, some thirty years ago, that force can neither be created nor annihilated, when it served as a basis for one of the boldest theories ever conceived in the history of science. Prof. William Thomson (now Prof. Sir William Thomson) in 1853 first broached the theory of the dissipation of energy, and since that time many other eminent men have enlarged it and speculated upon it.

The theory points out, in the first place, that different phases of energy are not transformable into one another with equal ease and completeness. Heat is the only form into which any other can be totally converted. When electricity, mechanical motion, or any kind of energy but heat is sought, an undesired production of thermal effect is unavoidable in the most favorable conditions for efficient conversion known to science. Therefore, in the catalogue of terrestrial forces heat is continually gaining in amount at the expense of every other mode of motion.

Further, not only is it impossible, by any known method, to regain from heat more than one-fourth its theoretical value in useful work, but, as the tendency of all heat is ever to become of uniform temperature, by radiation and conduction, the differences of degree wherein its value as a source of other motion solely lies are being continually abolished. The tendency of energy to appear more and more as uniformly diffused heat is further shown to be true not only on earth but in the heavens. With respect to the solar system, our present information, it is held, indicates that it is gradually drifting toward an utterly lifeless state. The sun is parting with its stores of force most lavishly, and must, at however distant a period, become as cold as its planets are now. The planets are little by little losing their force of axial rotation from the friction of their tides, which transmute it into heat;

at some future age they will doubtless present a single side to the sun, as our moon, from similar causes, now does to the earth.

Furthermore, it is thought that the medium which conveys light through space, extremely attenuated though it may be, is capable of opposing some resistance to planetary movements, so that the sun may at last unite with itself all the orbs now circling around it. The collision between the sun and its worlds would render the whole mass fiery hot; but radiation, in the course of time, would slowly bring its temperature lower and lower, until it would cease to shine altogether. The theory then supposes that the fate which shall have overtaken the solar system will then attack the sidereal heavens; that the causes which shall first make the planets unite with their primary will make stars unite with one another, until the ultimate result of all these changes may be that a solitary gigantic ball shall contain all the matter now interfused through space, its enormous store of energy, in the form of equably-diffused heat, being incapable of further change, and utterly unfit for the production or maintenance of life.

All this is assuredly very bold, and deduced most fairly from its premises; but premises in truth and completeness are of much more account and far more difficult of discovery than methods of logical inference. Let us briefly examine the grounds on which it is supposed that Nature is doomed to a death without resurrection, and see if they warrant the tremendous conclusions drawn from them.

The theory illustrates very pointedly the difficulties in which the finite mind of man becomes involved when it attempts to deal with what is not thinkably finite—or, if the term be preferred, infinite. In the first place, the theory under consideration assumes the finiteness in amount of matter and motion; but we do not know, nor can we imagine, that space has bounds, neither can we limit the extent of the orbs and movements which, as far as we can see, occupy it.

Secondly, the theory makes another conjecture in the realm of the absolute, when it presumes that heat is an absolutely homogeneous motion—that particles endowed with it move with so perfect a uniformity that there is an exclusion of any difference of motion which might serve as a starting-point for mechanical changes. But has science advanced far enough to make such a proposition tenable? Our knowledge of the ultimate structure of matter is very restricted; and as to what the modes of motion are which we call heat, electricity, and so on, we are entirely in the dark. Their quantities we know, but their qualities, their peculiar orbits, have scarcely been guessed at as yet. From a variety of reasons, however, the modern opinion, like the ancient one, is that matter is made up of atoms, which in the circumstances are units even if ideally divisible. Approximate measurements of them have been made by Prof. Sir William Thomson himself. (*See* his paper in *Nature*, vol. i., p. 551.)

Now, if atoms by virtue of their heat moved uninterruptedly in a simple straight line, their motion would be uniform and undifferenced; but, as neither the position nor the size of a mass undergoes change when temperature does not vary, atomic paths must suffer oft-repeated stops. Elastic particles in this state must have incessantly fluctuating velocities, yet always oscillating about a fixed mean. Matter endued with heat cannot have its particles in absolute contact, or the compressibility or contractibility which is the inseparable property of any mass would not exist. For argument's sake, however, let it be admitted that from absolute contact or any other cause heat-motion is a uniform one. If it be a purely axial rotation, then the equators of the atoms move faster than the poles, and the movement is not homogeneous. Exactly so, if the atom describe as an orbit a circle, ellipse, or other figure recurrently. Such motion would involve axial rotation, the atom would resemble our earth, and different parts of it would move with different velocities. In the case of two tangible spheres of like dimensions it is easy to show that, when swiftly moving at an equal rate, the speed of the one can be accelerated at the expense of the other, by applying it at a point not equatorial to the equator of its neighbor. In some such way it is conceivable that differences in molecular motion may widen from those subsisting between the parts of an individual molecule.

The imperfect homogeneity of thermal motion, which is here contended for, has some palpable parallels in the distribution of two other phases of energy—electricity of high tension and magnetism; these forces are cumulative in their manifestations, increasing in intensity toward the poles of the masses presenting them.

Thirdly, it is not strictly an accurate premise in the theory that, when heat is produced from any other force, it is unaccompanied by any phase of energy not thermal. Increments of heat invariably alter the dimensions of bodies, as a rule expand them, and thus part of the original energy applied appears as gravity. The sun in warming the earth's atmosphere lifts it, and, when the air cools, its fall is of no insignificant dynamic value. What is so evident in this extreme case is true of any mass whatever when heated. Not only is heat pitted against gravity, but at times against cohesive and crystalline forces, which, though overcome, must modify and diminish its effects.

There is a check to the continuous increase of temperature which is of much more importance than those just noted, but akin to them. A compound substance receives additions of heat with tolerable evenness up to a certain point, when it is resolved into two or more simple constituents, according to its complexity. These if compound are in turn decomposed into their chemical elements if more heat be applied. Now, chemical energy is a motion quite distinct by itself, and we find that heat in its higher degrees must coexist with it. So that on this account we cannot accept the notion that heat is ever to become the only kind of motion in the universe. In so doing we recognize another reason for believing that Nature will never attain absolute equilibrium, from the variety of forces ever abiding together within her sphere.

Fourthly, our present inability to obtain the movement of masses from the motion of molecules or small masses—that is, the derivation of work from uniformly heated matter—does not decide that such conversion is impossible in Nature, or even to science in the future. While it is perfectly right to reason from what we know, it is of yet higher importance to constantly bear in mind how little we know. It would require infinite knowledge to say that the motion of uniform heat may not be transformable into phases of energy quite as diverse as high and low temperatures.

Such a change would not contravene the truth of the uncreatability or indestructibility of force, but would simply be an enlargement of the known, which every one feels to be indefinitely small as compared with the knowable. The possibility here suggested may be conceivable as depending on the definiteness in size of atoms; or, on the variety of motions to which the differences between atoms, as chemical elements, may give rise—differences in size and form; or, on the variety of motions implied by the checks offered to steady accessions of temperature, already explained in this paper.

One of the first principles to which the mind clings as fundamental is, that every truth has its converse. Although this may seem an axiom, yet its demonstration may be often very difficult, and, at times, even impossible. A knife-blade held over a gas-flame for a moment shows that hydrogen and oxygen combine to form watery vapor; yet the proof of the converse—the decomposition of water into its elements—demands extensive and powerful apparatus. Oersted, in a happy hour, noticed that an electric wire moved a magnetic needle; but years of experiment had to elapse before the electro-magnet and the magneto-electric machine established the complementary principles in a practical form. The analysis of compounds, chemically, is vastly easier than the building them up from their elements. We know the exact percentages of carbon, hydrogen, and oxygen, that go to make up sugar, and can express to a nicety the dynamical relations of the compound to its elements; but *how* to bring about the changes desired, with economy, is what puzzles us.

When we see high and low temperatures coming to an equality, it is certainly permissible to entertain faith in the possibility of the converse; in a change equivalent to a mass becoming, in its several parts, hotter and colder. To have recourse to such a supposition is less straining to the mind than the alternatives usually proposed by the theory under consideration.

If that theory be true, the question suggests itself, "Why has not the universe come to death by this time, for limits cannot be imagined to past duration?"

To this two replies have been given by the maintainers of the theory: That the universe has either had a beginning in time; or that, if it be really eternal, there are revolutions in its laws unknowable to man—interpositions of Creative Will!

These men of science are plainly not afraid of carrying out their opinions rigorously to their logical conclusions, but is their information as to the nature and relations of the phases of energy wide and deep enough to warrant them in framing an hypothesis so lofty as to include the cosmos and eternity? Hardly.

At the present stage of science, a student pondering the subject so briefly presented here may be compared to a judge before whom a few witnesses in an important case have appeared. As he hears each one, he makes, for convenience' sake, a provisional summing-up, and tacks the testimony together in one directive line. But it would be a most injudicial act to mistake a provisional opinion for a final judgment, and, with an indefinite number of witnesses unheard, to pronounce sentence of death.

ILLUSTRATIONS OF THE LOGIC OF SCIENCE.

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FOURTH PAPER.—THE PROBABILITY OF INDUCTION.

I.

WE have found that every argument derives its force from the general truth of the class of inferences to which it belongs; and that probability is the proportion of arguments carrying truth with them among those of any *genus*. This is most conveniently expressed in the nomenclature of the mediæval logicians. They called the fact expressed by a premise an *antecedent*, and that which follows from it its *consequent;* while the leading principle, that every (or almost every) such antecedent is followed by such a consequent, they termed the *consequence*. Using this language, we may say that probability belongs exclusively to *consequences*, and the probability of any consequence is the number of times in which antecedent and consequent both occur divided by the number of all the times in which the antecedent occurs. From this definition are deduced the following rules for the addition and multiplication of probabilities:

Rule for the Addition of Probabilities.—Given the separate probabilities of two consequences having the same antecedent and incompatible consequents. Then the sum of these two numbers is the probability of the consequence, that from the same antecedent one or other of those consequents follows.

Rule for the Multiplication of Probabilities.—Given the separate probabilities of the two consequences, "If A then B," and "If both A and B, then C." Then the product of these two numbers is the probability of the consequence, "If A, then both B and C."

Special Rule for the Multiplication of Independent Probabilities.—Given the separate probabilities of two consequences having the same antecedents, "If A, then B," and "If A, then C." Suppose that these consequences are such that the probability of the second is equal to the probability of the consequence, "If both A and B, then C." Then the product of the two given numbers is equal to the probability of the consequence, "If A, then both B and C."

To show the working of these rules we may examine the probabilities in regard to throwing dice. What is the probability of throwing a six with one die? The antecedent here is the event of throwing a die; the consequent, its turning up a six. As the die has six sides, all of which are turned up with equal frequency, the probability of turning up any one is $\frac{1}{6}$. Suppose two dice are thrown, what is the probability of throwing sixes? The probability of either coming up six is obviously the same when both are thrown as when one is thrown—namely, $\frac{1}{6}$. The probability that either will come up six when the other does is also the same as that of its coming up six whether the other does or not. The probabilities are, therefore, independent; and, by our rule, the probability that both events will happen together is the product of their several probabilities, or $\frac{1}{6} \times \frac{1}{6}$. What is the probability of throwing deuce-ace? The probability that the first die will turn up ace and the second deuce is the same as the probability that both will turn up sixes—namely, $\frac{1}{36}$; the probability that the *second* will turn up ace and the *first* deuce is likewise $\frac{1}{36}$; these two events—first, ace; second, deuce; and, second, ace; first, deuce—are incompatible. Hence the rule for addition holds, and the probability that either will come up ace and the other deuce is $\frac{1}{36} + \frac{1}{36}$, or $\frac{1}{18}$.

In this way all problems about dice, etc., may be solved. When the number of dice thrown is supposed very large, mathematics (which may be defined as the art of making groups to facilitate numeration) comes to our aid with certain devices to reduce the difficulties.

II.

The conception of probability as a matter of *fact*, i. e., as the proportion of times in which an occurrence of one kind is accompanied by an occurrence of another kind, is termed by Mr. Venn the materialistic view of the subject. But probability has often been regarded as being simply the degree of belief which ought to attach to a proposition; and this mode of explaining the idea is termed by Venn the conceptualistic view. Most writers have mixed the two conceptions together. They, first, define the probability of an event as the reason we have to believe that it has taken place, which is conceptualistic; but shortly after they state that it is the ratio of the number of cases favorable to the event to the total number of cases favorable or contrary, and all equally possible. Except that this introduces the thoroughly unclear idea of cases equally possible in place of cases equally frequent, this is a tolerable statement of the materialistic view. The pure conceptualistic theory has been best expounded by Mr. De Morgan in his "Formal Logic: or, the Calculus of Inference, Necessary and Probable."

The great difference between the two analyses is, that the conceptualists refer probability to an event, while the materialists make it the ratio of frequency of events of a *species* to those of a *genus* over that *species*, thus *giving it two terms instead of one.* The opposition may be made to appear as follows:

Suppose that we have two rules of inference, such that, of all the questions to the solution of which both can be applied, the first yields correct answers to $\frac{81}{100}$, and incorrect answers to the remaining $\frac{19}{100}$; while the second yields correct answers to $\frac{93}{100}$, and incorrect answers to the remaining $\frac{7}{100}$. Suppose, further, that the two rules are entirely independent as to their truth, so that the second answers correctly $\frac{93}{100}$ of the questions which the first answers correctly, and also $\frac{93}{100}$ of the questions which the first answers incorrectly, and answers incorrectly the remaining $\frac{7}{100}$ of the questions which the first answers correctly, and also the remaining $\frac{7}{100}$ of the questions which the first answers incorrectly. Then, of all the questions to the solution of which both rules can be applied—

both answer correctly . . . . $\frac{93}{100}$ of $\frac{81}{100}$, or $\frac{93 \times 81}{100 \times 100}$;

the second answers correctly and the first incorrectly . . . . . $\frac{93}{100}$ of $\frac{19}{100}$, or $\frac{93 \times 19}{100 \times 100}$;

the second answers incorrectly and the first correctly . . . . . $\frac{7}{100}$ of $\frac{81}{100}$, or $\frac{7 \times 81}{100 \times 100}$;

and both answer correctly . . . . $\frac{7}{100}$ of $\frac{19}{100}$, or $\frac{7 \times 19}{100 \times 100}$;

Suppose, now, that, in reference to any question, both give the same answer. Then (the questions being always such as are to be answered by *yes* or *no*), those in reference to which their answers agree are the same as those which both answer correctly together with those which both answer falsely, or $\frac{93 \times 81}{100 \times 100} + \frac{7 \times 19}{100 \times 100}$ of all. The proportion of those which both answer correctly out of those their answers to which agree is, therefore—

$$\frac{\frac{93 \times 81}{100 \times 100}}{\frac{93 \times 81}{100 \times 100} + \frac{7 \times 19}{100 \times 100}} \text{ or } \frac{93 \times 81}{(93 \times 81) + (7 \times 19)}.$$

This is, therefore, the probability that, if both modes of inference yield the same result, that result is correct. We may here conveniently make use of another mode of expression. *Probability* is the ratio of the favorable cases to all the cases. Instead of expressing our result in terms of this ratio, we may make use of another—the ratio of favorable to unfavorable cases. This last ratio may be called the *chance* of an event. Then the chance of a true answer by the first mode of inference is $\frac{81}{19}$ and by the second is $\frac{93}{7}$; and the chance of a correct answer from both, when they agree, is—

$$\frac{81 \times 93}{19 \times 7} \text{ or } \frac{81}{19} \times \frac{93}{7},$$

or the product of the chances of each singly yielding a true answer.

It will be seen that a chance is a quantity which may have any magnitude, however great. An event in whose favor there is an even chance, or $\frac{1}{1}$, has a probability of $\frac{1}{2}$. An argument having an even chance can do nothing toward reënforcing others, since according to the rule its combination with another would only multiply the chance of the latter by 1.

Probability and chance undoubtedly belong primarily to consequences, and are relative to premises; but we may, nevertheless, speak of the chance of an event absolutely, meaning by that the chance of the combination of all arguments in reference to it which exist for us in the given state of our knowledge. Taken in this sense it is incontestable that the chance of an event has an intimate connection with the degree of our belief in it. Belief is certainly something more than a mere feeling; yet there is a feeling of believing, and this feeling does and ought to vary with the chance of the thing believed, as deduced from all the arguments. Any quantity which varies with the chance might, therefore, it would seem, serve as a thermometer for the proper intensity of belief. Among all such quantities there is one which is peculiarly appropriate. When there is a very great chance, the feeling of belief ought to be very intense. Absolute certainty, or an infinite chance, can never be attained by mortals, and this may be represented appropriately by an infinite belief. As the chance diminishes the feeling of believing should diminish, until an even chance is reached, where it should completely vanish and not incline either toward or away from the proposition. When the chance becomes less, then a contrary belief should spring up and should increase in intensity as the chance diminishes, and as the chance almost vanishes (which it can never quite do) the contrary belief should tend toward an infinite intensity. Now, there is one quantity which, more simply than any other, fulfills these conditions; it is the *logarithm* of the chance. But there is another consideration which must, if admitted, fix us to this choice for our thermometer. It is that our belief ought to be proportional to the weight of evidence, in this sense, that two arguments which are entirely independent, neither weakening nor strengthening each other, ought, when they concur, to produce a belief equal to the sum of the intensities of belief which either would produce separately. Now, we have seen that the chances of independent concurrent arguments are to be multiplied together to get the chance of their combination, and therefore the quantities which best express the intensities of belief should be such that they are to be *added* when the *chances* are multiplied in order to produce the quantity which corresponds to the combined chance. Now, the logarithm is the only quantity which fulfills this condition. There is a general law of sensibility, called Fechner's psychophysical law. It is that the intensity of any sensation is proportional to the logarithm of the external force which produces it. It is entirely in harmony with this law that the feeling of belief should be as the logarithm of the chance, this latter being the expression of the state of facts which produces the belief.

The rule for the combination of independent concurrent arguments takes a very simple form when expressed in terms of the intensity of belief, measured in the proposed way. It is this: Take the sum of all the feelings of belief which would be produced separately by all the arguments *pro*, subtract from that the similar sum for arguments *con*, and the remainder is the feeling of belief which we ought to have on the whole. This is a proceeding which men often resort to, under the name of *balancing reasons.*

These considerations constitute an argument in favor of the conceptualistic view. The kernel of it is that the conjoint probability of all the arguments in our possession, with reference to any fact, must be intimately connected with the just degree of our belief in that fact; and this point is supplemented by various others showing the consistency of the theory with itself and with the rest of our knowledge.

But probability, to have any value at all, must express a fact. It is, therefore, a thing to be inferred upon evidence. Let us, then, consider for a moment the formation of a belief of probability. Suppose we have a large bag of beans from which one has been secretly taken at random and hidden under a thimble. We are now to form a probable judgment of the color of that bean, by drawing others singly from the bag and looking at them, each one to be thrown back, and the whole well mixed up after each drawing. Suppose the first drawing is white and the next black. We conclude that there is not an immense preponderance of either color, and that there is something like an even chance that the bean under the thimble is black. But this judgment may be altered by the next few drawings. When we have drawn ten times, if 4, 5, or 6, are white, we have more confidence that the chance is even. When we have drawn a thousand times, if about half have been white, we have great confidence in this result.

We now feel pretty sure that, if we were to make a large number of bets upon the color of single beans drawn from the bag, we could approximately insure ourselves in the long run by betting each time upon the white, a confidence which would be entirely wanting if, instead of sampling the bag by 1,000 drawings, we had done so by only two. Now, as the whole utility of probability is to insure us in the long run, and as that assurance depends, not merely on the value of the chance, but also on the accuracy of the evaluation, it follows that we ought not to have the same feeling of belief in reference to all events of which the chance is even. In short, to express the proper state of our belief, not *one* number but *two* are requisite, the first depending on the inferred probability, the second on the amount of knowledge on which that probability is based.[1] It is true that when our knowledge is very precise, when we have made many drawings from the bag, or, as in most of the examples in the books, when the total contents of the bag are absolutely known, the number which expresses the uncertainty of the assumed probability and its liability to be changed by further experience may become insignificant, or utterly vanish. But, when our knowledge is very slight, this number may be even more important than the probability itself; and when we have no knowledge at all this completely overwhelms the other, so that there is no sense in saying that the chance of the totally unknown event is even (for what expresses absolutely no fact has absolutely no meaning), and what ought to be said is that the chance is entirely indefinite. We thus perceive that the conceptualistic view, though answering well enough in some cases, is quite inadequate.

Suppose that the first bean which we drew from our bag were black. That would constitute an argument, no matter how slender, that the bean under the thimble was also black. If the second bean were also to turn out black, that would be a second independent argument reënforcing the first. If the whole of the first twenty beans drawn should prove black, our confidence that the hidden bean was black would justly attain considerable strength. But suppose the twenty-first bean were to be white and that we were to go on drawing until we found that we had drawn 1,010 black beans and 990 white ones. We should conclude that our first twenty beans being black was simply an extraordinary accident, and that in fact the proportion of white beans to black was sensibly equal, and that it was an even chance that the hidden bean was black. Yet according to the rule of *balancing reasons*, since all the drawings of black beans are so many independent arguments in favor of the one under the thimble being black, and all the white drawings so many against it, an excess of twenty black beans ought to produce the same degree of belief that the hidden bean was black, whatever the total number drawn.

[1] Strictly we should need an infinite series of numbers each depending on the probable error of the last.

In the conceptualistic view of probability, complete ignorance, where the judgment ought not to swerve either toward or away from the hypothesis, is represented by the probability $\frac{1}{2}$.[1]

But let us suppose that we are totally ignorant what colored hair the inhabitants of Saturn have. Let us, then, take a color-chart in which all possible colors are shown shading into one another by imperceptible degrees. In such a chart the relative areas occupied by different classes of colors are perfectly arbitrary. Let us inclose such an area with a closed line, and ask what is the chance on conceptualistic principles that the color of the hair of the inhabitants of Saturn falls within that area? The answer cannot be indeterminate because we must be in some state of belief; and, indeed, conceptualistic writers do not admit indeterminate probabilities. As there is no certainty in the matter, the answer lies between *zero* and *unity*. As no numerical value is afforded by the data, the number must be determined by the nature of the scale of probability itself, and not by calculation from the data. The answer can, therefore, only be one-half, since the judgment should neither favor nor oppose the hypothesis. What is true of this area is true of any other one; and it will equally be true of a third area which embraces the other two. But the probability for each of the smaller areas being one-half, that for the larger should be at least unity, which is absurd.

III.

All our reasonings are of two kinds: 1. *Explicative*, *analytic*, or *deductive*; 2. *Amplifiative*, *synthetic*, or (loosely speaking) *inductive*. In explicative reasoning, certain facts are first laid down in the premises. These facts are, in every case, an inexhaustible multitude, but they may often be summed up in one simple proposition by means of some regularity which runs through them all. Thus, take the proposition that Socrates was a man; this implies (to go no further) that during every fraction of a second of his whole life (or, if you please, during the greater part of them) he was a man. He did not at one instant appear as a tree and at another as a dog; he did not flow into water, or appear in two places at once; you could not put your finger through him as if he were an optical image, etc. Now, the facts being thus laid down, some order among some of them, not particularly made use of for the purpose of stating them, may perhaps be discovered; and this will enable us to throw part or all of them into a new statement, the possibility of which might have escaped attention. Such a statement will be the conclusion of an analytic inference. Of this sort are all mathematical demonstrations. But synthetic reasoning is of another kind. In this case the facts summed up in the conclusion are not among those stated in the prem-

[1] "Perfect indecision, belief inclining neither way, an even chance."—De Morgan, p. 182.

ises. They are different facts, as when one sees that the tide rises m times and concludes that it will rise the next time. These are the only inferences which increase our real knowledge, however useful the others may be.

