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THE RENAISSANCE OF SCIENCE.

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THE centuries immediately following the disruption of the Roman empire witnessed the formation of the languages of southern Europe—Italian, Spanish, French—and the process of their building-up placed an almost insuperable barrier in the way of the advancement of learning. Latin became a dead language; Greek was entirely unknown; the spoken languages were never written. 'The whole treasury of knowledge was locked up from the eyes of the people.' All legal documents and all correspondence as well as all the rituals of the church were couched in Latin, and until the end of the thirteenth century it was very unusual for a layman to write or even to read. The clergy were the only clerks. It is disputed whether Charlemagne could sign his name, and it is certain that Alfred the Great had but an indifferent knowledge of Latin. From the sixth to the eleventh century the mass of the clergy were only slightly more enlightened. Alfred declares that at the date of his accession (871) he did not know a single priest south of the Thames who understood the ordinary prayers of the church, or who could translate Latin into his mother tongue. The ignorance of the dark ages in Europe is a direct consequence of the confusion of tongues.

Through the translations of Nestorian monks in the orient the works of Greek philosophers, physicians, mathematicians and astronomers became known to the Arabs in the eighth and ninth centuries. The precepts of Ptolemy were followed closely, even slavishly, by the astronomers of Bagdad, Persia, Egypt, Spain and Turkistan, so long as learning lasted in these lands. We owe an immense debt to the Arabs for their faithful transmission of astronomical theories which they had not sufficient mathematical genius to greatly improve; for thousands of observations made to increase the accuracy of the tables of the motions of the sun and planets; for catalogues of the position and brilliancy of the fixed stars; and last and not least, for keeping the lamp of learning burning in their great schools, or universities, in Spain and elsewhere during the centuries from the eighth to the fifteenth. Since the time of the Greek schools of Alexandria the home of the exact sciences has been successively in Bagdad, Cordova, Seville, Tangiers, Bokhara and Samarkand. It was only in the sixteenth century that they were firmly domiciled in christian Europe.

Even in the shortest sketch it is necessary to point out that a great part of the astronomical learning of the Moorish schools was due to Jews; and that it is to orientals and not to Europeans that we owe the earliest recognition of the fundamental truth that all sound progress in astronomy must be based on actual and continued observation of the places of the heavenly bodies; that theory must be based upon practise. It is usual to credit this insight to Tycho Brahe, and it is certain that his greatest claim to our gratitude is based upon a thorough recognition of the fact that until observations have shown us exactly how the planets move we can form no adequate theories to account for their motions. But the astronomers of India and Persia in the ninth and tenth centuries thoroughly understood this fundamental notion, as did Ulugh Beg (1393–1449) at Samarkand, and they invented means to obtain observations of adequate accuracy and in sufficient number.

The need for more observations and for greater precision was also fully realized by Purbach as early as 1450. Regiomontanus returned from Italy in 1471 to set up in Nuremberg an observatory for the especial purpose of correcting the Alphonsine tables, which Purbach and himself had found to be so defective a score of years earlier. Landgrave Wilhelm IV of Cassel and his astronomers were working in the same direction in Tycho's time. It is Tycho's merit that he was the first in Europe to create instruments of sufficient power, and to use them with exceeding diligence over a long series of years. There was little knowledge in Denmark of what was doing in the orient. Tycho's plans were made quite independently of the further east. At the same time Europe touched the orient closely, through Venice, and sent many of her sons to study at Moorish schools; and it is not conceivable that Tycho was entirely ignorant of the details of the work done, a century and a half before his time, in Samarkand.