In any problem in probabilities, we have given the relative frequency of certain events, and we perceive that in these facts the relative frequency of another event is given in a hidden way. This being stated makes the solution. This is therefore mere explicative reasoning, and is evidently entirely inadequate to the representation of synthetic reasoning, which goes out beyond the facts given in the premises. There is, therefore, a manifest impossibility in so tracing out any probability for a synthetic conclusion.

Most treatises on probability contain a very different doctrine. They state, for example, that if one of the ancient denizens of the shores of the Mediterranean, who had never heard of tides, had gone to the bay of Biscay, and had there seen the tide rise, say m times, he could know that there was a probability equal to

$$\frac{m+1}{m+2}$$

that it would rise the next time. In a well-known work by Quetelet, much stress is laid on this, and it is made the foundation of a theory of inductive reasoning.

But this solution betrays its origin if we apply it to the case in which the man has never seen the tide rise at all; that is, if we put $m = 0$. In this case, the probability that it will rise the next time comes out $\frac{1}{2}$, or, in other words, the solution involves the conceptualistic principle that there is an even chance of a totally unknown event. The manner in which it has been reached has been by considering a number of urns all containing the same number of balls, part white and part black. One urn contains all white balls, another one black and the rest white, a third two black and the rest white, and so on, one urn for each proportion, until an urn is reached containing only black balls. But the only possible reason for drawing any analogy between such an arrangement and that of Nature is the principle that alternatives of which we know nothing must be considered as equally probable. But this principle, is absurd. There is an indefinite variety of ways of enumerating the different possibilities, which, on the application of this principle, would give different results. If there be any way of enumerating the possibilities so as to make them all equal, it is not that from which this solution is derived, but is the following: Suppose we had an immense granary filled with black and white balls well mixed up; and suppose each urn were filled by taking a fixed number of balls from this granary quite at random. The relative number of white balls in the granary might be anything, say one in three. Then in one-third of the urns the first ball would be white, and in two-thirds black. In one-third of those urns of which the first ball was white, and also in one-third of those in which the first ball was black, the second ball would be white. In this way, we should have a distribution like that shown in the following table, where *w* stands for a white ball and *b* for a black one. The reader can, if he chooses, verify the table for himself.

wwww.					
wwwb.	wwbw.	wbww.	bwww.		
wwwb.	wwbw.	wbww.	bwww.		
wwbb.	wbwb.	bwwb.	wbbw.	bwbw.	bbww.
wwbb.	wbwb.	bwwb.	wbbw.	bwbw.	bbww.
wwbb.	wbwb.	bwwb.	wbbw.	bwbw.	bbww.
wwbb.	wbwb.	bwwb.	wbbw.	bwbw.	bbww.
wbbb.	bwbb.	bbwb.	bbbw.		
wbbb.	bwbb.	bbwb.	bbbw.		
wbbb.	bwbb.	bbwb.	bbbw.		
wbbb.	bwbb.	bbwb.	bbbw.		
wbbb.	bwbb.	bbwb.	bbbw.		
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In the second group, where there is one b, there are two sets just alike; in the third there are 4, in the fourth 8, and in the fifth 16, doubling every time. This is because we have supposed twice as many black balls in the granary as white ones; had we supposed 10 times as many, instead of

1, 2, 4, 8, 16

sets we should have had

1, 10, 100, 1000, 10000

sets; on the other hand, had the numbers of black and white balls in the granary been even, there would have been but one set in each group. Now suppose two balls were drawn from one of these urns and were found to be both white, what would be the probability of the next one being white? If the two drawn out were the first two put into the urns, and the next to be drawn out were the third put in, then the probability of this third being white would be the same whatever the colors of the first two, for it has been supposed that just the same proportion of urns has the third ball white among those which have the first two *white-white*, *white-black*, *black-white*, and *black-black*. Thus, in this case, the chance of the third ball being white would be the same whatever the first two were. But, by inspecting the table, the reader can see that in each group all orders of the balls occur with equal frequency, so that it makes no difference whether they are drawn out in the order they were put in or not. Hence the colors of the balls already drawn have no influence on the probability of any other being white or black.

Now, if there be any way of enumerating the possibilities of Nature so as to make them equally probable, it is clearly one which should make one arrangement or combination of the elements of Nature as probable as another, that is, a distribution like that we have supposed, and it, therefore, appears that the assumption that any such thing can be done, leads simply to the conclusion that reasoning from past to future experience is absolutely worthless. In fact, the moment that you assume that the chances in favor of that of which we are totally ignorant are even, the problem about the tides does not differ, in any arithmetical particular, from the case in which a penny (known to be equally likely to come up heads and tails) should turn up heads *m* times successively. In short, it would be to assume that Nature is a pure chaos, or chance combination of independent elements, in which reasoning from one fact to another would be impossible; and since, as we shall hereafter see, there is no judgment of pure observation without reasoning, it would be to suppose all human cognition illusory and no real knowledge possible. It would be to suppose that if we have found the order of Nature more or less regular in the past, this has been by a pure run of luck which we may expect is now at an end. Now, it may be we have no scintilla of proof to the contrary, but reason is unnecessary in reference to that belief which is of all the most settled, which nobody doubts or can doubt, and which he who should deny would stultify himself in so doing.

The relative probability of this or that arrangement of Nature is something which we should have a right to talk about if universes were as plenty as blackberries, if we could put a quantity of them in a bag, shake them well up, draw out a sample, and examine them to see what proportion of them had one arrangement and what proportion another. But, even in that case, a higher universe would contain us, in regard to whose arrangements the conception of probability could have no applicability.

IV.

We have examined the problem proposed by the conceptualists, which, translated into clear language, is this: Given a synthetic conclusion; required to know out of all possible states of things how many will accord, to any assigned extent, with this conclusion; and we have found that it is only an absurd attempt to reduce synthetic to analytic reason, and that no definite solution is possible.

But there is another problem in connection with this subject. It is this: Given a certain state of things, required to know what proportion of all synthetic inferences relating to it will be true within a given degree of approximation. Now, there is no difficulty about this problem (except for its mathematical complication); it has been much studied, and the answer is perfectly well known. And is not this, after all, what we want to know much rather than the other? Why should we want to know the probability that the fact will accord with our conclusion? That implies that we are interested in all possible worlds, and not merely the one in which we find ourselves placed. Why is it not much more to the purpose to know the probability that our conclusion will accord with the fact? One of these questions is the first above stated and the other the second, and I ask the reader whether, if people, instead of using the word probability without any clear apprehension of their own meaning, had always spoken of relative frequency, they could have failed to see that what they wanted was not to follow along the synthetic procedure with an analytic one, in order to find the probability of the conclusion; but, on the contrary, to begin with the fact at which the synthetic inference aims, and follow back to the facts it uses for premises in order to see the probability of their being such as will yield the truth.

As we cannot have an urn with an infinite number of balls to represent the inexhaustibleness of Nature, let us suppose one with a finite number, each ball being thrown back into the urn after being drawn out, so that there is no exhaustion of them. Suppose one ball out of three is white and the rest black, and that four balls are drawn. Then the table on page 713 represents the relative frequency of the different ways in which these balls might be drawn. It will be seen that if we should judge by these four balls of the proportion in the urn, 32 times out of 81 we should find it $\frac{1}{4}$, and 24 times out of 81 we should find it $\frac{1}{2}$, the truth being $\frac{1}{3}$. To extend this table to high numbers would be great labor, but the mathematicians have found some ingenious ways of reckoning what the numbers would be. It is found that, if the true proportion of white balls is p, and s balls are drawn, then the error of the proportion obtained by the induction will be—

half the time within	$0.477\sqrt{\frac{2p(1-p)}{s}}$
9 times out of 10 within	$1.163\sqrt{\frac{2p(1-p)}{s}}$
99 times out of 100 within	$1.821\sqrt{\frac{2p(1-p)}{s}}$
999 times out of 1,000 within	$2.328\sqrt{\frac{2p(1-p)}{s}}$
9,999 times out of 10,000 within	$2.751\sqrt{\frac{2p(1-p)}{s}}$
9,999,999,999 times out of 10,000,000,000 within	$4.77\sqrt{\frac{2p(1-p)}{s}}$

The use of this may be illustrated by an example. By the census of 1870, it appears that the proportion of males among native white children under one year old was 0.5082, while among colored children of the same age the proportion was only 0.4977. The difference between these is 0.0105, or about one in a 100. Can this be attributed to chance, or would the difference always exist among a great number of white and colored children under like circumstances? Here p may be taken at $\frac{1}{2}$; hence $2p\ (1-p)$ is also $\frac{1}{2}$. The number of white children counted was near 1,000,000; hence the fraction whose square-root is to be taken is about $\frac{1}{2000000}$. The root is about $\frac{1}{1400}$, and this multiplied by 0.477 gives about 0.0003 as the probable error in the ratio of males among the whites as obtained from the induction. The number of black children was about 150,000, which gives 0.0008 for the probable error. We see that the actual discrepancy is ten times the sum of these, and such a result would happen, according to our table, only once out of 10,000,000,000 censuses, in the long run.

It may be remarked that when the real value of the probability sought inductively is either very large or very small, the reasoning is more secure. Thus, suppose there were in reality one white ball in 100 in a certain urn, and we were to judge of the number by 100 drawings. The probability of drawing no white ball would be $\frac{366}{1000}$; that of drawing one white ball would be $\frac{370}{1000}$; that of drawing two would be $\frac{185}{1000}$; that of drawing three would be $\frac{61}{1000}$; that of drawing four would be $\frac{15}{1000}$; that of drawing five would be only $\frac{3}{1000}$, etc. Thus we should be tolerably certain of not being in error by more than one ball in 100.

It appears, then, that in one sense we can, and in another we cannot, determine the probability of synthetic inference. When I reason in this way:

Ninety-nine Cretans in a hundred are liars;
But Epimenides is a Cretan;
Therefore, Epimenides is a liar:—

I know that reasoning similar to that would carry truth 99 times in 100. But when I reason in the opposite direction:

Minos, Sarpedon, Rhadamanthus, Deucalion, and Epimenides, are all the Cretans I can think of;
But these were all atrocious liars,
Therefore, pretty much all Cretans must have been liars;

I do not in the least know how often such reasoning would carry me right. On the other hand, what I do know is that some definite proportion of Cretans must have been liars, and that this proportion can be probably approximated to by an induction from five or six instances. Even in the worst case for the probability of such an inference, that in which about half the Cretans are liars, the ratio so obtained would probably not be in error by more than $\frac{1}{6}$. So much

I know; but, then, in the present case the inference is that pretty much all Cretans are liars, and whether there may not be a special improbability in that I do not know.

V.

Late in the last century, Immanuel Kant asked the question, "How are synthetical judgments *a priori* possible?" By synthetical judgments he meant such as assert positive fact and are not mere affairs of arrangement; in short, judgments of the kind which synthetical reasoning produces, and which analytic reasoning cannot yield. By *a priori* judgments he meant such as that all outward objects are in space, every event has a cause, etc., propositions which according to him can never be inferred from experience. Not so much by his answer to this question as by the mere asking of it, the current philosophy of that time was shattered and destroyed, and a new epoch in its history was begun. But before asking *that* question he ought to have asked the more general one, "How are any synthetical judgments at all possible?" How is it that a man can observe one fact and straightway pronounce judgment concerning another different fact not involved in the first? Such reasoning, as we have seen, has, at least in the usual sense of the phrase, no definite probability; how, then, can it add to our knowledge? This is a strange paradox; the Abbé Gratry says it is a miracle, and that every true induction is an immediate inspiration from on high.[1] I respect this explanation far more than many a pedantic attempt to solve the question by some juggle with probabilities, with the forms of syllogism, or what not. I respect it because it shows an appreciation of the depth of the problem, because it assigns an adequate cause, and because it is intimately connected—as the true account should be—with a general philosophy of the universe. At the same time, I do not accept this explanation, because an explanation should tell *how* a thing is done, and to assert a perpetual miracle seems to be an abandonment of all hope of doing that, without sufficient justification.

It will be interesting to see how the answer which Kant gave to his question about synthetical judgments *a priori* will appear if extended to the question of synthetical judgments in general. That answer is, that synthetical judgments *a priori* are possible because whatever is universally true is involved in the conditions of experience. Let us apply this to a general synthetical reasoning. I take from a bag a handful of beans; they are all purple, and I infer that all the beans in the bag are purple. How can I do that? Why, upon the principle that whatever is universally true of my experience (which

[1] *Logique.* The same is true, according to him, of every performance of a differentiation, but not of integration. He does not tell us whether it is the supernatural assistance which makes the former process so much the easier.

is here the appearance of these different beans) is involved in the condition of experience. The condition of this special experience is that all these beans were taken from that bag. According to Kant's principle, then, whatever is found true of all the beans drawn from the bag must find its explanation in some peculiarity of the contents of the bag. This is a satisfactory statement of the principle of induction.

When we draw a deductive or analytic conclusion, our rule of inference is that facts of a certain general character are either invariably or in a certain proportion of cases accompanied by facts of another general character. Then our premise being a fact of the former class, we infer with certainty or with the appropriate degree of probability the existence of a fact of the second class. But the rule for synthetic inference is of a different kind. When we sample a bag of beans we do not in the least assume that the fact of some beans being purple involves the necessity or even the probability of other beans being so. On the contrary, the conceptualistic method of treating probabilities, which really amounts simply to the deductive treatment of them, when rightly carried out leads to the result that a synthetic inference has just an even chance in its favor, or in other words is absolutely worthless. The color of one bean is entirely independent of that of another. But synthetic inference is founded upon a classification of facts, not according to their characters, but according to the manner of obtaining them. Its rule is, that a number of facts obtained in a given way will in general more or less resemble other facts obtained in the same way; or, *experiences whose conditions are the same will have the same general characters.*

In the former case, we know that premises precisely similar in form to those of the given ones will yield true conclusions, just once in a calculable number of times. In the latter case, we only know that premises obtained under circumstances similar to the given ones (though perhaps themselves very different) will yield true conclusions, at least once in a calculable number of times. We may express this by saying that in the case of analytic inference we know the probability of our conclusion (if the premises are true), but in the case of synthetic inferences we only know the degree of trustworthiness of our proceeding. As all knowledge comes from synthetic inference, we must equally infer that all human certainty consists merely in our knowing that the processes by which our knowledge has been derived are such as must generally have led to true conclusions.

Though a synthetic inference cannot by any means be reduced to deduction, yet that the rule of induction will hold good in the long run may be deduced from the principle that reality is only the object of the final opinion to which sufficient investigation would lead. That belief gradually tends to fix itself under the influence of inquiry is, indeed, one of the facts with which logic sets out.

ON EDISON'S TALKING-MACHINE.[1]

By ALFRED M. MAYER.

MR. THOMAS A. EDISON has recently invented an instrument which is undoubtedly the acoustic marvel of the century. It is called the "Speaking Phonograph," or, adopting the Indian idiom, one may aptly call it "*The Sound-Writer who talks.*" Much curiosity has been expressed as to the workings of this instrument, so I purpose giving an account of it.

All talking-machines may be reduced to two types. That of Prof. Faber, of Vienna, is the most perfect example of one type; that of Mr. Edison is the only example of the other.

Faber worked at the source of articulate sounds, and built up an artificial organ of speech, whose parts, as nearly as possible, perform the same functions as corresponding organs in our vocal apparatus. A vibrating ivory reed, of variable pitch, forms its vocal chords. There is an oral cavity, whose size and shape can be rapidly changed by depressing the keys on a key-board. A rubber tongue and lips make the consonants; a little windmill, turning in its throat, rolls the letter *R*, and a tube is attached to its nose when it speaks French. This is the anatomy of this really wonderful piece of mechanism.

Faber attacked the problem on its physiological side. Quite differently works Mr. Edison: he attacks the problem, not at the source of origin of the vibrations which make articulate speech, but, considering these vibrations as already made, it matters not how, he makes these vibrations impress themselves on a sheet of metallic foil, and then reproduces from these impressions the sonorous vibrations which made them.

Faber solved the problem by reproducing the mechanical *causes* of the vibrations making voice and speech; Edison solved it by obtaining the mechanical *effects* of these vibrations. Faber reproduced the movements of our vocal organs; Edison reproduced the motions which the drum-skin of the ear has when this organ is acted on by the vibrations *caused* by the movements of the vocal organs.

Figs. 1 and 2 will render intelligible the construction of Mr. Edison's machine. A cylinder, *F*, turns on an axle which passes through the two standards, *A* and *B*. On one end of this axle is the crank, *D*; on the other the fly-wheel, *E*. The portion of this axle to the right of the cylinder has a screw-thread cut on it, which, working in a nut, *A*, causes the cylinder to move laterally when the crank is

[1] The figures in this article are taken from "Sound, a Series of Simple, Entertaining, and Inexpensive Experiments in the Phenomena of Sound, for the Use of Students of every Age." By Alfred M. Mayer. Vol. ii. of "Experimental Scienee Series for Beginners." (Now in press and soon to be published by D. Appleton & Co.)

turned. On the surface of the cylinder is scored the same thread as on its axle. At *F* (shown in one-half scale in Fig. 2) is a plate of iron, *A*, about $\frac{1}{100}$ of an inch thick. This plate can be moved toward and from the cylinder by pushing in or pulling out the lever *H G*, which turns in an horizontal plane around the pin *I*.

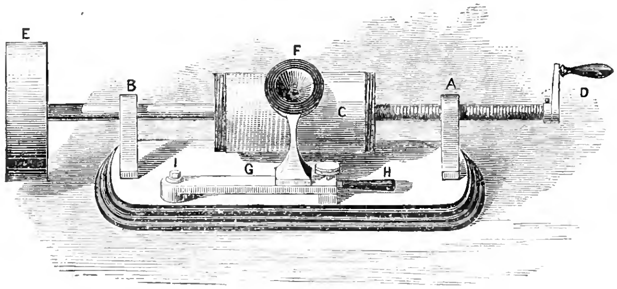

Fig. 1.—Edison's Talking-Phonograph.

The under side of this thin iron plate, *A* (Fig. 2), presses against short pieces of rubber tubing, *X* and *X*, which lie between the plate and a spring attached to *E*. The end of this spring carries a rounded steel point, *P*, which enters slightly between the threads scored on the cylinder *C*. The distance of this point, *P*, from the cylinder is regulated by a set-screw, *S*, against which abuts the lever, *H G*. Over the iron plate, *A*, is a disk of vulcanite, *B B*, with a hole in its centre. The under side of this disk nearly touches the plate *A*. Its upper surface is cut into a shallow, funnel-shaped cavity, leading to the opening in its centre.

To operate this machine, we first neatly coat the cylinder with a sheet of foil, made to adhere by gumming the corners; then we bring the point, *P*, to bear against this foil, so that, on turning the cylinder, it makes a depressed line, or furrow. The mouth is now placed close to the opening in the vulcanite disk, *B B*, and *the metal plate is talked to* while the cylinder is revolved with a uniform motion.

The plate, *A*, vibrates to the voice, and the point, *P*, indents the foil, impressing in it the varying numbers, amplitudes, and durations, of these vibrations. If the vibrations given by the voice are those causing simple sounds, and are of a uniform, regular character, then similar, regular, undulating depressions are made in the foil. If the vibrations are those causing complex and irregular sounds (like those of the voice in speaking), then, similarly, the depressions made in the foil are complex, having profiles like the curve, *B*, in Fig. 3. Thus the yielding and inelastic foil receives and *retains* the mechanical impressions of these vibrations with all their minute and subtile characteristics.

The permanent impressions of the vibrations of the voice are now made. It remains *to obtain from these impressions the aërial vibrations which made them.* Nothing is simpler. The plate *A*, with its point, *P*, is moved away from the cylinder by pulling toward you the lever *H G*. Then the motion of the cylinder is reversed till you have brought opposite to the point *P* the beginning of the series of impressions which it has made on the foil. Now bring the point up

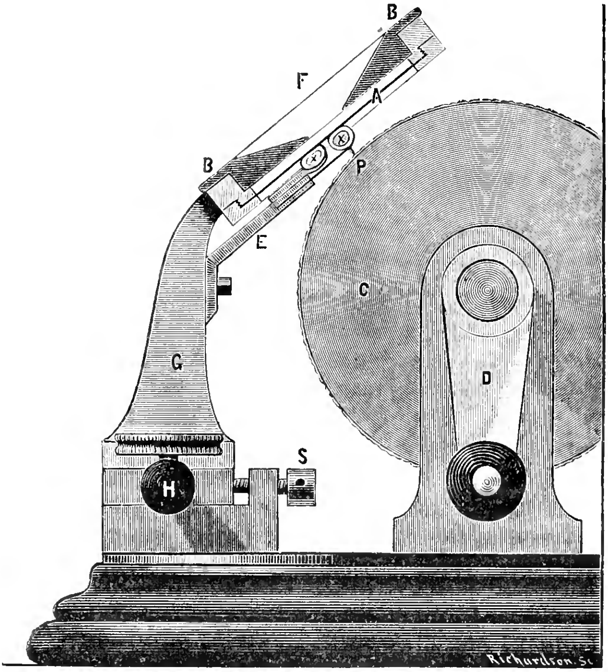

FIG. 2.

to the cylinder; place against the vulcanite plate, *B B*, a large cone of paper or tin to reënforce the sounds, and then steadily turn the crank *D*. The elevations and depressions which have been made by the point *P* now pass under this point, and in so doing they cause it and the thin iron plate to make over again the precise vibrations which animated them when they made these impressions under the action of the voice. The consequence of this is, that the iron plate gives out the vibrations which previously fell upon it, and it *talks back to you what you said to it.*

By the following method we have just obtained several magnified traces on smoked glass of the contour, or profile, of the elevations and depressions made in the foil by the sonorous vibrations. On the under side of the shorter arm of a delicate lever is a point, made as nearly as possible like the point *P* under the thin iron plate *A*. Cemented to the end of the longer arm of this lever is a pointed slip of thin copper-foil, which just touched the vertical surface of a smoked-glass plate. The point on the short arm of the lever rested in the furrow in which are the depressions and elevations made in the foil on the cylinder. Rotating the cylinder with a slow and uniform motion, while the plate of glass was slid along, the point of copper-foil scraped the lampblack off the smoked-glass plate and traced on it the magnified profile of the depressions and elevations in the foil on the cylinder. I say expressly *elevations* as well as depressions in the foil, because, when the plate vibrates outward, the furrow in the foil often entirely disappears, and is always lessened in its depth by this outward motion of the point. One who has never made a special investigation of the character of the impressions on the phonograph, and forms his opinion from their appearance to his eye, might state that they are simply dots and dashes, like the marks on the filet of a Morse instrument.

Another method of obtaining the profile of the impressions on the foil is to back it with an easily-fusible substance, and then, cutting through the middle of the furrows, we obtain a section, in which the edge of the foil presents to us the form of the elevations and depressions.

The instrument has been so short a time in my possession, that I have not had the leisure to make on it the careful and extended series of experiments which it deserves. I have, however, obtained several traces, and I have especially studied the characters of the trace of the sound of *bat*. As far as the few experiments warrant an expression of opinion, it seems that the profile of the impressions made on the phonograph and the contours of the flames of König, when vibrated by the same compound sound, bear a close resemblance.

In Fig. 3 we give on line *A* the appearance to the eye of the im-

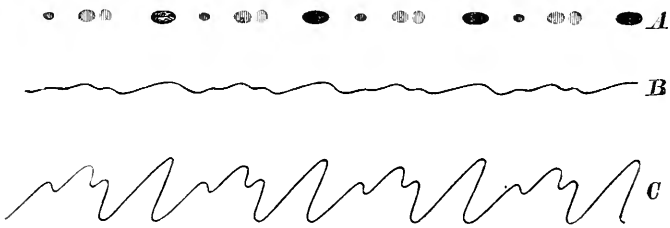

FIG. 3.

pressions on the foil, when the sound of *a* in *bat* is sung against the iron plate of the phonograph. *B* is the magnified profile of these impressions on the smoked glass obtained as described above. *C* gives the appearance of König's flame when the same sound is sung quite close to its membrane. I say expressly *quite close* to its membrane, for the form of the trace obtained from a point attached to a membrane vibrating under the influence of a compound sound depends on the *distance* of the source of the sound from the membrane, and the same compound sound will form an infinite number of different traces as we gradually increase the distance of its place of origin from the membrane; for, as you increase this distance, the waves of the components of the compound sound are made to strike on the membrane at different periods of their swings.

For example, if the compound sound is formed of six harmonics, the removal of the source of the sonorous vibrations, from the membrane to a distance equal to $\frac{1}{4}$ of a wave-length of the 1st harmonic, will remove the 2d, 3d, 4th, 5th, and 6th harmonics to distances from the membrane equal respectively to $\frac{1}{2}$, $\frac{3}{4}$, 1, $1\frac{1}{4}$, and $1\frac{1}{2}$ wave-lengths. The consequence evidently is, that the resultant wave-form is entirely changed by this motion of the source of the sound, though the sonorous sensation of the compound sound remains unchanged.

The above facts are readily proved experimentally by sending a constant compound sound into the cone of König's apparatus, while we gradually lengthen the tube between the cone and the membrane next to the flame. This is best done by the intervention of one tube sliding in another, like a trombone. These experiments I have recently made with entire success, and they explain the discussions which have arisen between different observers as to the composition of vocal and other composite sounds, as analyzed by means of König's vibrating flames.

These facts also show how futile it is for any one to hope to be able to *read* the impressions and traces of phonographs, for these traces will vary, not alone with the quality of the voices, but also with the differently-related times of starting of the harmonics of these voices, and with the different relative intensities of these harmonics.

It is necessary to give to the cylinder a very regular motion of rotation while it receives and reproduces the vibrations made in singing; for even slight irregularities in the velocity of the cylinder destroy the accuracy of the musical intervals, and cause the phonograph to sing falsetto. Even the reproducing of speech is greatly improved by rotating the cylinder by mechanism which gives it uniformity of motion. If you make the machine talk by giving it a more rapid rotation than it had when you spoke to it, the pitch of its voice is raised; and by varying the velocity of the cylinder the machine may be made to speak the same sentence in a very bass voice, or in a voice of a pitch so high that its sounds are really elfish and entirely unnatural.

Recent experiments seem to show that the nearer the diaphragm *A* approaches to the construction of the drum-skin of the human ear by "damping" it, as the hammer-bone does the latter, the better does it record and repeat the sonorous vibrations; for the motion of a membrane thus damped is ruled alone by the aërial vibrations falling on it.

Mr. Edison has just sent me the following notes of the results of recent experiments:

"That the size of the hole through which you speak has a great deal to do with the articulation. When words are spoken against the whole diaphragm, the hissing sounds, as in *shall*, *fleece*, *last*, are lost; whereas, by the use of a small hole provided with sharp edges, these words are reënforced and recorded. Also, teeth around the edge of a slot, instead of a round hole, give the hissing consonants clearer.

"That the best reading is obtained when the mouth-piece, *B F B* (Fig. 2), is covered with several thicknesses of cloth, so that the snapping noise on the foil is rendered less audible.

"I send you a sheet of copper-foil upon which I made records in Ansonia, Connecticut, that could be read 275 feet in the open air, and perhaps farther, if it had been tried."

Mr. Edison also states that impressions of sonorous vibrations have been made on a cylinder of soft Norway iron, and from these impressions have been reproduced the sonorous vibrations which made them.

THE MARPINGEN MIRACLES.

THE recent debate in the Lower House of the Prussian Parliament on the Marpingen miracles is in many ways remarkable. That the Ultramontane party should have had the courage themselves to force on the discussion is rather surprising, though it is true that all the speakers on that side were careful to deprecate the notion of attaching any religious importance to the question, and to treat it purely as one of law and equity, while they studiously avoided committing themselves to any belief in the alleged supernatural occurrences. Before, however, speaking of the debate, we may recall to the memory of our readers the circumstances which gave rise to it, and which occurred a year and a half ago in the month of July, 1876. And in doing so it may be well to repeat what we have before now had occasion to observe in dealing with narratives of this kind, that there is no need to enter on any general discussion of the existence or credibility of miraculous agency. There is certainly, to use Mr. Lecky's words, "no contradiction involved in the belief that spiritual beings of power and wisdom immeasurably transcending our own exist, or that, existing, they might, by the normal exercise of their powers, perform feats as far surpassing the understanding of the most gifted of mankind as the electric telegraph and the prediction of an eclipse surpass the faculties of a savage." Thus much would indeed be contended for by every Christian apologist, nor is it consistent to maintain the truth of the New Testament miracles and deny on *a priori* grounds the possibility or actual occurrence of any subsequent phenomena of the kind. That is a question of evidence, and, as Mr. Lecky goes on to observe, "very few of the minor facts of history are authenticated by as much evidence as" some of those later miracles which he specifies, to one of which, by no means a favorite with Ultramontanes, we may have occasion to refer presently. But there are few subjects on which ordinary persons, even educated persons, have such loose notions as on the true nature of evidence, or where the wish, whether it be an innate feeling of sympathy or of antipathy, is so apt to become father to the thought. And now we may proceed without further preface to reproduce the main details of the marvelous tale brought from Marpingen, a village in Rhenish Prussia, in July, 1876, and which formed the text of a long debate in the Prussian Parliament a fortnight ago.

It appears that on two successive days, July 3d and 4th, three little girls of the village of Marpingen announced that they had seen the Virgin with her infant Son, sitting on the ground in a neighboring wood, and on the second of these days she replied to their questions, "I am she who was conceived without sin, and you should pray and pray forever." On the third day the apparition was again visible and discoursed to the children for some time, while a crowd, who had followed them from the village kept apart reverentially from the hallowed spot, *the apparition being visible and audible to the three little girls only*. It was explained that this peculiar privilege was vouchsafed to them because they were "the only innocent persons in the wood," and the apparition expressly declined to see any of the neighboring priests, but *ordered a chapel to be built on the spot from the proceeds of a public subscription*. She finally, at their request, permitted an invalid to be brought by the children to touch her feet, though he also never saw her, and he was instantly cured. After this crowds came to spend the night praying and singing in the wood, two or three of whom declared that they saw the Virgin amid the trees, and the children were kept constantly employed in laying the hands of the sick on the feet of the invisible figure. They apparently, however, found this burden too great for them, for a few days later they announced that the water of a neighboring spring had been endowed with miraculous properties, and might be conveyed to those who were unable to come themselves, and thenceforth the concourse of pilgrims increased. Hereupon the civil authorities interfered, whether on account of disturbances caused by the multitudes who congregated in the forest, or from a fear that the miracle was intended to be utilized for purposes of agitation against the Government. On July 13th, ten days after the first apparition, the Burgomaster of Marpingen ordered the people to leave the wood, and on their refusal had it cleared by the military; from that time it was guarded by police and soldiers quartered in the village, where the inhabitants complain that forced requisitions were made on them, and the place treated as though occupied by a hostile army. It was a formal motion for the repayment to the commune of the 4,000 marks (about £200) said to have been thus levied on it, and for the reprimand of the local magistrates for harsh and arbitrary conduct, that led to the debate in the Prussian Parliament. It should be added that the three little girls and a priest of the district were arrested on suspicion of religious fraud, but eventually released for lack of sufficient evidence, the girls stoutly denying that they had been inspired by either priest or parent. Entrance to the wood is still prohibited, but processions take place to the miraculous spring.

Now, the first observation that would occur to any one on reading this strange story is the conspicuous absence of anything like evidence of the alleged apparition, even putting aside the suspicion of deliberate fraud. The Madonna is visible to three little girls only, of about seven years of age, whose religious imagination might easily be excited, especially if they had heard of former apparitions of the same kind, as is more than probable. And when once they had committed themselves to the story—whether in simple piety or under some external influence—fear of consequences would alone secure their adhesion to it. But this leads us on to another and more important comment, which will already have occurred to many of our readers, especially if they have taken note of the passages in the tale which we have italicized. The close resemblance in all its leading features to several former tales of miraculous apparition, and, above all, to the apparition at Lourdes, is too obvious and too minute to be considered accidental. Whether we suppose the whole affair to be an imposture pure and simple, as is likely enough, or whether we adopt the more charitable hypothesis of hallucination, there can hardly be a doubt that the Lourdes miracle suggested the incidents of the Marpingen one. In both cases, as before at La Salette, young children are the sole witnesses of the marvel; in both cases it is the Virgin who appears, and, while at Lourdes she oddly describes herself as being "the Immaculate Conception," at Marpingen the more grammatical formula is adopted, "I am she who was conceived without sin;" in both cases multitudes follow the children, but are obliged to take on faith what to them, and to them alone, is matter of sight and hearing; in both cases, and this is significant, the Madonna expressly directs a chapel to be built on the spot, and that indeed appears to be the chief object of the apparition; and, lastly, in both cases a miraculous spring is either created or disclosed. On this last point we have another word to say. It is of course argued by the defenders of these miracles, and is in fact the only plausible argument left to them, that whatever becomes of the evidence of the children for the original tale —even though they should turn out afterward as the boy and girl at La Salette did turn out—there is no getting over the evidence of the miraculous cures. The reply is not far to seek. There might be, and indeed are, examples of seemingly supernatural cures—we will mention one directly—attested by very strong evidence, but these are certainly not among them. Putting aside innumerable instances of failure and some of detected imposture which have been heard of in connection with Lourdes—it is too early yet to apply that test to Marpingen—it must never be forgotten how almost incalculable is the power of imagination over every kind especially of nervous disorder. There are unquestionably many persons of whom it may be said, in a different sense from that of the words as originally used, that "their faith has made them whole;" or, on the contrary, has made them ill. A ready instance comes to hand in connection with the recent hydrophobia scare. There can be no doubt that tetanus, which so closely simulates hydrophobia as often to be indistinguishable from it to all but adepts, may be and is produced by fear; and thus nervous persons who assume that a dog which bites them must be mad—though the chances are always really at least ten to one the other way—may easily give themselves a fatal disease without any external cause. On the other hand, a case was reported the other day from Italy, of a woman who was raving, as was supposed, from hydrophobia, but who promptly recovered on a miraculous relic being applied to her. The same explanation will cover innumerable cases, whether at Lourdes or elsewhere, of alleged miraculous cures. But we observed just now that there are examples on record of miraculous cures, the direct evidence of which is very striking. The late Sir James Stephen mentions one of them in these words: "The greatest genius, the most profound scholar, and the most eminent advocate of that age (the seventeenth century), all possessing the most ample means of knowledge, all carefully investigated, all admitted, and all defended with their pens, the miracle of the Holy Thorn. Europe at that time produced no three men more profoundly conversant with the laws of the material world, with the laws of the human mind, and with the municipal law, than Pascal, Arnauld, and Le Maître; and they were all sincere and earnest believers." Mr. Lecky similarly observes that few historical facts are so well authenticated as "the miracles of the Holy Thorn, or at the tomb of the Abbé Paris," which last, we may add, were attested among others by Voltaire. Be it so, but these are "Jansenist" miracles which Ultramontanes have always and scornfully refused to admit. The manifestations at the tomb of the Abbé Paris were actually suppressed by authority, ecclesiastical and civil, which suggested the famous epigram:

"De par le roi, défense à Dieu
De faire miracle en ce lieu."

Those who reject the far stronger evidence of these miracles must find some better argument than the alleged cures if they would have us accept the miraculous portents of Lourdes and Marpingen.

The debate in the Prussian Chamber was opened by Herr Bachem, who insisted that the conduct of the authorities had been very reprehensible; even assuming the alleged miracles to be illusory or fraudulent, the sincere belief of the multitude ought to have been respected. Dr. Friedenthal, acting Minister of the Interior, replied:

"He was prepared to defend the action of the police, there being plenty of *prima-facie* evidence to show that the Marpingen miracle was a fraud. The alleged miracle happened in a district strongly infected by the Ultramontane movement, and previously productive of similar apparitions that had attracted the notice of the law. Early in 1875 a woman began to work miracles at Eppelborn, close to Marpingen, under the patronage of the local priest. She was convicted of fraud and sentenced to imprisonment. The same woman and the local priest who assisted her were subsequently again convicted of fraud, false pretenses, and gross immorality. The Marpingen miracle was no sooner bruited about than a school-girl at Groning, also near Marpingen, stated that she had had an audience of the Virgin. The girl was severely reprimanded by her father, when the visions ceased. At Berschweiler, likewise near Marpingen, no less than five persons between eleven and nineteen years of age, in 1876, professed to be in daily intercourse with the Virgin. A profitable trade in exorcisms, salvations from purgatory, and the like, having been opened by them, the authorities interfered. The police court eventually sent the whole gang to prison. At Gappenach a married couple were convicted of fraud for stating that they had seen the Virgin conversing with the three little girls in a bottle of Marpingen water. At Münchwies, district of Ottweiler, a couple of school-girls pretended to have interviews with the Virgin, until the parish priest objected to the story, when the apparitions ceased. Considering this excited condition of the province in which Marpingen is situate, and taking into account the peculiar character the Ultramontane movement had recently assumed in Germany, the authorities were perfectly justified in putting a stop to the Marpingen revival. There were 8,000 persons in the hallowed wood when the military were called in. Though there was some show of resistance, nobody was wounded. Subsequently the police appointed to watch the wood were fired at in the dark. With reference to the legal proceedings instituted by the crown, he, the minister, was in a position to say that a formal accusation would be preferred against certain persons supposed to be implicated in the Marpingen affair, when the character of the miracle would be fully investigated in open court."

To this statement Herr Lipke added that the three little girls, when first examined by the magistrate, professed to have seen not only the Virgin but the devil also, whom they described as "black and white"—the German national colors. He said that many Catholic priests with whom he had conversed on "the Marpingen swindle" agreed with him in disapproving it, and he thought the Ultramontanes had not benefited their cause by bringing the subject pefore Parliament. Another speaker on the same side, Judge Sello, admitted that some excesses had been committed by the troops, but the burgomaster who ordered them to clear the wood had been tried and fined in consequence. The debate was closed by Dr. Windthorst, the leader of the Ultramontane party, who declined to commit himself to the reality of the miracles, but complained that, as long as the Government kept the see of Treves vacant, no proper investigation, as directed by the Council of Trent, could take place. Perhaps the legal investigation which is promised by Dr. Friedenthal may prove more efficacious in bringing the real facts to light. Meanwhile, it may be feared that belief in the Marpingen apparition will become a test question of Catholic orthodoxy in Germany, as belief in Lourdes and La Salette has long been a criterion for discriminating the *bien pensants* in France, in spite of the manly protests of some high authorities, such as Dupanloup, against this morbid craving for predictions and portents. We have never denied that German Catholics have a substantial grievance in the matter of the Falk laws, but they certainly will not improve their position with thinking men of any creed by adopting devices which can only escape graver censure if they are regarded as too silly to be dishonest.—*Saturday Review.*

THE SOURCE OF MUSCULAR POWER.

THE advance of modern research has brought the sciences of physics, chemistry, and physiology, into very close relations, and as the two former have given great help to the latter, many are looking to see all physiological problems finally resolved on physical and chemical principles. Much is to be expected from the future, but sanguine anticipations should not be allowed to misinterpret existing facts. Prof. Austin Flint, Jr., has been much occupied in investigating the living system as a dynamical engine, and has published the results of his experimental inquiries in a little volume, entitled "The Source of Muscular Power." He has made an important contribution to the subject of animal mechanics, and his views will be so interesting, alike to the physiologist and the general student, that a summary of his argument will be appreciated by the readers of the MONTHLY.

Since it has been ascertained that the force derived from chemical action which will raise the temperature of a pound of water 1° Fahr. will, under another form of manifestation, lift 772 pounds one foot high, 772 foot-pounds have been regarded as the force-equivalent of 1° of heat. In other words, if the burning or oxidation of a certain definite weight of matter will raise the temperature of one pound of water 1° Fahr., the force-value of this matter is said to be 772 foot-pounds.

In the animal economy, certain matters are taken in and consumed as food; matters are discharged from the body in the form of excretions, such as the constituents of the urine; a certain amount of heat is produced in the body in order to maintain the animal temperature, to supply the loss of heat dependent upon radiation from the surface; a certain amount of force is exerted in the processes of circulation of the blood and in the respiratory movements, and a certain amount of work is performed by muscular action. If it be assumed that the oxidation of matter in the animal economy involves, of necessity, either the production of heat or of force, an answer to the following question becomes at once of great importance as regards our ideas of the immediate source of muscular power:

Is the food directly oxidized in the perfected and adult animal organism, the result of this oxidation being heat and force, and is this the single source of muscular power, or is the perfected animal organism, particularly as regards the muscular system, itself consumed gradually as a result of muscular work, the waste of muscular tissue being represented by the excretions, and such waste being repaired constantly by food? To state this question in simpler terms, is the muscular system a part of a machine that consumes food as fuel in the production of force, not wearing its own substance to any considerable extent, or does the muscular system use its own substance in the production of force?

Before 1866, the following ideas, formulated by Liebig, Lehmann, and others, were pretty generally accepted by physiologists:

The muscular substance, which constitutes about two-fifths of the weight of the entire body, is composed mainly of matters containing carbon, hydrogen, oxygen, and nitrogen, in contradistinction to the fats, which contain only carbon, hydrogen, and oxygen. The most important excrementitious matter thrown off by the kidneys is urea, which contains carbon, hydrogen, oxygen, and nitrogen. The amount of urea excreted is to be regarded, to a certain extent, as a measure of the physiological wear of the muscular system, which wear is increased by muscular exertion, there being a corresponding increase in the excretion of urea by the kidneys. This wear of the muscular system is being constantly repaired by the nitrogenized elements of food. In discussing, then, this question, physiologists have come to speak of the excretion of nitrogen as measuring, more or less accurately, the physiological wear of the muscular system.

In 1866, two German physiologists, Fick and Wislicenus, ascended one of the Alpine peaks, and measured the influence of this unusual muscular exertion upon the excretion of nitrogen. As it is well known that the quantity of nitrogenized food, such as meat, eggs, etc., influences the amount of nitrogen excreted by the kidneys, these observers confined themselves to a diet without nitrogen during the ascent and for a number of hours immediately preceding and following. They found that the amount of nitrogen eliminated by the kidneys was diminished during the muscular exertion by about one-third. From these experiments, they concluded that muscular exercise does not increase the elimination of nitrogen, but rather diminishes it; and from this time dates the proposition, which is now adopted by many physiologists, that the muscular system is a machine which consumes food as fuel, and does not wear its own substance to any very great extent in the production of force. Fick and Wislicenus advanced the view that "the substances, by the burning of which force is generated in the muscles, are not the albuminous constituents of the tissues, but non-nitrogenous substances, either as fats or hydrates of carbon."

Such a doctrine as that advanced by Fick and Wislicenus, according to Prof. Flint, is not logical and is opposed to many well-known physiological facts. The arguments he advances against it are the following:

1. Physiological experiments should be made under strictly natural or physiological conditions of the system. A non-nitrogenized diet is not natural. No man would attempt to perform a feat of muscular endurance under a diet composed exclusively of fat, starch, and sugar, which was the exclusive diet of Fick and Wislicenus.

2. Lehmann has shown that an exclusively non-nitrogenized diet, of itself, without any variation in muscular exercise, will reduce the excretion of nitrogen by the kidneys more than one-half. Pavy has shown the same effects of non-nitrogenized food upon the system without any variation in muscular exercise.

3. Fick and Wislicenus do not show that extraordinary muscular exertion, with a non-nitrogenized diet, diminishes the excretion of nitrogen below the point to which it would be reduced by the diet itself, without muscular work; for they made no comparative experiments with a non-nitrogenized diet and no unusual exercise.

In view of these facts, the conclusion arrived at by Prof. Flint is, that the experiments of Fick and Wislicenus fail to show that muscular exercise diminishes, or even does not increase, the elimination of nitrogen, which is the very essence of their argument.

In 1870, Prof. Flint made a series of elaborate experiments upon Weston, during a walk of three hundred and seventeen and one-half miles in five consecutive days. Recognizing the fact that the elimination of nitrogen bears a certain relation to the nitrogen of the food, in these experiments, Prof. Flint estimated the nitrogen of the food and calculated the proportion of nitrogen excreted to the nitrogen ingested, which had never been done in any previous experiments upon the physiological effects of muscular exercise. His observations were continued for five days before the walk, the five days of the walk, and five days after the walk. Prof. Flint, or his assistants, were with Weston, day and night, for the entire fifteen days. Every article of food was weighed or measured, and its nitrogen carefully estimated, as was the nitrogen excreted. The variations in body-weight, temperature, etc., were also taken. No accident occurred, and the observations were absolutely complete. The most important general results of these experiments were the following:

For the five days before the walk, the average daily exercise being eight and one-fifth miles, the average proportionate excretion of nitrogen by the kidneys was 86.58 parts for every 100 parts of nitrogen of food.

For the five days of the walk, the average daily exercise being sixty-three and one-half miles, the average proportionate excretion of nitrogen by the kidneys was 143.98 parts for every 100 parts of nitrogen of food.

For the five days after the walk, the average daily exercise being two and one-fifth miles, the average proportionate excretion of nitrogen by the kidneys was 77.03 parts for every 100 parts of nitrogen of food.

These facts showed conclusively that, in this instance, at least, the extraordinary exertion of walking three hundred and seventeen and one-half miles in five consecutive days very largely increased the proportionate excretion of nitrogen by the kidneys.