The debt of Europe to the remoter east has never yet been fully reckoned out. For thirty centuries the culture of the orient has, in one way or another, created, informed or modified our own. The religion, the learning, the art, the architecture of the east have most intimately influenced the west. The chivalry of Europe is, in great measure, a product of the Saracen chivalry which entered Europe in two streams flowing through Constantinople and through Spain. The poetry of the Troubadours and the romances of the feudal period are directly derived from the Arabs. Even the rhythms of the Troubadours are copied from Arab models, and the three-stringed lyre of the Jongleur is from an Arab original. It is from the east that the very idea of rhymed poetry is derived. To speak only of Persia: Alexander the Great destroyed at Persepolis buildings more magnificent than any others ever seen on the round world, not excepting the monuments of Athens; the looms of Persia made imperial Constantinople splendid; chemistry is a Persian word, and the Arabs borrowed their knowledge of the art from Iran; all the drugs of Hippocrates have Persian names; the Persians transmitted the immortal fables and apologues of India to the Arabs, and through them to the west; the works of the Persian sage Avicenna were text-books in the universities of Paris and Montpellier as late as the time of Louis the Fourteenth; our little children are bred up on the tales of the Arabian Nights, a great part of which are of Persian origin; in a thousand unacknowledged ways the west has been taught by the east. When England was a wilderness, inhabited by savages, Persia was polite, cultivated, ingenious, learned and illustrious. Whether we know it or not, we have learned much from them, though the debt is all but ignored except in the writings of scholars.

Moslems took the alien culture of the Greeks much as the Japanese of our own time have taken the culture of Europe. I remember well handing an astrolabe made in England in the seventeenth century, for one of the ships of the Alaskan fleet of Russia, to an accomplished officer of the Japanese navy. He was perfectly familiar with modern navigation and with the sextant, but this classic instrument was a complete puzzle to his mind. The contemporaries of his father had sailed their little boats by timid coasting from headland to headland of the Inland Sea; but no one of them had ever seen a sextant or a quadrant. Like the Arabs of long ago they made one leap from complete ignorance of such matters to the possession of the most refined apparatus, while English navigators, our ancestors, slowly mastered the use of the backstaff, the cross-staff, the astrolabe, the quadrant, the sextant, during a long succession of centuries.

Such considerations as these partly account for the fact that, in spite of their wonderful acumen, the Arabs added little or nothing to the theory of scientific astronomy. Moreover, their religion allowed them but scant liberty. They were confined within the narrow limits of Koranic permissions and prohibitions. It was forbidden to make an image of any living thing either by painting or sculpture. Poetry was discouraged by the traditions of Mohammed. Architecture was the only outlet for their artistic impulse. They could not dissect the human body. Original investigation was closed on nearly every side. What they were permitted to do, they did well. In astronomy they preserved the classic books and they made many precise observations. It is almost an accident that so little use was made of their work by Europeans. If there had been an active commerce between the east and all the countries of the west the history of Europe in the middle ages would have been changed and brightened.

The scientific history of the middle ages is sharply divided into two periods. In the first, no part of Arabic learning had penetrated the west. All knowledge came from the Greeks through the Romans. In the second, the treasures of the Greeks were made known together with the results of three centuries of acute commentary by the subtle-minded philosophers of the east. The astronomy of the first period was represented by Manilius, Hyginus and Bede. The works of Ptolemy were unknown. These were indeed dark ages for science. In the second, all the wealth of Alexandria was opened, and it was increased by the observations of Albategnius and Ibn Yunos and the commentaries of Albumasar and his successors.

A satisfactory history of science in the middle ages is still a desideratum. Such a book could not possibly have been written before 1860, for the doctrine of special creations would then have assumed the place of the doctrine of a slow, steady and continuous evolution. Episodes of decadence are as much a part of evolution as examples of advancement. The book might well be written as a series of biographies of great men, if this were done without forgetting that, in the strictest sense, every man, even the greatest, is the product of his time.

With the advent of the christian religion theology had become the supreme science of the west. In theory, at least, the whole of philosophy could be deduced from revelation, and at all events theology was the standard to which all philosophizing was obliged to conform. Just as philosophy could be got, by deductive reasoning, from theology, so the whole of science could be deduced from a few fundamental facts, precisely as the whole of geometry of the ancients was derived from a few axioms. Under pre-suppositions of this sort, there could be no natural science, since our very conception of science implies theory compared with, and controlled by, observation and experiment. The method of medieval science was logical deduction. The method of modern science is a very different thing.