The source of the excess of nitrogen excreted during the walk must have been the excessive wear of muscular tissue engendered by the extraordinary exertion, which was not repaired by the food. This is rendered almost certain by the following calculation:

At the beginning of the walk, Weston was in good condition, with little or no fat, and he weighed 119.20 pounds. "At the end of the five days' walk, the weight had been reduced from 119.20 to 115.75 pounds, showing a loss of 3.45 pounds. According to Payen, three parts of nitrogen represent one hundred parts of fresh muscular tissue. The total quantity of nitrogen discharged during these five days was 1,811.62 grains. The total nitrogen of food during the same period amounted to 1,173.82 grains, giving an excess of 637.80 grains of nitrogen discharged over the nitrogen of food. The 637.80 grains of nitrogen, according to Payen's formula, would represent 21,260.00 grains, or 3.037 pounds of muscular tissue. The actual loss of muscular tissue was 3.45 pounds, and the loss unaccounted for, amounting to only 0.413 of a pound, is very small. It might be fat or water, or the difference might be due to inaccuracies in the estimates of the nitrogen of food, which, of necessity, were approximative."

In 1876, Dr. Pavy, of London, made a series of experiments upon Perkins, a pedestrian, and upon Weston, similar to those made by Prof. Flint upon Weston, in 1870. The following were the general results of these observations:

Perkins walked sixty-five and one-half miles in twenty-four hours. During this time, he excreted 190.37 parts of nitrogen by the kidneys for every 100 parts of nitrogen of food. For twenty-four hours of rest, several days after this walk, Perkins excreted 76.58 parts of nitrogen by the kidneys for every 100 parts of nitrogen of food.

Observations were made upon Weston for eleven days of walking, as follows: 1. A walk of one hundred and eighty and one-half miles in two consecutive days; 2. A walk of two hundred and sixty-three miles in seventy-five consecutive hours; 3. A walk of four hundred and fifty miles in six consecutive days. The proportionate excretion of nitrogen was estimated for these periods of exercise, and was also calculated for eight days of rest. The daily average excretion of nitrogen for the eight days of rest was 60.90 parts for every 100 parts of nitrogen of food. The daily average excretion of nitrogen for the eleven days of walking was 87.34 parts for every 100 parts of nitrogen of food—an increased proportion of 43.44 per cent. These experiments, like those of Prof. Flint, show a very great increase in the proportionate excretion of nitrogen produced by the excessive and prolonged muscular exertion.

Dr. Pavy admits, as the result of his own experiments, the simple fact that muscular exercise increases the proportionate excretion of nitrogen, but he does not accept the view advanced by Prof. Flint, that the muscular system, in exerting force, consumes its own substance, and that this substance is repaired by food. Dr. Pavy made a series of calculations, in connection with his experiments, comparing the force-value of the excess of nitrogen excreted during exercise over the nitrogen excreted during rest with the work actually performed in walking. He attempted to show that the force represented by this excess of nitrogen excreted would not account for the work accomplished. These calculations of Dr. Pavy involve formulæ for reducing miles walked to foot-pounds, and estimates of the force exerted in respiratory movements, the action of the heart, etc. Prof. Flint, in his essay, gives an elaborate review of these calculations, and objects to many of the formulæ as necessarily inaccurate. It is impossible, in a short abstract, to give a satisfactory account of Prof. Flint's argument upon these points. The following are the conclusions arrived at by Prof. Flint, as the result of the various experiments which he has discussed:

"I. While the various elements of food burned in oxygen out of the body will produce a definite amount of heat which may be calculated as equivalent to a definite number of foot-pounds of force, the application of this law to the changes which food or certain of the constituents of the body undergo in the living organism is uncertain and unsatisfactory, for the following reasons:

"(*a*.) There is no proof that the elements of food undergo the same changes in the living body as when burned in oxygen, or that definite amounts of heat or force are necessarily manifested by their metamorphoses in such a way that they can be accurately measured.

"(*b*.) Assuming that the elements of food contain a definite amount of locked-up force, to measure the part of this force which is expended in muscular work, it is indispensable to be able to estimate accurately the force used in circulation, respiration, and the various nutritive processes, and to measure the heat evolved which maintains the standard animal temperature and which compensates the heat lost by evaporation from the general surface. It does not seem that any accurate idea can be formed of the amount of force used in circulation and respiration, and the estimates made by different observers of authority present variations sometimes of more than one hundred per cent. Such estimates are usually made in view of some dynamic theory, and they are based upon physiological data which are necessarily uncertain and subject to wide and frequent variations. No approximate estimate, even, can be made of the actual amount of heat produced within the living organism, except, perhaps, during a condition of nearly absolute muscular repose. The only way in which this could be done would be to deduct the force used in muscular work, circulation, respiration, and the nutritive processes, from the heat-value or force-value of the food. These elements of the question being uncertain, an accurate estimate of the heat produced becomes impossible, as, at the best, the only definite quantity in the problem is the total heat-value or force-value of food.

"(*c*.) To compare an amount of muscular work actually performed with the estimated force-value of food, apart from the impossibility of arriving at an accurate estimate of the amount of food consumed in circulation, respiration, the nutritive processes, and the production of heat, which is a necessary element in the problem, the work actually performed in walking a certain distance must be reduced to foot-pounds or foot-tons. The formula for this is so uncertain that no such reduction can be made which can be assumed to be even approximatively correct.

"II. The method of calculating the possible amount of force of which the body is capable, by using as the sole basis for this calculation the force-value of food, must be abandoned until the various necessary elements of the problem can be made sufficiently accurate to accord with the results of experiments upon the living body. Until that time arrives, physiologists should rely upon the positive results obtained by experiments rather than upon calculations made from uncertain data and under the influence of special theories. In case of fatal disagreement between any theory and definite experimental facts, the theory must be abandoned, provided the facts be incontestable.

"III. Experiments show that the estimated force-value of food, after deducting the estimated force used in circulation, respiration, the nutritive processes, and in the production of heat, will sometimes account for a small fraction only of muscular work actually performed, this work being reduced to foot-tons by the uncertain process to which I have already alluded. The errors in these calculations are manifestly so considerable that the calculated results seem to be of little value, while the experimental fact that a certain amount of work has been accomplished must remain.

"IV. It must be admitted that, under ordinary and normal conditions of diet and muscular exercise, the weight of the body being uniform, the ingress and egress of matter necessarily balance each other. If this balance be disturbed by diminishing the supply of food below the requirements of the system for its nutrition and for muscular work, the body necessarily loses weight, a certain portion of its constituent parts being consumed and not repaired. If the balance be disturbed by increasing the muscular work to the maximum of endurance and beyond the possibility of complete repair by food, the body loses weight. The probable source of muscular power may be most easily and satisfactorily studied by disturbing the balance between consumption and repair by increasing the work. In this, it is rational to assume that the processes of physiological wear of the tissues are not modified in kind, but simply in degree of activity.

"V. Experiments show that excessive and prolonged muscular exercise may increase the waste or wear of certain of the constituents of the body to such a degree that this wear is not repaired by food. Under these conditions, there is an increased discharge of nitrogen, particularly in the urine. This waste of tissue may be repaired if food can be assimilated in sufficient quantity, but in my experiments it was not repaired. The most important question to determine experimentally in this connection is with regard to the influence of excessive and prolonged muscular exercise upon the excretion of nitrogen. It is shown experimentally that such exercise always increases the excretion of nitrogen to a very marked degree, under normal conditions of alimentation; but the proportionate quantity to the nitrogen of food is great when the nitrogen of food remains the same as at rest, and is not so great, naturally, when the nitrogen of food is increased. In the latter case, the excessive waste of the tissues is in part, or it may be wholly, repaired by the increased quantity of food. Experiments upon excessive exertion with a non-nitrogenous diet are made under conditions of the system that are not physiological; and the want of nitrogen in the food in such observations satisfactorily accounts for the diminished excretion of nitrogen.

"VI. By systematic exercise of the general muscular system or of particular muscles, with proper intervals of repose for repair and growth, muscles may be developed in size, hardness, power, and endurance. The only reasonable theory that can be offered in explanation of this process is the following: While exercise increases the activity of disassimilation of the muscular substance, a necessary accompaniment of this is an increased activity in the circulation in the muscles, for the purpose of removing the products of their physiological wear. This increased activity of the circulation is attended with an increased activity of the nutritive processes, provided the supply of nutriment be sufficient, and provided also, that the exercise be succeeded by proper periods of rest. It is in this way only that we can comprehend the process of development of muscles by training; the conditions in training being exercise, rest following the exercise, and appropriate alimentation, the food furnishing nitrogenized matters to supply the waste of the nitrogenized parts of the tissues. This theory involves the idea that muscular work consumes a certain part of the muscular substance, which is repaired by food. The theory that the muscles simply transform the elements of food into force directly, these elements not becoming at any time a part of the muscular substance, is not in accordance with the facts known with regard to training.

"VII. All that is known with regard to the nutrition and disassimilation of muscles during ordinary or extraordinary work teaches that such work is always attended with destruction of muscular substance, which may not be completely repaired by food, according to the amount of work performed and the quantity and kind of alimentation.

"VIII. In my experiments upon a man walking three hundred and seventeen and one-half miles in five consecutive days, who at the beginning of the five days had no superfluous fat, the loss of weight was actually 3.45 pounds, while the total amount of nitrogen discharged from the body in excess of the nitrogen of food taken for these five days, assuming that three parts of nitrogen represent one hundred parts of muscular substance, as has been shown by analysis to be the fact, represented 3.037 pounds of muscular substance. This close correspondence between the actual loss of weight and the loss that should have occurred, as deduced from a calculation of the nitrogen discharged in excess of the nitrogen of food, seems to show very clearly that, during these five days of excessive muscular work, a certain amount of muscular substance was consumed which had not been repaired, and that this loss could be calculated with reasonable accuracy from the excess of nitrogen excreted.

"IX. Finally, experiments upon the human subject show that the direct source of muscular power is to be looked for in the muscular system itself. The exercise of muscular power immediately involves the destruction of a certain amount of muscular substance, of which the nitrogen excreted is a measure. Indirectly, nitrogenized food is a source of power, as, by its assimilation by the muscular tissue, it repairs the waste and develops the capacity for work; but food is not directly converted into force in the living body, nor is it a source of muscular power, except that it maintains the muscular system in a proper condition for work. In ordinary daily muscular work, which may be continued indefinitely, except as it is restricted by the conditions of nutrition and the limits of age, the loss of muscular substance produced by work is balanced by the assimilation of alimentary matters. A condition of the existence of the muscular tissue, however, is that it cannot be absolutely stationary, and that disassimilation must go on to a certain extent, even if no work be done. This loss must be repaired by food to maintain life. A similar condition of existence applies to every highly-organized part of the body and marks a broad distinction between a living organism and an artificially constructed machine, which latter can exert no motive power of itself, and can develop no force that is not supplied artificially by the consumption of fuel or otherwise."

Prof. Flint, in an appendix, has added a calculation of the non-nitrogenized food taken by Weston during his five days' walk, in order "to answer the possible objections of those who may contend that, in his discussion, he should have included the heat-producing and force-producing power of non-nitrogenized alimentary substances." This calculation is briefly as follows:

Force-value of nitrogenized food	2,858.79	foot-tons.
" " loss of weight of the body	1,764.52	" "
" " non-nitrogenized food, in excess of that required to produce 17,787 heat-units (the amount of animal heat) produced in five days	597.75	" "
Total	5,221.06	" "
Deduct the estimated force used in circulation and respiration	1,339.29	" "
Force remaining for muscular work	3,881.77	" "

"The actual work represented by walking three hundred and seventeen and one-half miles is estimated at 4,321.33 foot-tons. This leaves 439.56 foot-tons of work which cannot be accounted for in any way, according to the estimates of the observers quoted, leaving a deficiency of a little more than ten per cent.

"These calculations show the fallacy of such estimates, and the impossibility of accounting for work actually performed, even when we include the heat-value and the force-value of non-nitrogenized food."

The estimates of the force used in circulation and respiration, and of the heat produced by the body, were all calculated for a condition of rest, and they are much less than the estimates that should be made for a period of excessive muscular exercise.

LIVING CORALS.

By W. E. DAMON.

PERHAPS enough already has been written about corals and coral-builders, but certainly too little is really *known* about the habits and mode of growth of this interesting animal. I am fortunate enough to possess fine specimens of some three or four varieties of living, working coral "polyps," for such is the name by which the coral-builder is designated. These specimens are kept in pure sea-water, and I have studied their habits very carefully for years; they seem to be in perfect health, full of activity, and generally industrious, although I can hardly observe that they have added to their corallum during this period. A specimen of *Astrangia* which has been described by Dana and Elizabeth Agassiz, although it has not, perhaps, increased visibly in height, has enlarged in size by building from its outer edges, and numbers of young and smaller polyps have appeared. I have noticed that this budding and increase occur about October or November of each year.

Nothing can be more beautiful than a group of these corallets. Sometimes a mass of them of three or four inches across is dredged up at Wood's Hole, Massachusetts. The polyps rise high above the cells, and, with their long, slender, fleecy, silk-like tentacles swaying to and fro, remind one of a living bed of roses, or of a mossy bank covered with heavy frost.

I have seen the animal of a single corallet standing above the surface of its cell an inch in height and expanded to one-third of an inch in diameter, and yet many—I may safely say, most people—believe the "coral-insect" (not an insect at all) to be a microscopic or a very minute animal. Its long, snowy tentacles are covered all over with warts or dots, with a larger one at the tip of each. All these contain its weapons of defense, called lasso-cells, or capsule-threads, with which the animal captures its prey. The smaller crustacea, coming in contact with these nettle-like arrows, are surely and suddenly disabled, and then with the longer tentacles are drawn inward to the mouth, which is situated in the centre of all these arms. This food passes into the stomach, which can be plainly seen through its glass-like walls, and must be digested before the animal retreats into its calicle. I have given them pieces of clams or oysters as large as half a pea, which they would seize with their tentacles and readily swallow. Another reason for this particular variety of coral-builder being so interesting to us is, that it is the only true coral-building polyp we have north of the Florida reefs, or nearer our homes than the Bermuda Islands.

Another variety, which belongs to the *Oculina* tribe, I have in the same healthful condition. This one assumes a branched or tree-like form, and is, if possible, more elegant and beautiful than the last. Its zoöthome, when fully expanded, seems to completely hide the whole corallum, and nothing is visible but one mass or tree of *living, moving flowers.*

This polyp does not elongate itself so much as does *Astrangia*, and its tentacles are much shorter; and, instead of being white, it is of an umber-like color, and covered all over with iridescent hues. Its septa, or radiated plates of the corallum, are the same as in *Astrangia.* The common mass of coral is of a more solid, stone-like nature; the epitheca, or outer coral layer, which the *Astrangia* has not, and the endotheca, or coral inside the cells, are also more compact and hard.

POISONS OF THE INTELLIGENCE.—CHLOROFORM.[1]

By CHARLES RICHET.

CHLOROFORM is a colorless, volatile, oily liquid; it is denser than water, and does not mix with it. It was discovered by Soubeiran in 1831,[2] and Soubeiran's process for obtaining it is still in use, viz., distilling alcohol with calcium hypochlorite and lime. The hypnotic properties of chloroform were discovered in 1847 by Flourens, a few months after Jackson had recognized similar properties in ether; but the first surgeon who made use of it in an operation on the human subject was Simpson, of Edinburgh, in November, 1847. Since then, the use of chloroform has become so general, that nowadays no great operation in surgery is attempted without employing it. We may, therefore, justly regard the discovery of surgical anæsthesia as one of the greatest scientific achievements of the present century, so fruitful of benefits to the human race.

The principal effect of chloroform is the paralysis of sensibility, or anæsthesia. In so far forth it acts upon the mind, for sensibility is only one of the forms of mind; but this point, which as yet is rather obscure, calls for a few words of explanation.

Two great functions devolve upon the nervous system, sensibility and motion: it is through sensibility that we receive impressions from without; and it is through the excitation of the muscles, or movement, that we manifest our will, or act upon external objects. In the absence of both disease and poisoning, the will—that is, the

[1] Translated from the *Revue des Deux Mondes*, by J. Fitzgerald, A. M.

[2] The first discoverer of chloroform—for it was discovered independently by at least three chemists—was Samuel Guthrie, of Sackett's Harbor, New York. His discovery antedates Soubeiran's several months. Liebig's discovery of chloroform was intermediate between Guthrie's and Soubeiran's.—TRANSLATOR.

mind—excites, through the spinal cord, the various muscles, producing movement; but this condition is not absolutely necessary, since in decapitated animals, for instance, the nervous system of the spinal cord can of itself produce motion of the muscles. Here we have motor activity, but no sensibility. Sensibility exists only where the mind is intact and capable of perceiving, so that a creature which has no mind is void of sensibility. This fact is confirmed by pathological observation; for, whenever the mind is affected, there appear at the same time symptoms of disordered sensibility, and *vice versa.* And when we find a patient exhibiting notable disorder of the sensibility, then, if the nerves are intact, we can safely conclude that the central nervous system is affected, and to that degree that the mind has not escaped.

Anatomy and physiology here are in accord with pathology. Some animals possess little or no sensibility: they belong to the lower grades of animals; their intelligence is obscure, and their sensibility is as obtuse as their intelligence. On the other hand, if we consider animals of higher intelligence, we find their sensibility becoming more and more keen, till we come to man, at once the most intelligent and the most sensitive of animals. And even in man himself we find race-differences, those races being most sensitive which possess the highest degree of intelligence. The anatomical structure of the nervous centres is in harmony with this coincidence, for it is in man that the posterior columns of the spinal cord are most voluminous, as compared with the anterior. Now, the anterior columns transmit the motor excitations to the nerves, while the posterior columns transmit the sensory excitations. Again, the posterior lobes of the brain in man, as compared with animals, are more developed than the anterior. But it is in the posterior lobes that perception of sensitive excitations appears to reside.

Nor is it surprising that there should exist so intimate a relation between mind and sensibility. Indeed, whatever may be the influence of the spontaneous development of the mind itself, resulting from the constitution of the brain, which is its organ, it still holds true that all our knowledge comes from our sensations, and from the brain-work thence resulting. Mind is, so to speak, the product of these two factors; and our notions of the world around us, elaborated and fecundated by the mind's spontaneous action, constitute individual personality. Hence, inasmuch as anatomy, physiology, and pathology, show intimate relation between sensibility and intelligence, we can justly say that psychology confirms the positive data furnished by these three sciences.

Accordingly, poisons which affect the intelligence are *ipso facto* poisons of the sensibility. In this respect alcohol does not differ from chloroform. When alcoholic intoxication is only beginning, we find already a notable degree of insensibility; but at the comatose stage the insensibility is total, just as in the last stage of chloroform. Thus intoxication by chloroform and intoxication by alcohol proceed along parallel lines, and we can distinguish a first period of intoxication, properly so called, and a second period of sleep or coma.

When a person takes chloroform, the first few inhalations make him dizzy; he is seized with a sort of vertigo and dimness of vision. This vertigo goes on increasing, and, as the patient continues to respire the toxic agent, his ideas become more and more exalted. He hears what is said to him and makes replies, but he does so after the manner of a drunken man, at first exaggerating his impressions and regardless of proportion. His judgment has already disappeared, and he utters the most insignificant replies with a theatrical accent, the effect being often grotesque. Next, his ideas grow more and more mixed: will and judgment being gone, ideation is disordered and delirious; in short, we have a state of sleep accompanied with dreaming, closely resembling ordinary sleep.

When the chloroform absorbed by the mucous membrane of the lungs has passed into the blood, *active* memory, which presupposes attention and will, has disappeared; still, the intelligence is not yet dead. Ideas are still conceived, old recollections persist, and sometimes even the memory of past events is strangely quickened. The patient will speak in a language he thought he had forgotten, and recall old stories that seemed to have passed into oblivion. This superexcitation of memory is all the more interesting because in sundry forms of mental alienation it occurs with the same characters—these, too, being accompanied by entire loss of *active* memory.

Though insensibility supervenes very soon after the administration of chloroform, commonly it occurs only after the loss of memory, and this circumstance leads to very singular results. Thus, if the surgeon begins the operation before perfect insensibility has been produced, the patient will cry out, and beg to have it delayed till the drug has had full influence. One might suppose, from his cries of pain and his contortions, that the chloroform had produced no effect, and yet on awaking he has no recollection of what has taken place.

Is that real pain which leaves in the mind no trace? The answer to this question is not so easy as one might imagine. Suppose an acute, penetrating pain, continuing only for about one minute. Undoubtedly the patient suffers real pain during that minute; but, if all memory of it disappeared at once, then the patient would deny that he had suffered at all, and would not hesitate to undergo the operation again. In short, he would have enjoyed the benefits of chloroformic anæsthesia.

In administering chloroform, we must take account of the patient's temperament. If he is a resolute, courageous person, all will go on well, and the insensibility will readily disappear; if, on the contrary, he has an unconquerable dread of the operation, great watchfulness will be necessary, for in such cases syncope is very frequent. Besides, such a patient resists the action of the drug for a long time, and it must be administered in far greater quantity than in the other case. The chloroform always retains its power, but the cerebral excitation to which some patients are subject enables them to resist its toxic action, as though the will could, so to speak, brace itself up to resist the action of the poison on the nerve-centres. The same occurs in the use of alcohol. One who *will* not be intoxicated may drink a large quantity without being drunk. At length, however, his will is conquered, and he falls to the ground, but he will not have experienced the exhilaration, the mad excitation, of the man who gives himself up to the influence of the liquor.

Thus, then, under the action of chloroform we find an antagonism existing between the various intellectual faculties—on the one hand the voluntary, and on the other the unconscious faculties. The latter are slowest to disappear; ideation, its guide and check, being deranged or destroyed, follows its habitual laws: association of ideas persists. External sensations are still borne in upon the mind, each one awaking a long series of ideas. As the sense of hearing is the last to disappear, the patient, though he can no longer either see or feel, hears every word that is spoken, and is set a-thinking at once. The same thing occurs in ordinary sleep, rarely in adults, but very frequently in young children. In fact, a certain degree of natural somnambulism is nearly always to be found in children. The child speaks out aloud without waking, he laughs and talks; more frequently he is frightened and cries. The course of his thoughts may be altered, diverted into another channel, by speaking to him gently, and this without arousing him from sleep. On awaking, all recollection of this has vanished. This method has been tried in mental alienation, to divert the thoughts of melancholics and hypochondriacs.

But soon these external phenomena which indicate the preservation of the intelligence, if not its integrity, disappear in their turn. The period of excitation is succeeded by the period of relaxation, and then the patient is in a deep sleep. However violent the external excitations, however painful the surgical operation, nothing can arouse the patient out of the comatose state into which he has fallen. His respiration is regular, his pulse slow and full, his pupils are motionless, and his features, paralyzed as it were, no longer wear that convulsive grimace which may be regarded as the last trace of sensibility. Intelligence is now destroyed. The coma of chloroform and that of alcohol appear to be essentially one. And, yet, what a difference! The former saves man from pain, the latter drags man down to the lowest depths of degradation; yet in both all signs of intellectual life have disappeared—there is a temporary death of the mind. It may be that, in the inmost nerve-tissues, brain-work still goes on, unconscious and silent, but whether this is so we know not.

SKETCH OF PROFESSOR SECCHI.

THIS distinguished Italian physicist and astronomer died on the 26th of February. PIETRO ANGELO SECCHI was born in Reggio, in Emilia, July 29, 1818. He was educated for the Church, and joined the order of the Jesuits November 3, 1833. He studied mathematics, physics, and astronomy, under Padre de Vico, and taught physics in the college of Loreto from 1841 to 1843. In 1844 he began his course of theology in the Roman College, and in 1848 came to the United States, and pursued his theological studies, at the same time teaching physics and mathematics, in the Georgetown College, District of Columbia. There he remained until 1850, when he was recalled to Rome.

He now entered upon his public career as an astronomer and physicist. He was appointed Director of the Observatory of the Roman College, reconstructed it on a new site and plan, invented and perfected an improved system of meteorological observation, published a monthly bulletin, which was continued until 1873, and invented and constructed a meteorograph, which was much admired by *savants* at the Paris Exhibition of 1867.

Prof. Secchi was commissioned by Pope Pius IX. to complete the trigonometrical survey of the Papal States, begun by Boscovitch in 1851, and to rectify the measurements already made of the meridional arc. He also superintended and executed successfully a commission to bring a supply of water to Rome from Frosinone, forty-eight miles distant. After the closing of the Roman College, and the expulsion of the Jesuits (1870–'73), Prof. Secchi was allowed to retain his post, and continued to lecture on astronomy in the ecclesiastical schools at Rome. In 1875 he was sent by the Italian Government on a scientific mission to Sicily.

Prof. Secchi was a man of great industry, and cultivated the astronomical field assiduously. The results of his scientific labors will be found chronicled in the periodicals of Italy, France, Germany, and England, and the "Smithsonian Contributions to Knowledge" in this country. But he is especially known in the scientific world for his researches and discoveries in spectroscopic analysis, and in solar and stellar physics. Among the most important of these are his "Spectrum Observations on the Rotation of the Sun," published in 1870. The same year he printed a large work on the sun, which was highly regarded, and immediately translated into French and German. His last considerable publication is a popular book on "The Stars," contributed to the Italian branch of the "International Scientific Series."

CORRESPONDENCE.

THE GERM THEORY.

To the Editor of the Popular Science Monthly.

IN your February number, Dr. J. R. Black assumes to correct Dr. Niemeyer's statement that the night-air of large cities is less noxious than the stirred-up air of the daytime, and he does so with a degree of confidence that seems to imply that there can be no such thing as doubting that he speaks *ex cathedra*.

Now, Dr. Black evidently believes that the insalubrity of city air depends upon the amount of non-respirable gases that may be diffused into the respirable ones; and is wholly independent of the condensible effluvia of the vaporous kind, or of the organic germ-dust that the heat and stir of the day may keep suspended, but would settle with the cooling and quiet of the night.

Now, while the precise application of the law to cities has not been made before, perhaps, in your journal, the teaching which inevitably leads to it has been abundant, and from unquestionable authority, so that, if Dr. Black wishes to correct so fatal an error as he charges this to be, he is very late with his solicitude. One lecture of Tyndall's, published by you, devoted much detail to the experiments of the professor, in his attempts to bottle a sterilized infusion in the laboratory of the Royal Institution, in air he had attempted to sterilize there, and explaining that he did succeed in a special chamber elsewhere. If, as Dr. Black would imply, noxious effluvia obey the law of diffusion of permanent gases, how comes it that they specially hover over low marshes and putrefying cesspools, while the ascent of a mountain of considerable elevation carries us above malaria and aërial infection, and often above bacterial decay?

A recent experiment of Tyndall's was to sterilize a bottle of infusion and open it upon the brink of a precipice, and, after contact with the air, recork it, to observe whether the infusion retained its sterility or not. He found the air germless. The experiment was made to test this identical question of the settling of ferment-germs.

Pasteur tried similar experiments, ascending to high points in Paris, bottling and comparing the air so bottled in putrefactive power with air bottled upon Mont Blanc, and with the air of the streets of Paris, always with the result of finding the air of the street levels more laden with micronymes than that obtained at considerable elevations. Upon the Western Plains, before civilization had scattered its filth, laden with zymogens, meats hung up in the air, even in midsummer, would keep sweet for days. The emigrants of 1849, in crossing the Plains, were surprised to find often the carcasses of dead animals of a previous caravan, drying-up viscera, and all without decay. This is easily explained on the germ-theory; without, it is inexplicable. If Dr. Black has any evidence that the germ-theory of decay and zymotic diseases is untenable, he should presently submit it, for, to my thinking, the world is only waiting to hear from Dr. Charlton Bastian, when the testimony and argument will be declared closed.

Respectfully,

C. W. JOHNSON.

ATCHISON, KANSAS, *February* 20, 1878.

THE HORSE IN AMERICA.

WE extract the following from a private letter of a Swiss archæologist:

"In THE POPULAR SCIENCE MONTHLY of last November, page 121, I read that in Colorado on ruins more than 500 years old, probably much older, there are found drawings of horses. Can this be correct? I know there are found fossil remains of horses in America, but I know also that the horse was totally extinct in America at the time of its discovery by the Spaniards. Ruins on which drawings of horses are found must, therefore, be more recent than the discovery of America by the Spaniards. The well-preserved cedar-wood indicates that the ruins cannot be as old as the fossil horse. From the fact that no signs of a door are visible in the outer walls, and the ingress was from the top, I conclude that these ruins must have been built by the Pueblo Indians, or an allied race. I believe the Pueblo Indians to be the last remains of a more highly-civilized race, perhaps identical with the mound-builders, and would attribute to the same race the antiquities of Arizona. They have been almost exterminated by the later invasions of very distinct tribes. The aborigines of America did not know in 1492 the use of iron. That a skeleton in a Utah mound (page 123, ibid.) would have been found with a huge iron weapon in the right hand is therefore, for me, quite incredible. Also the occurrence of wheat in the same mound and of bones of *sheep* in the Colorado ruins. Except the llamas and alpacas of Peru, the aborigines of America in the fifteenth century had no cattle whatever, and the domestic sheep and the wheat have been introduced by the Europeans in America.

"Was the skeleton in the Utah mound of the Indian red race? Then it must be more recent than the European invasion which brought wheat and cattle to America. Or is it possible that the Colorado ruins and the Utah mounds relate to an Asiatic invasion which brought iron, wheat, horses, and sheep, into America before the European invasion, but was exterminated, with its wheat and cattle, by the Indians long before Columbus. Elephants' heads, represented on the walls of Palenque and other Mexican ruins, would support a similar view, if they do not belong to extinct species, which would prove an enormous age for these ruins. However this may be, it cannot be doubted that in 1492 the natives of America knew neither elephants, nor horses, nor sheep, nor wheat."

EDITOR'S TABLE.

AMERICAN CONTRIBUTIONS TO ELECTRICAL SCIENCE.

THE story of electricity forms the most romantic chapter in the history of science. The curious thing about it is, that it has been a progress from utter and absolute ignorance to the most familiar and extensive practical results. In all the other sciences—mechanics, optics, physiology, astronomy—there was a basis of common knowledge, consisting of many familiar facts to start with, and there is ever a rudiment of science in the loose observations of uninstructed people concerning things that fall within the range of ordinary experience. But electrical science had no such starting-point—nothing was known by common people of any such agent. Lightning was hardly regarded as a terrestrial thing. It was the bolt of Jove, a minister of God's wrath, or a malign agency of the prince of the powers of the air, a kind of preternatural phenomenon; and, when amber was rubbed and found to attract light bodies in a mysterious way, it was assumed to have a soul and to be a sacred thing. This little seed of the science did not germinate for thousands of years. It was an instructive test of the culture of the human mind, and shows what an enormous amount of preliminary mental activity had to be expended before men were prepared to engage in the study of Nature. The natural world was filled with this force which we now call electrical; all things were pervaded by it, but it was beneath the surface; it did not strike the senses, and compel attention; it could be discovered only by thought, and the investigation could not commence until the human intellect had been turned in a systematic way upon natural things. But when experimental inquiries in electricity were once begun, their results were so curious and peculiar that they exerted a powerful fascination over the wonder-loving, and by this stimulus the science grew rapidly. It has given rise to a brilliant series of electrical and magnetic discoveries, inventions, and useful applications, of the widest range and the highest utility to civilization, such as no other science has afforded. The intellectual movement has here been from the zero of total ignorance, through long observation and experiment, up to the richest harvest of wonderful works.

It is interesting to note how fully this science belongs in its development to civilization, and how widely its discoveries are to be apportioned among different nations, and it is not to be overlooked that the New World shares these honors conspicuously with the Old. The Englishmen Gilbert and Gray were prominent in laying its foundations; the German Guericke contributed essentially to the work, and Du Fay, the Frenchman, gave early form to its theoretic structure. The next, and by far the most brilliant step yet taken, was made by the American Franklin in demonstrating the identity of lightning and common electricity, and in the invention of the lightning-rod. The Italians Galvani and Volta then followed, giving us the electrical batteries that bear their names; the Englishman Davy soon made an epoch in electro-chemistry; and Oersted, the Dane, came next with the discovery of electro-magnetism. This paved the way for the era of the successful establishment of the telegraph; and here our countryman Morse was a leader, whose name is everywhere indissolubly linked with the system.

All these achievements in the progress of the science were regarded with incredulous astonishment when they were made; but the recent exploits in the field of electrical invention and discovery surpass, if possible, in their wonderful results, all that has gone before, and here the work is exclusively American. The musical telephone of Elisha Gray, and the speaking telephone of Graham Bell, together with the Phonograph of Thomas Edison (which, although not an electrical machine, grew out of the telephone), were all invented in this country, and they nobly "crown the first two years of our new century." The import of these devices is being increasingly appreciated by scientific men as their powers are developed, and eminent foreign electricians have pronounced them the most extraordinary productions of the present century. Experimenters abroad may be expected to contribute to the elucidation of their conditions and principles, but they will do well not to overlook what has been accomplished here. Already, they are taking credit for contrivances which are but repetitions of American work. Dr. William F. Channing, of Providence, who, with other gentlemen of that city, have taken an active interest in the telephone from the outset, and contributed valuable aid to Prof. Bell in perfecting his invention, thus writes to the *Journal of the Telegraph* in reference to things done on the other side, that had been anticipated here:

"A considerable flourish has recently been made over the multiple telephone of M. Trouvé in Paris. As the speaking telephone is entirely an American discovery, it is worth while to keep the credit of what we do at home.

"The multiple telephone, that is, a cubical or polyhedral chamber, every side of which, except the front, is occupied by telephone-plates with magnets, etc., behind, was made last summer, by Henry W. Vaughan in Providence, before the speaking telephone had been seen in France.

"In a recent lecture upon the telephone before the Franklin Society of Providence, I had the pleasure of using a pair of sympathetic or rather responsive tuning-forks, made many months ago by Prof. E. W. Blake, of Brown University. These tuning-forks were of the same musical pitch, and each mounted on a sounding-board. They were also tempered and magnetized, so as really to constitute permanent U magnets. Between the poles or ends of the prongs of each of these magnetic tuning-forks, a short soft-iron core, surrounded with a coil of fine insulated wire, was supported, very near, but not in contact with, the prongs of the tuning-fork. These instruments were placed in a common telegraphic circuit a sixth of a mile apart. When the distant instrument was struck, the other responded so as to be heard throughout the lecture-room. This is a form of the responsive tuning-fork, much more beautiful than that figured in *Nature*, and ascribed to W. C. Röntgen; and it anticipated European application by several months."

MR. WALLACE AND CLAIRVOYANCE.

We have followed up the controversy that grew out of the publication of Dr. Carpenter's lectures on spiritualism, and, having printed in the Monthly an adverse review of that book by a leading representative of the spiritualist party in this country, we have republished in successive numbers of the Supplement the replies to Dr. Carpenter made by those eminent scientists, Mr. William Crookes and Mr. A. R. Wallace. We supposed, from intimations in this last and shorter installment, that the discussion was ended; but Mr. Wallace comes on again in the last *Athenæum*, and, as the logomachy may prove interminable, *we*, at all events, shall have to stop. Nothing would be gained by printing Mr. Wallace's last letter in full, but some notice of his positions may be desirable.

The relation of official French inquiry into mesmerism, animal magnetism, and clairvoyance, has been a prominent question in this controversy. The main facts seem to be these: In 1784 the French Government ordered the medical faculty of Paris to investigate the theories of Mesmer, who had been making a great stir in that city, and report upon them. A committee was appointed, of which Franklin and Lavoisier were members, and their report was adverse to the validity of Mesmer's claims. In 1825 the believers in animal magnetism applied for a new commission, which was appointed by the Academy of Sciences, and consisted of five members, who made a favorable report upon the subject in 1831; but this report was neither adopted by the Academy nor regularly printed in its memoirs. In 1837 the French Academy appointed a new commission of nine members, who reported adversely upon the doctrine of animal magnetism, and their report was adopted by the Academy; and still another commission was afterward ordered by the same body, and with the same result. Mr. Wallace complains that Dr. Carpenter, in his historical sketch of the subject, ignored the report of 1831, which was on the side of mesmerism, and was not accepted by the French Academy, and he devotes his last letter to a statement of the points made in that report. Mr. Wallace assures us that the commission "obtained absolutely conclusive facts, which have subsequently been often confirmed, but have never been satisfactorily explained away." Among these is the proof of clairvoyance. The committee say that "prevision of organic phenomena, knowledge of the internal conditions of other persons, and true clairvoyance, had been demonstrated to them." Mr. Wallace adds: "One of the somnambulists determined correctly the symptoms of M. Marc, a commissioner; and also the disease of another person, the accuracy of the diagnosis being confirmed by *post-mortem* examination. Clairvoyance was proved by one of the patients repeatedly reading and naming cards while four of the commissioners successively held his eyes closed with their fingers—a test, the absolute conclusiveness of which each one may satisfy himself of."

The term *clairvoyance* means literally clear sight. But everybody with good eyes has clear sight; the alleged vision is, therefore, not of the ordinary kind. It claims to be an extraordinary kind of seeing, a seeing through opaque objects—through the eyelids, through bandages, or through the back of the head, and into objects not penetrable by ordinary vision. The term "clear," as applied to this kind of sight, is intended to denote especial or remarkable clearness, or a transcendental vision, which opens to sight things not sensible to the normal eye. In short, clairvoyance affirms an extra endowment for making things visible which goes beyond the range of that sense which is our usual source of knowledge.

Now, Mr. Wallace says that this is an "absolute fact," which has been conclusively proved and known for forty-seven years, or since the report of 1831, that declared it to be demonstrated. As, therefore, this remarkable endowment of human nature has been established as a fact for nearly half a century, we are fairly entitled to ask, What have been its results? If it be true, no discovery ever made in science can for a moment bear comparison with it in importance; and if it be true, we have a right to demand the legitimate results that must flow from it, as we expect and require the natural results of all other genuine discoveries. Of course, the objection may be interposed that we must not be premature in anticipating the fruits of discovery, because the history of all science shows that the interval between the dawn of a new principle and its developments and applications may be very long. This is true; yet, in every case, we demand at once the effects that flow immediately from the quality of the discovery; in fact, we only know it by these results. It would, of course, have been absurd to expect from the invention of the spy-glass the great results of the modern telescope, which has grown out of it; but it would have been proper to expect from the spy-glass that which was properly claimed for it, and which it at once compelled all men to yield. All scientific discoveries, in fact, are new procurable effects, and are, therefore, their own witnesses. Clairvoyance *must* give us the new results of a marvelously-sharpened vision; the extra faculty implies extra disclosures. And again we ask, where are they? With a new capacity for seeing, what new thing has been seen? The limitations of vision restrict and measure the usual sphere of knowledge, and with every increase in the power of optical instruments, as the microscope and telescope, in aiding the eye, knowledge has been extended, novel facts brought to light, and it is these that attest the instrumental improvements. But with a power of vision so mysteriously sharpened that opaque objects become transparent, with the barriers actually taken away, what has been revealed? There are thousands of perplexing and unsettled questions, regarding the constitution of material things, which might be cleared up by another increment of visual penetration; but clairvoyance has given no help in conquering these difficulties. If it has been a demonstrated reality these fifty years, it ought long ago to have vindicated its claims by unveiling some of the obscurities of material objects. Yet, claiming to be a superior means of laying open the inner constitution of things, it has not even proved equal to ordinary sight, and has, in fact, done nothing whatever toward extending the boundaries of knowledge. It may, perhaps, be objected that clairvoyant power of seeing through opaque things no more implies a revealing of their inner nature, than looking through the air with the eye implies the recognition of its physical and chemical constitution. But this plea for seeing nothing, with a preternatural gift of sight, is futile, and the advocates of clairvoyance understand well enough that the validity of the claim must turn on what is recognized; accordingly, the French commissioners say it had been demonstrated to them that clairvoyance gave a knowledge of the internal condition of other persons. The body was not looked through as we look through the air, where nothing is seen; but it is claimed that things were seen, internal conditions perceived, morbid actions identified, and features of disease described, that were confirmed by *post-mortem* examination. Why, then, should this power be confined to the identification of things already ascertained by the common resources of inquiry? The new way of getting into the mysteries of the organism should have attested itself by results not accessible by ordinary means. It is significant that the clairvoyant reports only as far as normal knowing had already reached. Yet the human system is filled with physiological and pathological enigmas and obscurities, the clearing up of which would be priceless to science. Why, then, did not the physicians of the French commission close the investigation at once and forever by throwing light upon organic processes not before understood, and thus vindicating the new method, by showing that it could do, in a direct way, at least as much as we are now able to do indirectly, though only by long and difficult processes of investigation?

This is certainly a dictate of common-sense. The test of clairvoyance is what the alleged exceptional clearness shows. The question is, Can the clairvoyant actually do what he pretends to do? And the proof is not the mere testimony of a few parties, who say they have seen extraordinary things, but what has been positively, and demonstrably, and openly gained to science? This is the test in the case of all other scientific discoveries. M. Burdin, a member of the Academy of Sciences, put the claims of clairvoyance to very simple and decisive proof in 1837, when the real "evidence" signally failed. He placed 3,000 francs in the hands of a notary, subject to the order of the Academy, to be given to any one who would read writing placed in an opaque box, a committee of the Academy being appointed to supervise the experiments. The conditions were modified in various ways to suit objectors, the only point being to determine whether the clairvoyant could actually see through an opaque substance, and the time allowed to find a party who could do this, at first two years, was extended to three. Numerous trials were made, but none succeeded. The result, however, of the carefully-conducted experiments was to detect, in several instances, the fraudulent mode in which the alleged previous successes had been obtained.

NEW SOLAR PHOTOGRAPHS.

M. Janssen, the eminent director of the observatory at Meudon (France), has for some time been giving his attention to solar photography, and with singular success. The very remarkable photographs he has lately produced have hardly yet reached this country; but, from the examination of one, sent by him to the Allegheny Observatory, and which we have had the opportunity of seeing, we find that the praise bestowed abroad upon these new results is fully deserved.

The surface of the sun itself has been described by recent observers as consisting of a relatively *dark* background, thickly starred in every part by those strange objects called technically "granules," or "rice-grains," and which constitute the real source of the solar light. These, which have hitherto only occasionally been seen by good telescopes, are now definitely fixed for us by the camera, and we may see for ourselves that they, with their surrounding gray, do resemble—to compare great things with small—rice in a plate of soup, though the photograph shows that they are not in general elongated, but nearly round, with an irregular outline, as described by careful observers. We must leave, however, to special students the study of these details, and only observe that the photograph, besides confirming previous optical observations as to the remarkable fact that the light and heat of the sun come from but a small part of its surface, adds otherwise directly to our knowledge, by presenting new facts, such as the evidence of storms upon the solar surface (quite away from the spots), which have never yet been distinctly observed by the telescope.

These admirable photographs can hardly fail to soon become known, by copies to the scientific public, for they constitute a most essential step in the study of the sun, and one on which M. Janssen is certainly to be congratulated.

THE EDISON PHONOGRAPH.

In a certain sense, this "acoustical marvel of the century" is as simple as a grindstone; but, in a scientific point of view, there are subtile questions about it that only trained physicists can appreciate. Prof. Mayer's article upon the subject, in the foregoing pages, besides accurately explaining the mechanism and its operation, points out the delicate complexity of its effects in a way that will interest all curious-minded readers. Mr. Edison, by this invention, has done for sound what Daguerre did for light—made it possible to fix and permanently retain the most fleeting impressions. We pointed out, last month, the marvelous capacities of cold iron, magnetism, and an electric wire; but the capacities of the phonograph are still more marvelous, for, with only a vibrating plate, a sheet of tin-foil, and a crank, it is possible to arrest and fix all kinds of sound, and, having preserved them as long as metals will hold their properties, to give them forth again in all their original qualities. The voice, indeed, is somewhat muffled and minified when returned from the iron tongue of the phonograph; but its intonations, inflections, pauses, and quality, are rendered with surprising fidelity. By the simple turning of the crank, the machine talks, sings, shouts, laughs, whistles, and coughs, so naturally and distinctly, that the listener can hardly believe his senses, or escape from the suspicion that there is some ventriloquist hocus-pocus about it, or a little fellow concealed somewhere about the arrangement. But the fact is established, and must be made the most of. A machine, as simple as a coffee-mill, hears a speech or a song, and gives it back as perfectly as it was at first uttered by the living organs of voice. And so, again, we have the lesson repeated, with still greater emphasis, that we must raise our estimate of the powers and potencies of "mere dead matter."

LITERARY NOTICES.

Physiography: An Introduction to the Study of Nature. By T. H. Huxley, F. R. S. With Illustrations and Colored Plates. Second edition. Pp. 377. New York: D. Appleton & Co. Price, $2.50.

This volume has been prepared as a school text-book on the subject hitherto known as physical geography, but in its method it is very different from the usual works upon that subject. Of course, Prof. Huxley could not enter upon this field without taking his own view of its method of treatment, and making an original book, but beyond this he has unquestionably made a very valuable contribution to educational literature. In the following passage from the preface he puts the subject upon its rational and proper basis. He says:

"I do not think that a description of the earth which commences by telling a child that it is an oblate spheroid moving round the sun in an elliptical orbit, and ends without giving him the slightest hint toward understanding the ordnance-map of his own county, or any suggestion as to the meaning of the phenomena offered by the brook which runs through his village, or the gravel-pit whence the roads are mended, is calculated either to interest or to instruct. And the attempt to convey scientific conceptions without the appeal to observation which can alone give such conceptions firmness and reality, appears to me to be in direct antagonism to the fundamental principles of scientific education."

Prof. Huxley was led to the preparation of this volume in consequence of having been invited, several years ago, to give a course of lectures before the London Institution, which were intended to initiate young people into the elements of physical science. Prof. Huxley took the opportunity thus afforded to put into practical shape ideas long entertained respecting the proper method of approaching the study of Nature. Twelve lectures were given, not on any particular branch of knowledge, but on natural phenomena in general, and the title "Physiography" was taken to distinguish both as to matter and method between the subject and what is commonly understood as physical geography. The ideas which Prof. Huxley aimed to embody in these lectures, and which characterize the present work, are thus happily presented by himself:

"It appeared to me to be plainly dictated by common-sense, that the teacher, who wishes to lead his pupil to form a clear mental picture of the order which pervades the multiform and endlessly-shifting phenomena of Nature, should commence with the familiar facts of the scholar's daily experience; and that, from the firm ground of such experience he should lead the beginner, step by step, to remoter objects and to the less readily comprehensible relations of things. In short, that the knowledge of the child should, of set purpose, be made to grow, in the same manner as that of the human race has spontaneously grown.