'Thus,' as Whewell formulates it:

A universal science was established with the authority of a religious creed. Its universality rested on erroneous views of the relations of words and truths; its pretensions as a science were admitted by the servile temper of men's intellects; and its religious authority was assigned to it by making all truth a part of religion. And as Religion claimed assent within her own jurisdiction under the most solemn and imperative sanctions, Philosophy shared in her imperial power, and dissent from their doctrines was no longer blameless or allowable. Error became wicked, dissent became heresy; to reject received human doctrines was nearly the same as to doubt Divine declarations.

Aristotle became the sole authority in science, just as the church was the sole authority in religion.

While a general statement like the foregoing is, in the main, true, it requires countless modifications if it is to be taken as an explanation of the course of intellectual progress in the middle ages. Their conditions were almost as complex as those that surround our own century. They were modified by unnumbered circumstances of place, time and personality. No one formula can possibly express the spirit of the middle ages, even in respect of a single branch of science. It is, for example, entirely true that the authority of Aristotle was overwhelming. What was not found in his works was, necessarily, false. This is a general truth, and the career of Galileo is a commentary upon it. On the other hand, it must not be supposed that Aristotle was always and everywhere unquestioned.

It was not until two great doctors of the church—Albertus Magnus and St. Thomas Aquinas—had adopted, explained and consecrated Aristotle's doctrines in the thirteenth century that his authority became overpowering and universal. Roger Bacon, the great contemporary of St. Thomas and Albert, was also, as Voltaire has said, "un homme admirable pour son siècle. Quel siècle? me direz-vous. C'était celui du gouvernement féodal et des scholastiques. Figurez vous les Samoïdes et les Ostiasques qui aurient lu Aristote et Avicenne—voilà ce que nous étions."

In the year 1000, the world did not come to an end, as had been prophesied and expected: 'Whereupon men took renewed possession of the Earth and of themselves.' This gave leisure to the spirit; leisure and comfort for the body had already, in some measure, been conquered. Men again began to be curious regarding humanity, life, nature. Science for the first time became possible. It is with the greatest difficulty that the attitude of the middle ages towards scientific matters can be comprehended. The time is full of the sharpest contrasts. Roger Bacon illustrates its highest lights. Its deepest shadows are found in the doings of the inquisitors of Spain. Its everyday aspect is, perhaps, best to be conceived from poems and legends that pleased the people. *Bestiaries,* or story-books of animals, were extremely popular.

They declared, among other things, that:

The basilisk kills with a glance of his eye; "the bite of the cockatrice is fatal to the weasel if the weasel eat not rue before"; the salamander lives in fire;

the mandrake groans when pulled from the ground; the pelican in her piety feeds her brood by blood plucked from her breast; the barnacle is half herb, half animal; the hyena converses with shepherds; the crocodile weeps over his victims; the barometz is a lamb that is also partly a vegetable; the fleeing lion erases his tracks with the end of his tail; the father of the ant-lion "hath a shape like a lion, his mother that of an ant; the father liveth on flesh and the mother on herbs; his fore-part is like that of a lion and his hind-part like that of an ant; being thus composed he is neither able to eat flesh like his father, or herbs like his mother, and so he perisheth."

These are a few extracts from the story books that delighted Europe for centuries.

The earth was generally believed to be flat, though the Greeks of Alexandria knew better. The 'waters above the firmament' were navigable; and there was a story of an anchor dropped to earth from a ship sailing in this second ocean. There were races of men with one eye, others with one leg, others whose enormous feet served as umbrellas to keep away the rays of the torrid sun. Shakespeare's 'men whose heads do lie between their shoulders' date from these legends. Fauns, fairies, lamiæ, sylphs, vampires and the like were dreaded. Everything was received with acquiescent wonder, and without criticism, whether it were a miracle done by the relic of a saint, or the extravagant tale of a traveler. The age of faith deserves its name in so far as it was characteristically an age devoid of criticism.

An Arabic compilation of the tenth century, *Adja ib al-Hind*—the marvels of India—is composed of a hundred and twenty-four paragraphs, each relating to some wonder recounted to the author by persons whom he names. The work is entirely serious and the narrators were famous seamen, merchants and travelers who were familiar with the Indian Ocean, the Malay archipelago, the China seas and Ceylon. These stories taken as a whole exhibit the extensive commerce carried on, even at that day, between the nearer and the farther east, and speak eloquently for the skill and courage of those early navigators who traversed almost unknown seas with nothing but the stars to guide them. Many of the marvels of the Arabian Nights are to be found here—the *roc,* the valley of diamonds guarded by serpents, the shipmen who mistake the back of a sleeping turtle of gigantic size for an island, and the like. The legend of the Island of Women, under the star *Canopus,* where the sea slopes downward, and where only women dwell, is gravely given without even the phrase 'But Allah alone knows if this be true,' by which a good Muslim shows his doubts. Of the existence of the gigantic bird, the *roc,* the author says 'This is a fact well known to shipmen, and I have never known any one to doubt it.' The crocodiles of the Harbor of Serira do not bite men, he says, because they were enchanted by a magician who had the power to make them harmless and harmful at will. The prudent king of the country caused them to be made harmless—and then slew the magician; so that to this day the water is safe. Stories of this sort are interwoven with admirably intelligent accounts of these distant countries. All are equally credited and credible.

What strikes a modern reader with astonishment is by no means the ignorance of the writer, but rather his entire lack of the critical faculty. This lack, for Europeans as well as for Arabs, may be taken as characteristic of the middle ages. Our ancestors appear, at times, nothing but adventurous Eskimo who had read Aristotle.

In the year 1238 the inhabitants of Sweden were prevented by their fear of the Tartars, from sending as usual, their ships to the herring fishery on the coast of England; and as there was no exportation, forty or fifty of these fish sold for a shilling. "It is whimsical enough," says Gibbon, "that the orders of a Mogul Khan, who reigned on the borders of China, should have lowered the price of herrings in the English market."

The reign of Faith appears, at first glance, so absolute during the Middle Ages, that one is tempted to believe that for a thousand years no voice was lifted against established religion. A study of the details of history brings, however, many episodes to light that exhibit something like a continuous change from the rationalism of the ancients to that of the moderns. The chain is easiest to trace, of course, in the history of philosophy. It existed likewise in the history of science. The whole of the thirteenth century, exclusively religious as it appears at first sight, was stirred by an undercurrent of free inquiry which has left little trace in written history solely because the history of that period was written by the Dominican school. Roger Bacon was a product of his age, then, not a *lusus naturæ*.

The philosophy of the Arab commentators of Aristotle—pantheistic in its essence—was utterly opposed to the philosophy of orthodox scholastics. In the year 1209 the council of Paris condemned the *Natural Philosophy* of Aristotle and its commentaries. A bull of Gregory IX. in 1231 confirmed the condemnation. Such condemnations demonstrated the prevalence of presumed error. By the middle of the century Albertus Magnus had arranged Aristotelian teachings so that they were again in favor, and he incorporated in his text, from the Arabs, all that was useful to his argument. Heterodox comments were refuted when they were not rejected outright. St. Thomas Aquinas gave an even more solid form to orthodox philosophy and waged persistent war on the specific doctrines of the Arabs. In the year 1277 a series of thirteen propositions, mostly taken from Avicenna and Averroës, was formally condemned at Paris and at Oxford. In the general chapter of the Franciscans held at Assisi in 1295, an especial warning was given against 'exotic' opinions. These instances from the history of a single century indicate that there was no universal stagnation. Condemnations of heterodox philosophizing were required every twenty years or so. The thirteenth century is so far removed from us, that we only see its larger features and the main trend of its current. Could we take a nearer view all would be complexity. The conclusion is as true of moslem as of Christian Europe.