"I conceived that a vast amount of knowledge respecting natural phenomena and their interdependence, and even some practical experience of scientific method, could be conveyed, with all the precision of statement which is what distinguishes science from common information; and yet, without overstepping the comprehension of learners who possessed no further share of preliminary educational discipline than that which falls to the lot of the boys and girls who pass through an ordinary primary school. And I thought that, if my plan could be properly carried out, it would not only yield results of value in themselves, but would facilitate the subsequent entrance of the learners into the portals of the special sciences."

Prof. Huxley fulfilled this idea with great approval in his lectures. He began by ideally placing his audience upon London Bridge to observe and consider the river-phenomena of the Thames. From this point, step by step, he worked over the field, constantly using illustrations and explaining effects that were familiar to his hearers. In this aspect, therefore, the book has a flavor of locality, but the thoughtful teacher in using it will simply transfer its applications to his own region. The book is beautifully illustrated, and should find its place, if not as a class-book, at least as a book for reading and reference, in every school.

Letters of Chauncey Wright. With Some Account of his Life. By James Bradley Thayer. Privately printed. Pp. 383. Cambridge: Little, Brown & Co. Price, $2.50.

We have found this volume very pleasant reading, as it delineates the features of a marked personality, and makes us acquainted with the somewhat peculiar life of a man who was thoroughly appreciated and much beloved by his friends. His printed letters are most readable, and, though not brilliant, they seem to us quite superior in simplicity and clearness of style to his more elaborate published essays; and this too when he is treating of the same subjects. He was born at Northampton, Massachusetts, in 1830, entered Harvard College in 1848, passed the rest of his life at Cambridge, and died suddenly of apoplexy in 1875. He was employed in the office of the *Nautical Almanac*, took occasional private pupils, taught in Prof. Agassiz's school for young ladies, was an instructor in the college, and one of the university lecturers. His literary work consists of articles contributed to the *North American Review* and the *Nation*. The following passages from his biographer's description of his character will give the reader a good idea of some of its aspects:

"Calm, gentle, unassuming; ready to be pleased; demanding little of his friends; as pure as a woman in thought and speech; fond of children, and unwearied in giving them pleasure; free from passion to a defect; never selfish, though at times, from preoccupation of mind or from lack of imagination, not wholly considerate; deficient in ambition; devoid of jealousy and envy; perfectly honorable and perfectly amiable—these stand out in the memory of his oldest friends, as the last impressions of his character, the same large features, great simplicity and great dignity, which would have struck an observer meeting him for the first time. . . .

"His writings were more like simple transverse sections from a web that was ever unrolling itself from the loom of his busy brain than like pieces woven for the occasion, in which a particular effect was to be produced by proper combination of the material at his command. I fear that my illustration may not seem a very pertinent one; but it presents itself naturally to me as I recall the process of composition of the bulk of his published essays, and many more that never went beyond his friends. He wrote with pencil, usually in a note-book; and, when he was in the mood of composition, wrote pretty steadily all day and far into the night. He was too precise in thought and expression to need to correct much or to revise what he had written; and I can hardly recall an instance of his rewriting, or rather reshaping, an essay, short or long. The starting-point was usually some fruitful reflection that promised to reward development; and from this point he would proceed on what was really a voyage of discovery, though in waters that were in general familiar to him. What he wrote during the day would probably be read to me, or the friend that was nearest, the next day, and talked over in a way. The end often came quite as much because the *afflatus* had ceased as because a natural conclusion had been reached. What he thus produced were rather studies than finished work. They aided him to make his own thought clear to himself, but were little fitted to impress that thought upon others. Original, solid, suggestive, as they always were, from the very manner of their production they lacked proportion, relief, perspective. It seems a hard thing to say of our Chauncey, the most simple, modest, and unconscious of men, that he never knew how to sink himself in his subject; yet just here, in the lack of instinct to discern how the minds he was addressing would be affected, and in the lack of discipline to accommodate the workings of his own mind to their needs and not unreasonable demands, lies the explanation that an intelligence so rich and powerful, so eager to give of its abundance, has not left the world more in his debt. He fell dead at the very noon of intellectual life, as he would have wished to do, at his desk; but, from the qualities of which I have spoken, I doubt whether he would ever have been appreciated properly as a thinker outside of a small circle of readers, had his life been prolonged ten or twenty years."

Freethinking and Plain Speaking. By Leslie Stephen. Pp. 362. New York: G. P. Putnam's Sons. Price, $2.50.

This is an able vindication of what surely needs to be vindicated—the duty of plain speaking. The peril of it is chiefly maintained by those who are skeptical at the core about things to which they give a public adhesion. There has been a great advance in the liberty of plain speaking, and almost a corresponding advance in the liberality with which it is received. And, with this increasing toleration of it, plain speaking has grown more civil, and no longer means, as too often it used, violent and ill-tempered assaults on decent and cherished, though antiquated, theories of life here and hereafter. This book is itself an excellent example of the lesson it inculcates. The first essay is entitled "The Broad Church." It examines the position of those who adopt the formularies of the Church as being the expression of their deepest conviction, who repeat the creeds, who subscribe to the Thirty-nine Articles as often as desired, but who at the same time express their desire to discover and follow the truth, and do actually hold rationalistic views. The various arguments by which this course is sustained are considered, and attention is given to the ingenious devices by which these gentlemen, who are given the fullest credit for honesty and sincerity, endeavor to reconcile the difficulties of their position. The conclusion is reached that the attitude is a perilous one, and that the efforts to maintain it are painful and humiliating. We have a good illustration of this in the recent discussion of eternal punishment.

In the excellent chapter on "Darwinism and Divinity" is shown, among other things, the utter fallacy of the notion that existing creeds are the sole bulwarks of morality. Of course, if it be admitted that God gave the Commandments directly to man; that he proclaimed from Sinai the existence of a heaven and a hell; and that these are the foundation, instead of the outgrowths, of our moral nature—then their overthrow might imperil morality. But this radical ground is seldom taken now, and, if it be conceded that beliefs are generated from within, the argument disappears. The virtuous instincts which have contributed the best which is in theology may safely be intrusted with the care of morality when theological dogmas have become obsolete.

The last essay, called "An Apology for Plain Speaking," is an appeal to those who agree with Mr. Stephen in his conclusions to state their agreement in plain terms, and meets the questions, "Why attack a system of beliefs which is crumbling away quite fast enough without your help?" "Why try to shake beliefs which, whether true or false, are infinitely consoling to the weaker brethren?" For the answer to these questions, we must refer the reader to the book itself, commending its closing passage: "Let us think freely and speak plainly, and we shall have the highest satisfaction man can enjoy—the consciousness that we have done what little lies in ourselves to do for the maintenance of the truths on which the moral improvement and the happiness of our race depend."

The Source of Muscular Power. Arguments and Conclusions drawn from Observations upon the Human Subject under Conditions of Rest and of Muscular Exercise. By Austin Flint, Jr., M. D. Pp. 103. D. Appleton & Co. Price, $1.

Dr. Flint here attacks one of the most interesting questions in physiology—one which has attracted much recent attention, and given rise to earnest controversy. The issue discussed in this volume was first brought prominently forward and closely investigated by Prof. Liebig nearly forty years ago. It received a new impulse in 1866 by the researches of Professors Fick and Wislicenus, and the views put forth by these *savants* have been brought under critical scrutiny in later observations upon the expenditure of force by celebrated pedestrians. Prof. Flint had a hand in this work, and, after the publication of Dr. Pavy's experiments upon Perkins and Weston in

London, he reviews the whole subject for the purpose of determining how the question stands at present. The problem is so important that we print an article giving a compact presentation of his reasonings and conclusions; but those who desire to become familiar with the complete inquiry will find the volume indispensable.

THE KABALA: OR, THE TRUE SCIENCE OF LIGHT; an Introduction to the Philosophy and Theosophy of the Ancient Sages, together with a Chapter on Light in the Vegetable Kingdom. By S. PANCOAST, M. D. Pp. 304. Philadelphia: J. M. Stoddart & Co. Price $2.

THERE is an old mystical Jewish tradition in regard to occult meanings of Scripture which is called the Kabala. An amazing amount of learned ingenuity has been expended upon it, and many books written of kabalistic lore, designed to solve these enigmas, and bring out their mysterious meanings. It has been held, indeed, that the Kabala is nothing less than a profound science, which, if opened up, would explain numberless hidden things in regard to prophecy, Scriptural interpretation, theosophy, and the order of Nature itself.

Dr. Pancoast calls his book the Kabala, and says he has been working at it for thirty years, and has found the keys that open its mysteries; and he says, furthermore, that it is a great thing, and is all that has been claimed for it. Nor does he suppose that its benefits are to be confined merely to the explanations of old riddles, or the development of a fruitless philosophy; he holds its results to be of a very practical kind in influencing modern opinion. One of these important advantages is stated to be that "a just appreciation and knowledge of the Kabala would stop infidelity, that is defiantly stalking through the world, uprooting, tearing down, razing, actually burying faith in God and his salvation." So potent an instrumentality is certain to be well appreciated, but expectation is dampened when we are informed that this book is not designed to contain the presentation that will work such important effects. Dr. Pancoast proposes, therefore, to make another, saying, "We have in contemplation the publication of a large, full, candid exhibit of what the Kabala is, has done, is doing, and shall do for the world." If it is to be as efficacious in composing men's distracted beliefs as is here proclaimed, we say, let the doctor hurry up his big book with all dispatch.

But let nobody buy the present volume in the hope of getting any help from it in the direction indicated. It is in fact as remote as possible from any such end. It is nothing less than a kind of doctor's book on light, which the author proposes to substitute for pills. He is a collaborator in the curious field, cultivated with such brilliant but transitory results by General Pleasonton. He believes in the remedial efficacy of blue light, and prints his book in blue ink; but he goes further than General Pleasonton, and holds also to the therapeutic virtues of red light. He talks a great deal about the science of light, and his discourse is quite in the Pleasonton strain. That is, his science is his own, and is very much freed from the trammels and limitations of the common kind of science that goes current in the textbooks. His view of the luminiferous agent is thus stated: "Light is the original source of Life. Motion is Life, and Light is the Universal Motor. There is no force in Nature that is not directly derived from Light; the Physical Forces, Attraction and Repulsion, with all their modifications, are the positive and negative principles of Light, acting in matter—they are the objective Forces of Light as they operate in creating and dissolving inorganic material forms." The author has given us a book full of such kabalistic conundrums in the science of optics.

WHAT WAS HE? OR, JESUS IN THE LIGHT OF THE NINETEENTH CENTURY. By WILLIAM DENTON. Pp. 259. Wellesley (near Boston): The Author. Price, $1.

THE "light of the nineteenth century," in which the author studies Jesus of Nazareth, is the "new light" of spiritism. In this light, supplemented with scintillations of "psychometry," Mr. Denton proves (to his own satisfaction) that Jesus was a "medium" of considerable power—a clairvoyant, and a natural healer. In the latter capacity, however, he was hardly the equal, in this author's opinion, of a certain notorious "magnetic physician" whom he names, and whose "testimonials from the people" he reproduces.

Contributions to North American Ethnology. Vol. I., pp. 361, with numerous Plates. Washington: Government Printing-Office.

For many years Prof. J. W. Powell, geologist in charge of the United States survey of the Rocky Mountain region, has made the languages of the Indian tribes an object of special study, the result being the collection of a large number of vocabularies. Having decided to prepare this material for publication, he invited the coöperation of the Smithsonian Institution, whose collections of similar materials are very extensive. Prof. Henry, secretary of the Institution, promptly consented to place in the hands of Prof. Powell all this material, consisting of several hundred MS. vocabularies, together with voluminous grammatical notes on the dialects of the Indians throughout the greater part of North America. This first volume of the "Contributions" is made up of two parts, the first, by William H. Dall, treating of the "Distribution, Population, Origin, and Condition, past and present, of the Native Races inhabiting our Extreme Northwestern Territory;" and the second by Dr. George Gibbs, on "The Indians of Western Washington and Northwestern Oregon."

A Manual of Heating and Ventilation. By F. Schumann, C. E. Pp. 89. New York: Van Nostrand. Price, $1.50.

The design of this manual is to furnish to the hand of the engineer and the architect, in such shape as to be fitted for practical application, the formulæ and data necessary for computing the dimensions and determining the other conditions of heating and ventilating appliances. A manual of this kind is simply indispensable to the professions for whose use the work was compiled.

A Manual of Inorganic Chemistry. Vol. II. The Metals. By T. E. Thorpe, Ph. D. Pp. 406. New York: Putnams. Price, $1.50.

The properties and combinations of the metals are here fully and clearly described, the text being very efficiently supplemented by numerous well-executed wood engravings. The volume belongs to the excellent "Advanced Science Series," published simultaneously in Glasgow and New York.

The *Bulletin of the Nuttall Ornithological Club* has been enlarged, the number of pages being now 48, whereas formerly it was only 24. It is gratifying to observe this sign of prosperity, and we have no doubt that the *Bulletin* is now on the high-road to assured success. It is eminently deserving of support from all lovers of the delightful branch of zoölogical science to which it is devoted. The *Bulletin* is edited by Mr. J. A. Allen, with the active assistance of Prof. S. F. Baird, and Dr. Elliott Coues, and the foremost ornithologists of the United States are frequent contributors either of set articles, or of brief notes of observation. For the scientific ornithologist, no less than the amateur, it is indispensable. Subscription, $2 a year. Address, Ruthven Deane, Cambridge, Mass.

The Silver Country, or the Great Southwest. By A. D. Anderson. Pp. 221, with Map. New York: Putnams. Price, $1.75.

The "Great Southwest" of this author is the "New Spain" of the period of Spanish power in America. In successive chapters the author describes the physical and political geography of this region; its wealth in silver and gold; other wealth than the precious metals, i. e., its agricultural productions, luxuries, and attractions, with sections on such topics as facilities for acquiring wealth, scenery, and wonders, antiquities, etc.; foreign commerce of Mexico; advance of railways. Finally, there is a very full bibliographical chapter on the "authorities" whose works have been of service in collecting materials for the work.

A Guide to the Determination of Rocks. By Edward Jannettas. Translated from the French by George W. Plympton, C. E., A. M. Pp. 161. New York: D. Van Nostrand, 1877. Price, $1.50.

This is a plain, brief, but comprehensive introduction to the study of the more common rocks, and of the minerals of which they are composed. The English synonyms for the rock-names are from Von Cotta's "Rocks classified."

Part III., giving the method to be followed in the practical determination of rocks, will be found of especial value to beginners.

A System of Volumetric Analysis. By Dr. Emil Fleischer. Translated from the German by Prof. Pattison Muir. Pp. 274. Macmillan & Co. Price, $2.50.

There are two methods of chemical analysis, when the operation is carried to its highest result for the purpose of establishing quantities in chemical composition. The first, and older method, is that by weighing; it involves the use of the balance, and is called the gravimetric method. The second, and newer mode, is by measurement of bulk; instead of the balance, it employs the burette, a graduated glass tube, and it is called the volumetric method. There are certain advantages in the newer process which are becoming more marked as it is more practised and developed. The superiority claimed is greater simplification and quickness of operation, with an equal and sometimes a greater degree of accuracy. Dr. Fleischer's treatise has been translated into English because it is a systematic work upon the subject, accepted as a standard in Germany, and believed to be much better for students than any original contribution to the subject in our own language. The present transitional state of chemical science, in regard to theories and the modes of expression that follow them, is well illustrated by the fact that the author of the book adopts the old notation, while his translator adopts the new. The consequence is, that both methods are given, which is a good feature of the work, and the translator thinks that the putting of the two notations, side by side, will be useful as disclosing the superiority of the newer plan.

Philosophic Ideas. By J. Wilmshurst. Pp. 151. Boston: Colby & Rich.

The precise nature of this author's "philosophic ideas" may be inferred from his highly-satisfactory explanation of Newton's law of gravitation. "Why," he asks, "does matter tend to approach other matter, and why should it approach with constantly accelerating speed?" And his answer is: "This action is the necessary outflow of the deific attributes essential to matter. Its love and intelligence are shown in approximating, so that it can mutually impart and receive more of each other's beautiful and pleasing varieties of motion by sympathetic action." And so on.

Tenth Annual Report of the Peabody Museum of American Archæology and Ethnology. Cambridge, 1877. Price, $1.

Besides the report of additions made to the museum and library in 1876, which were large and valuable, this volume contains reports of explorations in American archæology, made by Dr. Charles C. Abbott, Prof. N. S. Shaler, Prof. E. B. Andrews, and Lucien Carr, Assistant Curator; also, an elaborate paper, by Ad. F. Bandelier, "On the Art of War and Mode of Warfare of the Ancient Mexicans."

Dr. Abbott's report is specially interesting, as containing an account of his discoveries of rude stone implements in the drift-gravels of the Atlantic border in New Jersey. These implements were found at various depths, mingled with the gravels, near Trenton and along the banks of the Delaware. In the opinion of both Dr. Abbott and Prof. Shaler these gravels are of glacial origin, and the implements obtained were wrought by man, who inhabited the region at the close of the ice age, or during interglacial periods, where the climate favored their existence.

This is in striking accord with the previously-expressed views of Prof. Grote, who, in a paper read at the Detroit meeting of the American Association in 1875, and later in an address entitled "Early Man in North America," published in this Journal for March, 1877, takes the ground that man lived here during the glacial period. In this address, alluding to the implements discovered by Dr. Abbott, he says: "To me it seems clear that the men who used these rough tools dwelt on the edge of the glacier, and their implements have become buried in the moraines which were forming at many different points during the ice period."

The Relations of Pain to Weather. By S. Weir Mitchell, M. D. Pp. 25. Philadelphia.

Dr. Mitchell's reputation as an original investigator will secure for this paper careful attention. It was first published in the *American Journal of Medical Sciences* for April, 1877, being a study of a case of traumatic neuralgia, considered especially in its relations to atmospheric conditions. This is probably the first attempt to study the subject in so thorough and systematic a manner as was done in the instance given. The observations extended through a period of three years, and fully justify the conclusion that neuralgic conditions have a close and very direct relation to atmospheric states or changes. Precisely what conditions of the atmosphere excite neuralgic pain is by no means determined. Dr. Mitchell says, "Either it is the combination (of conditions) which works the mischief, or else there is in times of storms some as yet unknown agency productive of evil."

A Review of the Birds of Connecticut. By C. Hart Merriam. New Haven: Tuttle, Morehouse & Taylor, 1877.

This catalogue of 165 pages is from No. 4 of the "Transactions of the Connecticut Academy," 1877, and is a valuable addition to the ornithology of New England. We are informed by it that 291 species of birds are found in the State. These are grouped in 47 families. Of these the scientific and common names are given, with copious notes on their habits and characteristics: 135 species are summer residents, 90 species are migratory only. The now familiar English sparrow is found in most parts of the State, and, so far as the author is aware, was first introduced into New England in the fall of 1858. At that time six birds were liberated in a large garden at Portland, Maine. The catalogue contains a list of works relating to New England ornithology, and is thoroughly indexed.

The Glacial Period in the Southern Hemisphere. By Thomas Belt, F. G. S. London, 1877.

In this pamphlet Mr. Belt presents many facts to show that extensive glaciation occurred in the Southern as well as in the Northern Hemisphere. It occurred in the southern part of Africa and of Australia, extensively in New Zealand and South America. His views in regard to elevation and subsidence of land in glacial times, and the development of ice, filling the beds of Northern and Southern oceans, so that the drainage of continents was arrested, the waters of rivers being "pounded back," probably will not be immediately accepted by practical geologists.

Poisonous Mushrooms. By J. Ott, M. D. Pp. 5.

The author's conclusions are that at least one species of mushrooms (*Agaricus muscarius*) contains a poisonous alkaloid, *muscarine*, which is probably the poisonous principle of all noxious mushrooms; and that, in cases of mushroom-poisoning, in addition to the usual treatment — emetics, stomach-pump, purgatives, and gallic acid —*atropine* should be administered subcutaneously.

Map of the White Mountains of New Hampshire, from Walling's Map of the State. Boston: Publication-Office of H. F. Walling, 1877.

This map is drawn to a scale of 2½ miles to an inch, and comprises the principal part of the White Mountain region. It gives in detail the routes, principal villages, streams, and elevations, which are indicated by color, and points of special interest accessible to tourists. The topographical features are well defined. As a pocket-guide for travelers the map is indispensable.

The *Young Scientist* is a monthly magazine designed to interest young persons in scientific subjects, and to familiarize them with scientific experiments and habits of thought. But, while it addresses mainly a juvenile audience, the *Young Scientist* is not in the least puerile, and may be read with no little profit by older heads. We wish it success. New York: Published at 176 Broadway. Subscription, fifty cents per year.

PUBLICATIONS RECEIVED.

Compendious German-and-English Dictionary. By William Dwight Whitney. New York: Henry Holt & Co. Pp. 905. $3.50.

Pottery: How it is made. By G. W. Nichols. With Illustrations. New York; Putnams. Pp. 142. $1.25.

The Boy Engineers. By Rev. J. Lukin. Same publishers. Pp. 344. With Illustrations. $.175.

Transmission; or, Variation of Character through the Mother. By G. B. Kirby. New York: S. R. Wells. Pp. 68. 25 cents.

Geographical Surveys west of the 100th Meridian. Vol. IV., Paleontology. Lieutenant G. W. Wheeler in charge. Washington: Government Printing-Office. Pp. 365 of Letter-press and numerous Lithographic Plates.

Transactions of the American Fish-Culturists' Association, 1876–'77. New York: J. M. Davis print. Pp. 131.

A Plea for Candor in Bible-Reading. By a Citizen of Jackson. Jackson, Tenn.: J. G. Cisco. Pp. 44.

Wisconsin Geological Survey. Report for the Year 1877. By T. C. Chamberlain. Madison, Wis.: D. Atwood print. Pp. 93.

Variations of the Leaf-Scars of *Lepidodendron aculeatum*. Pp. 15. Also of Certain Sigillariæ. Pp. 5, with Plates. By H. L. Fairchild. From "Annals of the New York Academy of Sciences."

Transactions of the American Entomological Society. Vol. VI., Nos. 3 and 4. With Plates. Philadelphia: The Society. Pp. 174.

Twelfth Annual Report of the Sheffield Scientific School. New Haven: Tuttle, Morehouse & Taylor print. Pp. 53.

Discovery of Stone Implements in Glacial Drift, in North America. By T. Belt. From *Quarterly Journal of Science*. Pp. 22.

Willard's Method of treating Ores. Plymouth, Mass.: Avery & Doten print. Pp. 15.

Bulletin of the University of California, No. 28. Pp. 72.

Dental School of Harvard University. Cambridge: C. W. Lever print. Pp. 9.