Hakim II., caliph of Cordova in the tenth century, had a library of six hundred thousand manuscripts. The catalogue alone filled forty-four volumes. He kept agents in residence at Alexandria, Cairo, Bagdad and Damascus to procure for him, at any price, books ancient or modern. Works composed in Persia or in Syria were thus often read in Spain before they were known in the city of the author—witness the *Anthology* of Abul-faradj of Isfahan, for which Hakim paid a thousand gold dinars. His eagerness to acquire was something more than the instinct of the collector, for there are authentic anecdotes of his extensive acquaintance with the biography and history of his times. Even before the reign of Hakim the Moors of Andalusia were inclined to liberal studies. From the tenth to the thirteenth century was the golden age of learning in Spain. Moors, Jews and Christians cooperated in scholarly works under the patronage of princes. The mosques of Cordova were crowded with students. The Giralda tower of Seville (1196) was built for Geber's observatory. The picture is alluring; but we must not fail to recognize that it presents only a part of the truth. In Spain, as elsewhere in Europe, these were the dark ages.

The wealth of manuscripts in the whole of the moslem world was immense. There were, it is said, above seventy public libraries in Moorish Spain alone. The library of the Fatimite caliphs in Cairo contained 100,000 manuscripts, of which 6,500 were devoted to medicine and astronomy. When the Crusaders took Tripoli in Syria (1109) 100,000 manuscripts were destroyed. Private libraries were often extensive. Faizi, the poet-laureate of Akbar, the Great Mogul, had a private collection of 4,600 manuscripts.

Europeans of the twelfth and thirteenth centuries had a veritable passion for collecting manuscripts also. Charles the Wise in 1373 had a library of 900 manuscripts in the Louvre. Boccaccio, in the middle of the next century, complains that libraries were then falling into decay. The Vatican library was founded in 1453 and the Medicean collection at Florence a little earlier. The library of the Duke of Urbino (1474) cost 30,000 ducats and contained all known classic books. We ask with wonder where these manuscripts came from. We must remember that the library at Alexandria possessed every treasure. Its manuscripts were removed to Rome, and thence to Constantinople, and in the meanwhile copied, recopied and copied again. They passed from hand to hand as precious possessions, valued almost as sacred things. The *Sortes Virgilianæ* attributed magical powers to the mere manuscript. Pieces of Homer were sold for charms. European manuscripts were, at first, preserved in churches, and later, in convents and abbeys, where they were copied and recopied and sold at high prices. It is, finally, to the church that we owe their preservation. Wars and strifes were not so fatal to manuscripts in the west as in the east. When Constantinople was taken by the Crusaders (1204), thousands of manuscripts perished. Many others were lost in its three great conflagrations, but in spite of these misfortunes thousands of volumes were preserved and have come down to us. The fragment that has been saved may give some notion of the magnitude of the original collections. Ximenes in the beginning of the sixteenth century burned 80,000 manuscripts in the public squares of Grenada. The magnificent collection of the Escurial comes from Morocco, and at least half of it was destroyed by the fire of 1671.

The Abbaside caliphs were liberal patrons of learning, as was the fashion of their time and race. Harun's quick intelligence was interested in scientific matters and he had very wise advisers. Al-Mamun was even more interested. To patronize science and the arts was a part of the state of a sultan. It had to do with Aristotle's virtue of *magnificence,* now erased from our list of cardinal excellences. The *Almagest* was first translated by learned Jews in the reign of Harun al-Raschid (765–809), and an observatory had been maintained by his predecessors at Damascus. His son, Al-Mamun (786–833) erected a magnificent establishment at Bagdad in 829, sixty-seven years after the foundation of the city. The Arab instruments were fashioned from descriptions given by Ptolemy, but they were much larger and far more accurate than those of the Greeks. Moreover, the Arab astronomers observed the heavenly bodies *continuously,* and this habit led them to a more precise knowledge of the elements of planetary motion. The attitude of an oriental monarch towards learning is well illustrated by a paragraph from the Memoirs of Tamerlane. Tamerlane was nearly a savage, but he had learned from contact with polite nations the fashion of kings, and it is interesting and significant that he cared to be in the fashion. He says:

> Men learned in medicine and skilled in the art of healing, and astrologers and mathematicians, who are essential to the dignity of empire, I drew around me; and by the aid of physicians and surgeons I gave health to the sick; with the assistance of astrologers I ascertained the benign or malevolent aspect of the stars, their motions, and the revolution of the heavens; and with the aid of geometricians and architects I laid out gardens and planned and constructed magnificent buildings. At the Court of Akbar (1575) there were thirty-eight doctors of the law and theologians, sixty-nine *literati,* fifteen physicians, one hundred and fifty-three poets, besides historians, artists, astrologers, three Jesuits, and translators, scribes and clerks without number.

Arab history shows, however, that culture and the desire for culture never penetrated the mass of the people. They were rigid Moslems;

and men of learning were suspected of heresy or worse. An aristocracy of learning has always been more odious to the people than one founded on wealth or birth; and there is no intolerance like that of the ignorant. Their princes could do no act more popular than to order the destruction of heretical books and manuscripts in the public square. All Hakim's manuscripts were so destroyed after his death to conciliate the people. Works on theology, grammar and medicine were alone spared, with a few treatises on elementary astronomy—for it was necessary to be able to calculate the direction in which Mecca lay, the *Kibla* towards which every Moslem turns his face in prayer.

In Arabia, in Spain and in Europe, the mass of the people was fanatical, brutal and ignorant. Dominion over them was gained and held by exciting their passions. The influence of sages, like Bacon and Averroës, of liberal princes, like Hakim and Frederick II., saved learning from extinction; but it has required the experience of centuries to raise the tolerance of new ideas to its present level; and even now, is not tolerance composed quite as much of indifference as of enlightenment? If the history of the renaissance of art in Italy is closely examined a corresponding ignorance and indifference is exhibited. Where art ministered to religion, to superstition or to local pride, the multitude was concerned for it. For art as art, only a select few were interested.

The writings of the Greeks first became known to the Arabs through translations from the Syrian. In the year 431 the Nestorian heresy was condemned at the council of Ephesus. Nestorian priests were banished and dispersed throughout Syria, Persia and the further east, and everywhere carried somewhat of the learning of the west. Under the caliphs they spread from Cyprus to China and outnumbered the Greek and Latin churches. There was a Nestorian bishop in Merv in A. D. 334; and at Herat and Samarkand in A. D. 500. The Kerait Turkomans accepted christianity about A. D. 1000, as a tribe. A Nestorian christian was superintendent of the city schools of Bagdad under one of the Abbaside caliphs. Until the death of Tamerlane (1405) Nestorians were to be found everywhere throughout the orient.

It is doubtful whether a single Arab scholar was acquainted with the Greek language, and certain that none of the Moorish doctors were so. The printed volumes of Averroës' Aristotle are a Latin translation of a Hebrew translation of a commentary made on an Arabic translation of a Syriac translation from a Greek text. The meaning of the original was almost lost in its transmigrations through tongues so different in spirit as Greek, Syrian, Arabic, Hebrew and Latin.

Latin editions of the whole or of parts of Averroës' Aristotle were greatly multiplied in Europe after the invention of printing. During the century 1480–1580 nearly a hundred editions were issued. At Venice alone more than fifty were put forth. It is in Avicenna that we must seek the full expression of Arab philosophical thought, while Algazel is its most original expositor. The greatest of the astronomers were Albategnius, Ibn Yonis and Abul-Wefa.