Memorial to Congress for the Improvement of the Mississippi River. St. Louis: J. J. Daly & Co. print. Pp. 38.

Froward to the Froward. By E. A. Beaman. New York: E. H. Swinney. Pp. 28.

Methods of Arithmetical Instruction. By F. W. Bardwell. New York: Putnams. Pp. 34. 15 cents.

The Glycogenic Function of the Liver. By J. Le Conte. From *American Journal of Science*. Pp. 9.

Nature and Possibilities of Social Science. By P. Burton. Aurora, Ill.: *Herald* print. Pp. 8.

On a Branch Naval Observatory. By Rear-Admiral Rodgers. Pp. 6.

The Kirografer and Stenografer Monthly. $1 per year. Amherst, Mass.: J. B. & E. G. Smith.

Is the Universe governed by a Devil? By J. F. Smith. Oak Lawn, R. I.: Home Publishing Co. Pp. 14. 15 cents.

Contributions from the Chemical Laboratory of Harvard College. By J. P. Cooke, Jr. Pp. 132.

Hereditary Epilepsy. By Dr. E. Dupuy. On the Seat of the Vaso-Motor Centres. By the same. New York: Reprinted from the "Transactions of the American Neurological Association."

Researches into the Physiology of the Brain. By the same. New York: Putnams. Pp. 31.

POPULAR MISCELLANY.

Anticipations concerning the Phonograph.—Dr. William F. Channing, writing to the *Providence Journal* on Edison's phonograph, thus presents its future: "The sheet of tin-foil or other plastic material receiving the impressions of sound will be stereotyped or electrotyped so as to be multiplied and made durable. Or the cylinder will be made of a material plastic when used, and hardening afterward. Thin sheets of papier-maché, or of various substances which soften by heat, would be of this character. Having provided thus for the durability of the phonotype plate (a better name than phonograph), it will be very easy to make it separable from the cylinder producing it, and attachable to a corresponding cylinder anywhere or at any time. There will doubtless be a standard of diameter and pitch of screw for phonotype cylinders. Friends at a distance will then send to each other phonotype letters, which will talk at any time in the friend's voice when put upon the instrument. How startling, also, it will be to reproduce and hear at pleasure the voice of the dead! All of these things are to be common, every-day experiences within a few years. It will be possible, a generation hence, to take a file of phonotype letters, spoken at different ages by the same person, and hear the early prattle, the changing voice, the manly tones, and also the varying manner and moods of the speaker—so expressive of character—from childhood up!

"These are some of the private applications. For public uses, we shall have galleries where phonotype sheets will be preserved as photographs and books now are. The utterances of great speakers and singers will there be kept for a thousand years. In these galleries, spoken languages will be preserved from century to century with all the peculiarities of pronunciation, dialect, and brogue. As we go now to see the stereopticon, we shall go to public halls to hear these treasures of speech and song brought out and reproduced as loud as, or louder than, when first spoken or sung by the truly great ones of earth. The ease with which the phonotype cylinders may be stereotyped or electrotyped and multiplied, has been spoken of. Certainly, within a dozen years, some of the great singers will be induced to sing into the ear of the phonograph, and the electrotyped cylinders thus obtained will be put into the hand-organs of the streets, and we shall hear the actual voice of Christine Nilsson, of Miss Cary, or even of Jenny Lind and Alboni, ground out at every corner!

"In public exhibitions, also, we shall have reproductions of the sounds of Nature, and of noises familiar and unfamiliar. Nothing will be easier than to catch the sounds of the waves on the beach, the roar of Niagara, the discords of the streets, the noises of animals, the puffing and rush of the railroad-train, the rolling of thunder, or even the tumult of a battle.

"Edison has recently stated that his best instrument will now talk so as to be heard at a distance of 175 feet. The conditions for increasing the sound are so simple that there can be no doubt of any desirable extension in this direction."

Garden-Schools.—The New York Academy of Sciences has twice had under consideration plans of using the public parks for scientific and hygienic purposes. One of these purposes was the propagation of febrifuge trees and plants; the other the use of part of these public grounds as garden-schools.

This latter project is to be commended for various reasons: As education becomes general, schoolhouses cannot contain all the scholars. The present school-crowding already necessarily generates or propagates among the pupils various epidemic and other diseases. The shutting of the children in class-rooms when the sun shines, and the air is bracing, is producing leucæmic affections. The eyesight is impaired by concentration on books; and the training of the mind to the exclusion of the exercise of the senses, and of the other active functions, isolates the child from the real world, and feeds him on abstractions which predispose to several forms of insanity.

On the other hand, open-air life, study, and exercise, invigorate all the tissues, organs, and functions of the body.

The plan of such garden-schools must vary, of course, for each locality. For the city of New York, as presented to the Academy of Sciences by Dr. E. Seguin, and by the Academy to the mayor, it would be somewhat as follows: A part of each of the small parks would be planted with specimens of ornamental, edible, medicinal, textile, and other plants, where groups of children could go with their teachers to breathe and learn.

In the Central Park large tracts would be devoted to indigenous and exotic plants, to zoölogy and ichthyology, mineralogy, and specimen sections of American geology, hydrology, etc. The public-school pupils would visit these places with their teachers; and, when the weather happened to be unfavorable, they could find shelter in the public libraries, museums of painting and natural history, which fringe the park, and where they could continue their studies of Nature.

In a word, the schoolhouse must be used only when it cannot be helped, the rules of physiological education needed by a free people, being: Never to teach in-doors what can be learned out-doors; never to explain in the abstract what can be demonstrated in the concrete; never to teach with books what can be perceived in objects; never to teach by images when Nature itself is at hand; never to show dead Nature when living Nature is obtainable; and never to require belief where seeing and understanding are possible. New York's beautiful Central Park might thus be made an educational establishment of the highest value. In the Kew Gardens at London, seventy-five acres are given up to the students, without at all impairing the beauty of the landscape. The same might be said of the Gardens of Acclimation of London, Paris, Algiers, Calcutta; of the Botanical Gardens of Montpellier, Brussels, Geneva, which are partly schools and partly pleasure grounds. In this respect we are sadly behind. Once reminded that our parks have been created "equally for the enjoyment of the public, and for the education of the children," our public authorities, it is to be hoped, will realize the need of preserving them for their original purposes, and so improving them that they may every year become more and more indispensable to our citizens.

New Fossil Reptiles.—In addition to the remarkable Jurassic reptiles recently described by Prof. Marsh from the Rocky Mountains, several others are announced by him in the March number of the *American Journal of Science*. One of these, a gigantic Dinosaur (*Atlantosaurus immanis*), was much larger than any land-animal, recent or fossil, hitherto described. The femur of this monster was over eight feet (2,500 millimetres) in length, and the other remains preserved are equally huge. If this reptile had the proportions of a crocodile, it must have been over a hundred feet long! It was certainly gigantic enough to entirely disprove the theory, generally accepted, that the elephant is as large as any animal can be that moves upon the land, for the bulk of this reptile must have been at least three times that of any known Proboscidian.

Among the other Dinosaurs described in this paper is *Morosaurus impar*, another herbivore belonging to the same family, and about twenty-five feet in length, and *Creosaurus atrox*, its carnivorous enemy, nearly as large, each representing a new genus. Two small species, belonging to the new genus *Laosaurus*, are also described. The large herbivorous Dinosaurs, from the American Jurassic, represent, according to Prof. Marsh, a well-marked family, the *Atlantosauridæ*, which have but three or four vertebræ in the sacrum, five well-developed digits in each foot, and the hind-feet ungulate and plantigrade—characters not before found in Dinosaurs.

Trees and Health.—Certain observations made by a correspondent of the *Chemical News* are deserving of the attention of sanitarians. According to him, the cantonment of Goruckpoor, in Northwest India, though situated near the forest and in the neighborhood of a large swamp, was thirty years ago considered a healthy station. A large grove of mango-trees existed between the swamp and the station. For some reason this grove was cut down, and *the station became unhealthy*. Again, the civil station of Futtehpoor is situated between Allahabad and Cawnpoor, in an arid plain, but near a pretty extensive marsh. This place was considered extremely unhealthy, until the magistrate planted *between the station and the swamp* a belt of quick-growning babool-trees. As the trees grew, the place became much less unhealthy. In these two cases the trees appear to have acted as a screen or filter, protecting the population from the effects of the malaria generated in the swamps. It may be added that it would be difficult to find trees more dissimilar in foliage than the mango and the babool. "Is it not probable," asks the author, "that where beneficial effects have followed the planting of the eucalyptus, the same may be due as much to the screen which the plantation has interposed, as to any peculiar action of, or exhalation from, the leaves or stem of the tree?" Referring to the changes produced, as regards salubrity, at the Trappist monastery of Tre Fontane, near Rome, which changes have been ascribed to the peculiar virtues of the eucalyptus, the author calls attention to the fact that the deep ploughing of the soil and the removal of seven hundred cart-loads of human bones from the precincts of the monastery may perhaps be credited with some share in producing the change. So, too, the eucalyptus-trees may have served, in this case also, as a screen.

Carnivorous Plants.—Mr. Francis Darwin, in a paper entitled "The Nutrition of *Drosera rotundifolia*," describes a series of experiments made by himself to determine whether or not insectivorous plants profit by their carnivorous habits. With this object two hundred plants of *Drosera rotundifolia* were transplanted (June 12, 1877) and cultivated in six soup-plates filled with moss during the rest of the summer. The area of each plate was equally divided by a low wooden partition, one side being destined for the plants to be fed with meat, the other for those to be starved. Access of insects was prevented by inclosing the plants in a gauze case. The method of feeding consisted in supplying each leaf (on the fed sides of the six plates) with one or two small bits of roast-meat, each weighing about one-fiftieth of a grain, every few days. On July 17th it was evident that the leaves on the "fed" side were of a distinctly brighter green, showing that the increased supply of nitrogen had allowed a more active formation of chlorophyll-grains to take place. From this time forward the "fed" sides of the plates were clearly distinguishable by their thriving appearance and their numerous tall and stout flower-stems. On August 7th the ratio between the number of "starved" and "fed" flower-stalks was 100 : 149.1. And on comparing the number of stems actually in flower, it was clear that the starved plants were losing the power of throwing up new flower-stems at an earlier date than their rivals. In the middle of August the leaves were counted in three plates, and were found to be one hundred and eighty-seven on the starved and two hundred and fifty-six on the fed side. The seeds being ripe at the beginning of September, all the flower-stems were gathered, and the plants of three plates were picked out of the moss and carefully washed. The other three plates were left undisturbed: the relative number of plants which will appear in the spring on their "fed" and "starved" sides will be a means of estimating the relative quantities of reserve material stored up. Mr. Darwin gives in the following table the results of counting, measuring, and weighing, the various parts of the two sets of plants:

Ratio between the number of starved and fed plants..........	100 : 101.2[1]
Ratio between weights of the plants *exclusive* of flower-stems...........	100 : 121.5
Total number of flower-stems........	100 : 164.9
Sum of the heights of the flower-stems	100 : 159.9
Total weight of flower-stems.........	100 : 231.9
Total number of capsules.............	100 : 194.4
Average number of seeds per capsule..	100 : 122.7
Average weight per seed.............	100 : 157.3
Total calculated *number* of seeds produced	100 : 241.5
Total calculated *weight* of seeds produced	100 : 379.7

New Process of Sugar-Manufacture.—Mention is made in the *Revue Scientifique* of a new process for sugar-manufacture, invented by Prof. Loewig, of Breslau, which greatly simplifies the work. Instead of using lime to defecate the liquor, then having recourse to a double carbonization by carbonic acid, with a view to eliminate this lime in the shape of lime carbonate, and lastly filtering the carbonated liquor through animal charcoal—processes which allow about one-third of the beet-sugar to be transformed into molasses.—Loewig simply adds to the crude liquor hydrate of alumina which he has discovered the means of preparing on the large scale. This hydrate of alumina retains the coloring albuminoid and nitrogenized matters, forming with them a black scum which is removed. All that remains to be done is to concentrate the almost absolutely pure sugary liquid which remains. If this process proves successful, it will revolutionize the sugar-manufacture.

Intensity of Different Colored Lights.—Prof. O. M. Rood describes, in the *American Journal of Science*, a simple method devised by him for comparing the intensities of light of different colors—a problem that has long been considered one of the most difficult in photometry. To measure the luminosity of *vermilion*, for example, he attaches a circular disk of vermilion cardboard to the axis of a rotation apparatus, a smaller circular disk of black-and-white cardboard being simultaneously fastened in the same axis, so that by varying the relative proportions of the latter a series of grays might be produced at will. First the compound black-and-white disk is so arranged that, on rotating the machine, a gray *decidedly darker* than the vermilion is produced. Then the gray is gradually lightened, till the observer becomes doubtful as to which is the more luminous, the gray or the vermilion; the angle occupied by the white sector is then measured. Next, a decidedly *more luminous* gray is compared with the vermilion, and its luminosity gradually diminished till again there is doubt as to which of the two, the gray or the vermilion, is the more luminous; and then, again, the white sector is measured. The mean of ten such experiments showed that when the luminosity of both disks was the same, the white sector of the black-and-white disk was 23.8 of its whole area, and hence that the luminosity of the vermilion cardboard was in the same ratio, namely, 23.8 per cent. to white. Proper allowance was made by Prof. Rood for the amount of white light reflected by the black disk. The relative luminosity of other colors may, of course, be ascertained in the same way.

Causes of the Chinese Famine.—According to a correspondent of the London *Spectator*, Frederick H. Barbour, the famine now prevailing in the northern provinces of China began in the fall of 1875. Its immediate cause was the long absence of rain, but the phenomenon to which it was and still is primarily due is the gradual desiccation of the vast plains of Chi-li and Shang-Tung, a process which, commencing in the table-lands of Central Asia, has now reached the densely-peopled northern provinces of China. Mr. Barbour has for the last two years been in constant communication with the famine-stricken districts, and the letters

[1] In all cases "starved"=100.

he receives convey appalling intelligence. "Fancy," says he, "a tract of country larger than thirteen Switzerlands a prey to want that it is wellnigh impossible to relieve. The people's faces are black with hunger; they are dying by thousands upon thousands. Women and girls and boys are openly offered for sale; when I left the country, a respectable married woman could be easily bought for six dollars, and a little girl for two. In cases where it was found impossible to dispose of their children, parents have been known to kill them, sooner than witness their prolonged sufferings, in many instances throwing themselves afterward down wells, or committing suicide by arsenic. . . . The population subsisted for a long time on roots and grass; then they found some nourishment in willow-buds, and finally *ate the thatches off their cottages.* The bark of trees served them for several months, and last July I received specimens of the stuff the unhappy creatures had been by that time reduced to. The most harmless kind was potato-stalks, tough, stringy fibres, which only the strongest teeth could reduce to pulp. The other description was *red slate-stone.*"

Proportion of Theine in Different Kinds of Tea.—It was some time ago asserted by Claus, as the result of his analyses of different grades of tea, that the lower the grade of tea the higher is the proportion of the alkaloid theine it contained. Thus, according to this author, the brick-tea used in Mongolia and Siberia, which is made up of all sorts of refuse, as dead leaves, stalks, and the like, contains far more theine (about 3.5 per cent.) than the higher qualities (in which the proportion found by him was from 1 to 1.3 per cent. only). Very different results have now been obtained by another chemist—Markovnikoff, of Moscow. Having made a series of analyses of one kind of tea by the various analytical methods hitherto in use, he is able to point out the deficiency of these methods. For instance, ether extracts only one-third of the whole amount of theine in a sample of tea, and benzole only one-quarter. Using, therefore, a more perfect method, and analyzing six kinds of tea—some of the very highest, others of the very lowest grades—he arrives at the result that the amount of theine in these varies very little—from 2.08 to 2.44—and that it increases regularly, with one exception, with the quality of the tea; while the amount of ash given by each kind regularly decreases from 6.1 to 5.7 per cent. from the highest to the lowest grade. These differences, however, being very small, Markovnikoff supposes that the quality of tea depends, not at all or only a very little, upon the amount of theine, and far more on the quantity of tannic acid and aromatic oils it contains; but that, on the whole, teas made from younger leaves contain more theine than those from older leaves.

Do Lightning-Rods attract?—The old dogma that a lightning-rod no more attracts electricity than an umbrella attracts rain, is not strictly exact—for, while the umbrella has no influence on the course of the descending rain-drops, it is certain that the presence of a conductor very materially changes the earthward course of the electric fluid. The Vice-President of the British Meteorological Society, Dr. R. J. Mann, in a letter to the London *Times*, states as follows the *rationale* of the action of lightning-rods in protecting buildings:

"A conductor in the near presence of a charged thunder-cloud becomes inductively excited, a very strong charge of the opposite kind of electricity to that in the cloud being drawn to the top of the rod. When this state of things has been brought about, there certainly is a stronger tendency for a spark or flash to pass across the intervening air-gap than there would be in the absence of any such inductive disturbance. The electricians who still hold this view [namely, that the lightning-rod's attraction is equal to the 'attraction' of an umbrella] would, nevertheless, hesitate to carry their argument home to its ultimate conclusion by saying that there is no attraction between the outer and the inner coating of a Leyden-jar immediately before the electric forces shatter the glass to effect the discharge of the jar. It is indeed almost universally held that the charge of a Leyden-jar is chiefly due to the attraction of the severed electric forces exerting themselves to unite through the insulating barrier of the glass. The charge in the outer coating of the jar comes up from the earth under what, in familiar terms, can hardly be called anything else but the 'attraction' of the inner charge."

Cooking.—Nothing, probably, has more direct influence over our physical and moral well-being than the preparation of the food we eat, and it is not too much to suppose that a proper knowledge of the culinary art would, if tolerably wide-spread, do not a little to diminish crime and drunkenness. Now that ladies are to be admitted without let or hinderance to all the degrees of the University of London, we hope the Senate will see fit to add "cooking" to the list of subjects for the B. Sc. Science in the kitchen has long been a desideratum, and cooking has not hitherto been regarded really as a branch of chemistry, and, as such, an ennobling occupation. The English of all classes have everything to learn on this subject, and even the very best of our cooks seem to go right rather by intuitive talent than by any exact knowledge which they may possess. In the cookery-book of the future, however, we may hope to see milligrammes, cubic centimetres, and degrees of Celsius, replace the less exact measurements to which cooks have been accustomed, and then, perhaps, success in cooking will become a certainty.—*London Lancet.*

Distribution of Color in Animals.—It is not in the least unusual to observe in domesticated mammals asymmetrical distribution of color, while in feral animals the distribution is always symmetrical. A number of facts illustrating this are cited by Mr. J. A. Ryder in the "Proceedings" of the Academy of Natural Sciences of Philadelphia. He instances the case of a raccoon in the collection of the Philadelphia Zoological Society, in which the variation from the typical coloration of the species was great. Here the color areas were disposed symmetrically in the same manner as in the ordinary specimens. The difference was only in the shade, this specimen being of a rich, brownish yellow, except the tail-rings and the lateral bands on the face, which were of a considerably deeper hue. The nose, feet, and eyes, in the ordinary specimens, are black, while in this specimen all the dermal structures were of a much lighter tint. Again, in a specimen of *Lepus silvaticus*, in the Academy's collection, the fur is cream-colored, and very long and soft, but perfectly symmetrical and uniform in color. In rats, nearly white, the color areas were also found to be very nearly the same on both sides. The same is to be said of specimens of Virginia deer. In many domestic animals there is a decided tendency to preserve the symmetry of the ancestral type, but domestication seems to be at the bottom of the variability and asymmetry of color of animals brought under its influence. In conclusion, the author summed up the facts as follows: 1. Bilateral symmetry of coloration is interfered with in some way by domestication; 2. Where variation of color takes place in feral animals, they are invariably, so far as observed, symmetrically colored; 3. It is possible that the degree of asymmetry is an indication of the length of time that domestication has been operative.

Travels in Formosa.—In the island of Formosa the inhabitants of all the level country are Chinese. Wages on the island are 20 per cent. higher than in Amoy. Opium makes up two-thirds of the value of all their foreign imports. Opium-smoking prevails to an extraordinary extent; but a traveler in the island, Mr. James Morrison, affirms that there is not much excess of indulgence in that habit. The coolies that carried his palanquin always smoked opium at night, and continued smoking after he had gone to bed; yet they were always ready to start before six o'clock in the morning, and seemed fresh. A coolie will carry twenty miles a day for ten consecutive days. Smoking in this way costs from ten to fifteen cents a day. The daily wage of a chair-coolie is seventy-five cents. The chair is the usual vehicle for travel in Formosa. Ponies may be used for riding short distances, but the numerons rivers, too deep to ford, and too rapid to swim, render them useless for long journeys. The Formosan chair is very light, but hardly roomy enough for the average man of European race. It is forty inches long, forty-eight inches high in the centre, and forty inches at the sides, twenty-one inches wide inside, with a seat about ten inches high. The method of carrying, says Mr. Morrison, is simply diabolical. Four men carry, two being placed at the ends of the poles, and two close to the chair, one in front and one behind, the two latter supporting the chair by means of cross-pieces or yokes passing over the shoulders and attached to the poles by ropes. These ropes are so adjusted that when the men stand still, and the chair is loaded, the poles are bent about three inches. In carrying, the easy swing of the ordinary chair is lost, for, just as the Formosan chair is coming down gently, it is brought up short by the men close to it. The motion is exactly the same as is used for jigging crushed metallic ores.

Chinese Medicines.—The Chinese pharmacopœia contains instructions for preparing sundry very curious medicines, as, for instance, various animal "wines"—mutton-wine, dog-wine, deer-wine, tiger-bone wine, snake-wine, tortoise-wine, and so on. These "wines" (*chiu*) are employed instead of alcohol as a solvent for articles used as medicines. The mode of preparing mutton-wine is described as follows by Dr. D. J. Macgowan, of Shanghai: The ingredients are one sheep, forty catties (a catty equals $1\frac{1}{3}$ pound) of cow's-milk wine, a pint of sour skimmed milk, eight ounces brown sugar, four ounces honey, four ounces fruit of dinocarpus, one catty raisins, and about one catty of half a dozen other drugs. The utensils employed are a large cast-iron pot, a wooden barrel (*boorher*) about two feet high, and tapering, open at both ends, a smaller iron pot, an earthenware jar; felt belts and cow-dung are used for making the apparatus air-tight. The boorher is set on the large pot, the joining being first calked with paper, and then daubed on the outside with cow-dung and ashes; the boorher, too, is made air-tight in the same way. Then pour in the wine, add half the raisins, cut or crushed, half the sugar, the milk, and the bones of the sheep's legs, from the knees down, after breaking them open. From the other bones strip all the fat and most of the flesh, and hang them inside the boorher beyond the reach of the wine. Put in the medicines, the honey, and the remainder of the sugar and raisins. The earthenware jar is then suspended in the centre of the boorher, and the smaller iron pot is set on top, the joint being made air-tight by paper, cloth, and felt bands. A fire is now made under the great pot; when the upper pot feels warm to the touch, fill it with cold water. When this water is too hot to touch, it is ladled out, and the pot filled again with cold water. When this in turn becomes hot, the fire is slackened, the upper pot taken off, and the earthenware pot, which is now found to be full of a dirty-brown liquor, is taken out, the liquid poured off, the vessel replaced, and the upper pot, filled with cold water, again set upon the top of the boorher. When the water on top is again heated, the whole operation is completed. The earthenware pot is now again found to be about half full, and its contents are poured off, allowed to cool, and put up in jars.