Greek made its way slowly in Europe, also, though it was never quite lost. In the tenth century, Sister Hrosvita, a nun of Hanover, composed Latin poems and dramas, learned Greek and read Aristotle. In the twelfth Abelard recommended the nuns of the Paraclete to study both Latin and Greek; and Héloise was acquainted with Latin, Greek, and Hebrew as well. In the thirteenth, Greek manuscripts were systematically collected by a few scholars—Robert of Lincoln, for example; and Roger Bacon's far-reaching proposal for the establishment of schools of comparative grammar for the study of Chaldean, Hebrew, Arabic and Greek, as well as Latin, represents the highest wave of a very widespread current. Petrarch's letters are a proof of a great rationalistic movement in the fourteenth century to which the study of the classic authors of Greece, in their original tongue, was a prime necessity. Neither Petrarch nor Dante knew Greek sufficiently well to read Homer in the original. The council which sat at Basel from 1431 to 1449 to consider the reconciliation of the Greek and Latin churches attracted many Greek scholars to western Europe, and by the fall of Constantinople in 1453 learned Greeks, who brought with them treasured manuscripts, were dispersed throughout all christian countries.

Raymond of Toledo, grand chancellor of Castile, established a college of translators shortly before the middle of the twelfth century, and the works of Avicenna and other Arab philosophers were translated into Latin. In all works of this kind learned Jews bore an important part. The translations were barbarous in the extreme. Each Arabic word was translated into Latin by one clerk, and the construction arranged by another. 'The Latin word covered the word in Arabic as a piece in chess covers the square.' The grammatical construction was Arabic rather than Roman. The style was barbaric. "*Inuarkin terra alkanarihy, stediei et baraki et castrum munitum destendedyn descenderunt adenkirati ubi descendit super eos aqua Euphratis veniens de Euetin*" is a phrase from Hermann, the German, and it bears out Roger Bacon's dictum that students would lose their time, trouble and money over translations of the sort. "Should Cicero or Livy return," says Petrarch, "and stumblingly read his own writings once more, he would promptly declare them the work of another, perhaps of a barbarian."

We have seen that the eagerness of collectors of manuscripts sometimes made Moorish scholars familiar with literary works even before they were published in their native country. Copies were rapidly made and distributed: a popular work would soon be known over the whole of Europe. "The French poems of the *trouvères* were, in less than a century, familiar in translations into German, Swedish, Norwegian, Icelandic, Flemish, Dutch, Bohemian, Italian and Spanish. A work composed at Morocco or Cairo was known at Paris or Cologne in less time than is now-a-days required for an important book published in Germany to cross the Rhine" (Renan). To this intellectual movement the commerce of the Jews powerfully contributed. If there were any demand for a particular manuscript they promptly supplied it. Books of science were, naturally, not multiplied with the same rapidity as works on medicine and philosophy, but whatever demands existed were supplied. A knowledge of Latin was widely spread among the Jews. In the thirteenth century Solomon of Barcelona reproves his co-religionaries of Provence for neglecting the study of Hebrew in their eagerness to acquire the Roman tongue.

Civic toleration has seldom been carried further than among the Arabs in Spain. Cordova was preeminently the city of learning; Seville of gaiety and music. Jews, Mohammedans and Christians were on the same official footing and spoke the same language. Hebrew and Spanish were often written in Arabic characters. John of Seville, a christian bishop, translated the Bible into Arabic. In spite of the opposition of the clergy mixed marriages were not very infrequent. This fact indicates that toleration had already begun to penetrate the mass of the people; yet this must not be taken as a general conclusion, for at the slightest sign religious feuds broke forth. It is probably more true to conclude that tolerance was the mark of liberal princes. Jews and Christians had a place among the Moors so long as their interests did not clash. There was no real learning among the masses in Spain or in Europe in the days of ignorance. The courts of princes, on the other hand, were alive with intellectual curiosity.