Utilization of Blast-Furnace Slag.—Within a few years great progress has been made in the utilization of blast-furnace slag, and that material is now applied in many ways with great advantage. Thus, slag "sand" is employed for making concrete, building-bricks, mortar, and cement; slag "shingle" for concrete, also for roadways; slag "wool" for covering steam-boilers and pipes, ice-houses, etc., also for filtering-purposes; blocks of slag-concrete are used for paving, for curbstones and the like; finally, by Britten's process, slag is used in the manufacture of glass for roofing, and for other purposes not requiring pure glass. In making building-bricks of slag, the slag-sand is mixed with selenitic lime, with the addition of iron oxide, and pressed in moulds. The cement is made from the slag-sand, common lime, and iron oxides. It is little inferior to Portland cement in strength, while it does not cost one-fourth as much. The concrete made from this cement, mixed with the "shingle," is an excellent conglomerate for use in monolithic structures. It is stated by Mr. Charles Wood, in a paper read before the British Iron and Steel Institute, that "it took two good men, with steel bars and sledge-hammers, as much as four days to cut through a wall of this concrete about twenty-six inches thick." Mr. Wood exhibited to the Institute bottles of slag-glass, also specimens of slag-wool. The latter product, according to Mr. Wood, is obtained as follows: A jet of steam is made to strike a stream of molten slag as it falls into the slag-bogies or wagons. This jet scatters the molten slag into shot, and as each shot leaves the stream it carries a fine thread or tail; the shot drops to the ground, but the fine woolly fibre is sucked into a large tube, and discharged into a chamber. This chamber is very large, and is covered with fine wire netting. The steam and air carry the woolly particles all over the chamber—the finest into recesses formed for the purpose, the heavier into the body of the chamber. . The wool is of a snowy-white appearance.

The Mechanics of Nature.—The Rev. J. G. Wood, author of several popular works on zoölogy, has lately published a volume entitled "Nature's Teachings," which is intended to show that nearly every one of man's mechanical inventions has been anticipated by Nature. From a notice of the work in an English journal we copy a few instances of human inventions that have their prototypes in the animal world. Alluding to the principle on which the life-boat is formed, Mr. Wood observes that "the eggs of the gnat, which adhere together by a glutinous coating, are arranged side by side so as to form the figure of a boat; that the lines of the best life-boats are almost identical with those of the gnat-boat; and that both possess the power of righting themselves if capsized." Mr. Wood observes the principle of the screw in a fish's tail; finds a remarkable resemblance in the iron mast to the quill of the porcupine; and explains how the improvement in the construction of iron ships caused by making the outer shell double and dividing it into separate compartments is exemplified in the skull of the elephant. Many of the author's nautical illustrations are curious, and among others he points out that the Boyton life-dress is simply a modification of the *Physalis*, "which floats on the surface of the ocean like a bubble." The weapons used in war have also their prototypes in the works of Nature. In a chapter on projectile weapons Mr. Wood notices the archer-fish, which gains its livelihood by shooting drops of water at flies, and reminds us that the same principle was employed, though unsuccessfully, on the so-called pneumatic railway at Croydon. From the archer-fish we may pass appropriately to the angler-fish, a creature with an enormous mouth and small body. On the top of its head are some bones set like a ring and staple, and, at the end of these bones, long fleshy appendages, which, on being waved about, look as if they were alive. "The fish darts at the supposed morsel, and is at once ingulfed in the huge jaws of the angler-fish, which, but for this remarkable apparatus, would be scarcely able to support existence, as it is but a sluggish swimmer, and yet needs a large supply of food." There are different modes of catching fish, and the capture by rod and line is curiously anticipated by the worm known to naturalists as *Nemertes Borlasii*, which can extend itself, some say, to ninety feet, and looks, as Kingsley has said, a mere knotted lump, small enough to be put in a dessert-spoon. The little fish that chances to touch this "slimy tape of living caoutchouc" has no chance of escape, for he is being "'played' with such a fishing-line as the skill of a Wilson or a Stoddart never could invent." The principle of the baited trap is illustrated by carnivorous plants like the Venus's flytrap of the Carolinas, and the *Drosera* or sundew of England, and the principle of the spring-trap by the jaws of the dolphin. Defensive armor in its several varieties is strikingly illustrated by the protection afforded in many instances by Nature, and Mr. Wood's treatment of this branch of his subject will be found of great interest.

How Ants stand Heat and Cold.—The ability of ants to survive exposure to great cold or great heat, and submersion in water, is shown in a very interesting note by the Rev. H. C. McCook, published in the "Proceedings of the Academy of Natural Sciences" of Philadelphia. In one instance, a few ants, of the species *Formica Pennsylvanica* (the Pennsylvania carpenter-ant) dropped out of their nest and fell upon ice, in the depth of winter. Forty-eight hours later they were alive, being imbedded in the ice within the small depressions made by their animal heat. They moved about on being taken from the ice, and became quite active when placed in the closed hand. The power of resisting great heat is illustrated by Mr. McCook's own observations, as also by a quotation from manuscript notes on the "Ants of Texas," written by the late Dr. Linceum. A community of that highly-interesting species, the "agricultural ant" (*Myrmica molefaciens*), was located near a blacksmith-shop, which had been in operation five years. During all that period the smiths had built their fires for heating wagon-tires on the pavement or flat mound of these ants. This occurred, on an average, as often as two or three times a week. Frequently, as many as nine tires a day had been heated upon the mound. After five years of such experience, Dr. Lincecum records that he saw numbers of ants at work clearing out the entrance to their city before the fire, that had just been used for heating tires, was entirely extinguished. They seemed to have learned all about fire, and knew how to work around and among the half-extinguished coals without injury. In illustration of the third point Mr. McCook writes as follows:

"Last summer (1876) I discovered a formicary of mason-ants, apparently a variety of *F. rufa*, the fallow-ant. I placed these ants in an artificial formicarium, which was insulated in a tub of water. One night the covering by which the formicarium was protected during bad weather was left off, or removed by some meddler. A heavy shower fell early in the evening. In the morning the formicary was flooded: the ants were dead—dead and lying under five inches of water, mixed up with the mortar, which the rain had formed with the soil that composed the galleries. I poured out the water, and set the box in the sun with a forlorn hope that some of the ants might revive. At noon I chanced to open a paper box in which I had placed a dead female ant of the genus *Myrmica*. It had fallen into the tub, where it had been floating for many hours, apparently drowned. It was now crawling about the box alive. Thereupon I visited my dead fallow-ants, and found three of them moving about in the slush, endeavoring to extricate themselves. Another was struggling out of the muddy sediment in the jar which formed the lower part of the formicary. In short, the greater part of the drowned ants proved themselves to be veritable Noachians, and survived the flood."

Poisonous Leguminous Plants.—Dr. Rothrock, of the Academy of Natural Sciences of Philadelphia, calls attention to the fact that certain leguminous plants existing in our Southwestern Territories possess poisonous properties. In the vicinity of Fort Gartland, in Southern Colorado, cattle have repeatedly manifested symptoms of poisoning, the cause of which has been found to be the plant *Oxytripis lamberti*. The effects of eating this plant appear to be long enduring, the animal becoming demented, and wasting away, as its fondness for the poison increases to something like the opium-habit in man. Dr. Rothrock found at New Camp Grant, Arizona, another plant (*Hosackia purshiana*) whose effects are similar. From *Sophora speciosa*, another poisonous leguminous plant from Texas, Prof. H. C. Wood, Jr., has obtained an alkaloid which he names *Sophoria*, from the bean; its effects are not unlike those of the Calabar-bean. The Indians of Texas use the Sophora-bean to induce an intoxication, which lasts from two to three days. Half a bean will, it is said, cause intoxication, and a whole one may be productive of dangerous symptoms.

The Value of Scientific Weather-Observations.—Three daily observations of weather-phenomena are made at eighty-three stations of the Central Pacific and Southern Pacific Railroads and their branches, the area covered by the observations extending through eight degrees of latitude and twelve degrees of longitude. New observing-stations are set up in proportion as a new line of road advances. The records of these stations form the basis of a singularly interesting and important paper by Mr. B. B. Redding, which was read at a meeting of the California Academy of Sciences on January 21st. In illustration of the *financial value* of systematic observations of this kind, the author gives two cases where even superficial study of the meteorological records would have demonstrated in advance the inevitable failure of certain enterprises. For instance, in 1869 a large sum of money was expended in covering over some lakes near Summit Station with sheds, under which to cut ice for the San Francisco market. No sheds of sufficient width could be built that could bear the weight of snow falling at that point, and consequently the undertaking ended in disastrous failure. The meteorological records of the railroad companies show that the average rainfall at this point is *over five feet!* "Nearly all of this falls in the form of snow, and is equal, if the snow that falls did not become compact or melt, to a bank of snow each winter of sixty feet in depth!" A similar instance of the value of these records is furnished by the experience of the farmers settled on the west side of the San Joaquin River. For years they have tried in vain to raise crops without artificial irrigation. That section of the State of California is an exemplification of the law thus expressed by Guyot, that "when a mountain-chain opposes an horizontal wind the air is forced up along the slopes, its vapors are condensed, and water the side exposed to the wind, while on the opposite slope the same wind descends into the valley dry and cloudless." The author considers very fully the operation of the chief laws of meteorology as applied to California in general, and to special localities in particular. Among the subjects discussed by him, we would mention the conflict between polar and equatorial winds; the influences of the Gulf of California; the comparative rainlessness of the Colorado and Mohave Deserts and the Tulare Valley; the rainfall in the great valleys and on the mountain-sides; the influence of the great deserts on temperature and rainfall; why the summer temperature of San Francisco is so low as it is, the mean temperature of summer at the Golden Gate being only 56°.

Purification of Illuminating Gas.—The method in common use for separating from coal-gas foreign suspended matter is founded on the principle of condensation by reduction of temperature on contact with water-cooled surfaces, or with water itself. But the liquid globules held in suspension in the gas may be condensed by causing a jet of gas to impinge upon any resisting surface, as a leaf of paper, or a plate of metal, and an apparatus for purifying gas according to this method has been constructed by Messrs. Pelouze & Audouin. The condenser of this apparatus consists mainly of an outer casing with a gas inlet at the lower part, and an outlet at the upper. Suspended within the casing is an annular water-tank, in which is balanced a miniature gas-holder, or bell, formed with four circumference-plates, two of which are perforated in rows with small holes, and two with large holes, the latter being opposite the blank spaces between the rows of the former. The gas from the inlet passes through the central space within the annular tank, and through the four perforated plates of the bell; the tar, etc., which condense on the non-perforated portions of the surface trickle down the plates into the water-tank. It has been found that if the perforated bell has a capacity of 35,317 cubic feet, it will suffice for works producing 3,531,700 cubic feet per twenty-four hours, or in the proportion of 1 to 100,000.

Properties and Production of Honey.—There was lately held in New York a convention of bee-masters from all parts of the United States, for the purpose of advancing the interests of the important industry with which they are identified. Among the papers read at this convention was one by Mr. F. B. Thurber, in which the commercial history of honey was given with considerable detail. The use of honey antedates that of sugar, going back many centuries before the Christian era, while the general use of sugar is of comparatively recent date. There are evidences of the high antiquity of sugar in China and India, but it appears to have been only vaguely known to the Greeks and Romans. The art of refining sugar was discovered by the Venetians in the sixteenth century. It is hard to say why the production of honey should have fallen so far behind the production of sugar. It is in the highest degree healthful and palatable, and its sources are as plentiful and as sure as those of sugar. In America, within the last few years, a wonderful advance has been made in the production of honey, as regards both quality and quantity.

Honey differs greatly in color and consistence. In the recent state it is fluid, but on being kept it is apt to form a crystalline deposit, and to be converted into a soft, granular mass; its color varies, being sometimes white, but usually yellowish, and occasionally of a brown or reddish tinge. When the bees are very young the honey undergoes less change, and remains nearly white: in this state it is called virgin honey. Ordinary honey is obtained both by pressure and by heat. Recently, however, a process has been invented by which honey is forced from the cells of the comb by centrifugal force, and the combs are then restored to the hives, to be again used by the bees for storing their honey. When honey is extracted from poisonous plants, it partakes of their noxious properties. An instance of this recently befell a newspaper correspondent in Armenia. Having drunk some honey-sweetened water he was shortly afterward seized with headache, vomiting, coldness of the extremities, and temporary blindness, followed by a cataleptic state. Inquiry showed that the honey had come from the Botum Valley, where hemlock and henbane grow abundantly. Mr. Thurber points out the singular coincidence that more than 2,000 years ago Xenophon's soldiers met with a similar accident in the same locality.

Beavers in Colorado.—Mr. E. A. Barber, connected with Prof. Hayden's survey of the Territories, in the year 1874 had an opportunity of examining, on the banks of the Grand River, in Northwestern Colorado, the work of a colony of beavers. His observations, as published in the *American Naturalist*, are highly interesting, and we present the substance of them to our readers. He was first apprised of the vicinity of the beavers by watching a timber-shoot or clearing scooped out from a willow-brake to the water. Through this slide Mr. Barber passed into a grove of slender willows forming a thicket. About fifty feet from the river was a circular clearing where the animals had been at work; here the trees were larger, and many of them had been cut off obliquely within six inches of the ground—the logs had been hauled away. Farther on larger trees had been felled, which were still lying there, most of them measuring six and eight inches diameter, and one at least fourteen inches. The wood had been gnawed around the circumference, a few inches from the base, the deepest cutting having been done on the side next the water, so that the tree might fall in that direction. "I noticed," writes Mr. Barber, "that, wherever there were trees which had been felled some time past and fallen in the wrong direction, the newer work had been accomplished, without exception, in a systematic manner, all of the logs being cut so as to fall toward the dam. As I passed along the bank of the stream, I observed about ten timber-shoots running parallel at right angles to the course of the current, and separated by about fifteen feet. The larger trees had been cut near the water and above the dam for the purpose of floating them down, to save the labor of dragging from the interior. . . . I picked up several chunks of wood, six or eight inches in diameter and about as much in length, the ends being obliquely parallel; these had probably been prepared to fill up chinks in the walls of the dam. The trees had been, for the most part, cut into sections averaging ten feet in length, and the branches and twigs had been trimmed off as cleanly as a wood-chopper could have done them. Along the banks of the White River, some weeks before, I noticed several artificial canals which had been dug out in the absence of natural side-channels in the river. These were designed for floating down logs. One canal was four feet in width, seven in length, and several feet deep."

How the Spiders spin.—Happening to be in the fields during a sunshiny day in autumn, while a gentle wind was blowing, the Rev. H. C. McCook, of the Philadelphia Academy of Natural Sciences, took occasion to observe the aëronautic flights of the young spiders, whose silken filaments were floating from every stalk of grass. He found that many of the young arachnids—mostly of the family *Lycosidæ*, which are ground-spiders—selected the tops of the fence-posts as their starting-point. Having reached this "point of vantage," the spider always turned the face toward the wind. Then the abdomen was elevated to an angle of about 45°, and at the same time the eight legs were stiffened, thus pushing the body upward. From the spinnerets at the apex of the abdomen a single thread was ejected and rapidly drawn out by the breeze, often to the length of five or even six feet. Gradually the legs were inclined in the direction of the breeze, and the joints straightened out. The foremost pair of legs sank almost to the level of the post. Suddenly the eight claws were released and the spider mounted with a bound into the air, and was quickly carried out of view. The author distinctly noticed that at the instant of beginning its aërial journey, the spider would make an upward spring. He was also so fortunate as to be able to follow the flight of a spider for a distance of about eighty feet, and observed that the position of the body was soon reversed, that is, with the head turned in the direction toward which the wind was blowing. Thus the long thread which streamed out above the aëronaut inclined forward, and at the top was in advance of its head. It was also observed that the legs were spread out, and that they had been united at the feet by delicate filaments of silk; this gave to the body increased buoyancy, owing to the increased surface thus offered to the resistance of the air. Before, or rather during its descent to the earth, a small white ball of silk was seen accumulated at the mouth of the spider, which, with the peculiar movements of the forefeet, palps, and mandibles, suggested the drawing in of a thread. The spider was, so to speak, *taking in sail.* Exactly the same effect was thus produced by the spider aëronaut, and by a strikingly analogous mode, as the human aëronaut accomplishes when he contracts the surface of his balloon by causing the inflating gas to escape.

NOTES.

Many of the ills and diseases prevalent among women in our day are, no doubt, traceable to the sedentary mode of life so common among them. The progress of modern industrial art has done away with much of the household drudgery to which women were formerly subjected, and the result is in too many cases want of sufficient occupation for needed bodily exercise. The fruits of this state of things are strikingly exhibited in certain observations made by the late Mr. Robertson, a Manchester surgeon, who in his practice as a specialist for women's diseases found that in women who themselves performed all their household work there was no trace of certain complaints; that these complaints begin to make their appearance in women with one servant, become more pronounced in women who have two servants, or worse still with those who have three servants, and so on. He showed statistically that the deaths from childbirth were four times greater in the case of women with four servants than those with none.

No doubt the most voluminous compilation in any language is the "Illustrated Imperial Collection of Ancient and Modern Literature," published by the Chinese Government early in the eighteenth century. It comprises about 6,000 volumes. A copy of the work is on sale in Peking, and the British Museum has entered into negotiations for its purchase.

During the year 1876, in India, 48,000 cattle were destroyed by wild animals and venomous snakes; 22,357 wild animals and 270,185 poisonous snakes were killed at a cost of 120,015 rupees for bounties. In 1877, 19,273 persons were killed, and 54,830 cattle were destroyed.

Regular professorships of hygiene are to be established in the universities of Holland. The Faculty of the University of Utrecht has unanimously chosen Dr. Ludwig Hirt, of Breslau, to fill the new chair in that university.

The Parkes Museum of Hygiene at University College, London, is approaching completion. The council of the college have devoted an area of 3,500 feet for the use of the museum, which is divided into a library and eight classes.

The thickness of the coal-measures of Missouri is, according to Prof. Broadhead, in the *Western Review of Science*, for the upper measures, 1,300 feet; for the middle measures, 323 feet; and for the lower measures, 290 feet.

While collecting corals on the reefs of Florida Mr. Pourtalès often felt the urticating effects of contact of the hands with millepora. It occurred to him to try the effect of applying a fresh piece of millepora to the tongue, when "instantly," he writes, "a most severe pain shot not only through that organ, but also through the jaws and teeth. The whole course of the dental nerves and their ramifications into every single tooth could be distinctly and painfully felt." The pain remained severe for about half an hour, but the sensation was perceptible for five or six hours.

The President of the American Association for the Cure of Inebriates in his anniversary address quotes Dr. Magnus Huss as authority for the statement that in Sweden 1,500,000 persons—about one-half the population—annually consume 140 to 170 pints of spirits each. By their indulgence in strong drink the Swedes have deteriorated in stature and physical strength; new diseases have appeared, and old ones have increased fearfully.

A summer school of zoölogy will next summer be stationed either on one of the Bahama Islands or at some point on our Southern coast, for the benefit of students of Union College, Schenectady.

The Dean of Carlisle, Dr. Close, having made a violent attack on the practice of vivisection, denouncing it as a crime in the sight of that God "who careth for the sparrows," the *Lancet* very wittily retorts by quoting another Scriptural passage which the anti-vivisectionists are too prone to overlook: "Men are of more value than many sparrows."

Experiments made by Astasheffsky go to prove that the saliva of the rat possesses very strong diastatic activity — in other words, very rapidly converts starch into glucose; and that, as a general rule, the saliva of the rodents holds the foremost place as regards the mammalia; next comes that of the carnivora; and lastly that of the herbivora—the latter being decidedly the weakest of the three.

A writer in the *School Journal* would have all school chairs or seats on their front edge not more than one-quarter the height of the occupant, or of such a height that when sitting well back the heels of the sitter may touch the floor at a distance in front of the seat equal to the height of the seat. This it is claimed allows the point of support to be changed for the sake of comfort, and yet allows no unhealthy pressure. The width of the seat should equal its height; the slant should be about three-quarters of an inch to the foot; the surface should be flat. The back should be not less than one-tenth in excess of the height of the seat, so as to give full support to the shoulder-blades; it should slant about two and a half inches to the foot. The desk at the edge next the sitter should be five-thirds the height of the highest edge of the seat; its slant should be about one inch to the foot; its lower edge should stand directly above the front edge of the seat.

The cremation of the dead on battle-fields is strongly advocated by Mr. William Eassie in an address to a sanitary congress in England. He is confident that by means of portable crematories he could reduce to ashes 10,000 bodies in as many minutes of time. Interment of bodies by thousands must of necessity pollute the springs and contaminate the air.

The building recently opened and dedicated in New York City for the use of the American Museum of Natural History consists of three stories, besides the basement and attic. These three stories constitute three halls, each 60 feet wide and 170 feet long, access being had by stairways in a tower at one end. The present building forms only a small part of a vast structure which it is designed to erect. The ground-plan of the future Museum may be described as a cross inclosed within a square. The portion of the structure now completed will form the northern end of the cross. The ground to be covered and inclosed by the buildings will be 850 feet in length by 650 feet in width.

A roof of zinc-coated sheet-iron, says the *Polytechnic Review*, does not wear out from oxidation, and does not crumble as does sheet-tin from the repeated contraction and expansion produced by changes of temperature. In Vienna and in Prague the manufacture of this roofing material is a growing industry.

The year 1877 showed a very considerable increase in the production of cocoon-silk in France over the preceding year, viz.: in 1876 the product was 2,396,000 kilogrammes, but last year it was 6,783,000 kilogrammes. But this industry has yet to struggle hard if it is to attain in France its former condition, when the annual yield of cocoons was over 25,000,000 kilogrammes.

The leather covers of books in public libraries suffer very much from the action of the combustion-products of coal-gas. According to Prof. A. H. Church, vellum appears to be unaffected by this cause; but calf is much injured, and russia still more so. Most damage is done to the books in the upper shelves of a library, where the heated products of combustion are mostly condensed and absorbed. The sulphur of the gas is the principal cause of its destructive influence. Analysis of watery extract of leather injured by this cause showed that sulphuric acid, free and combined, was present in the proportion of 8.42 per cent.

The truth of the germ-theory of disease would seem to be demonstrated, at least with regard to one disease—splenic fever—by the researches of Dr. Koch. In cases of this disease, there accumulates in the blood and tissues, but especially in the spleen, a peculiar kind of bacteria—*Bacillus anthracis*. On inoculating animals with fluid containing either the bacilli themselves or their spores, Dr. Koch produced all the phenomena of splenic fever.

An Italian chemist, Paesi, proposes to substitute, for the tannin-bath in the manufacture of leather, a solution, in water, of perchloride of iron and common salt. Hides may be tanned, according to this process, in from four to six months. Moreover, the perchloride of iron, being a powerful disinfectant, does away with many objectionable features of the tanning business as hitherto conducted.

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