Nothing was easier, however, than for a learned man to get a hearing in Moslem countries before other men of his class. The case was much the same at European universities. Any mosque would serve the Moslem doctor for an audience-hall, and as nearly all mosques had endowed schools attached to them, hearers were provided from the outset. If the teacher was eloquent, pupils flocked to hear him by hundreds. The subjects taught were jurisprudence, logic, philosophy, medicine, mathematics, astronomy. All except the first were derived directly from the Greeks, or from Arab commentators. Of Greek literature, poetry, drama, the Arabs were absolutely ignorant. They did not even know the distinction between Greek tragedy and comedy.

We may perhaps judge of the authority of Aristotle among them by quoting from Averroës's edition of his works:

"The author of this book," says the Arab commentator, is "Aristotle, wisest of the Greeks, who both founded and completed the sciences of Logic, Physics and Metaphysics" * * * "No one for fifteen hundred years has been able to add anything to his writings, or to find in them an error of any moment" * * * "He should rather be called divine than human" * * * "The doctrine of Aristotle is the sovereign truth, for his intelligence is the limit of human understanding."

A portion of this praise may be laid to the Arab habit of high sounding eulogy which made their ruling princes, 'the Shadow of God'; but the wisest of the pagans, and the christian doctors of all times, have praised him in almost equivalent terms.

Aristotle, in my opinion, stands almost alone in philosophy.—Cicero (106-43 B. C.).

Aristotle, Nature's private secretary, dipping his pen in intellect.—Eusebius (264-349 A. D.).

Whenever the divine wisdom of Aristotle has opened its mouth, the wisdom of others, so it seems to me, is to be disregarded.—Dante (1265-1321).

Aristotle was a man beside whom no age has an equal to place.—Hegel (1770-1831).

By a singular chance "the greatest of inductive philosophers became the hero of a recklessly deductive age" (Robinson). By a still more singular chance he became the corner-stone of Roman Catholic theology.

The Stagirite agrees with Catholic theism, though not with the Pentateuch, in saying that God is without parts or passions, but there his agreement ceases. Excluding such a thing as Divine interference with all Nature, his theology, of course, excludes the possibility of revelation, inspiration, miracles and grace. (Benn: Greek Philosophers, *i*, p. 312.)

Towards the end of the twelfth century a war on philosophy was set on foot throughout the Moslem world. A theological reaction like that which followed the Council of Trent (1545-63) in the Latin Church sought to conquer lost territory by dint of argumentation and violence. * * * Escaping more and more from the control of the Arab race, essentially skeptic in inclination, Islamism came by accidents of history to be the especial charge of races prone to fanaticism—the Berbers, Spanish, Persians and Turks—and took on the form of an austere and exclusive dogmatism. Islamism in general suffered the fate which befell Catholism in Spain; which would have befallen that of all Europe if the religious revival of the end of the sixteenth and beginning of the seventeenth century had succeeded in stifling all national development.*

The doctrines expounded by Arab writers were exoteric—intended for the mass of men. They taught their esoteric doctrines by word of mouth, or, occasionally, in works not confided to the multitude. Algazel, in his 'Logic,' declares that opinions which he does not share are there exposed, and that in his book on the contradictions of the philosophers his true views are to be found. The problems that he dismisses as insolvable in his published works are resolved in this book of esoteric doctrine. Abd-el-Melik Ibn-Wahib of Seville would not even converse on delicate subjects, 'so that, in *his* writings, one does

* Renan: Averroës et l'averroisme, Chapter I. Like all general statements this one requires completion in order to be exact in all its details; the Persians, for instance, were never austere or dogmatic, so far as I know.

not find, as in those of other philosophers, secret matters only to be expounded after they are dead.' Avicenna explains the views of others and conceals his own, and avows that beside his published works he has written a treatise in which he has expounded philosophy 'according to Nature and Reason alone.' This was his *Oriental Philosophy*, now lost, if indeed it was ever current. On this declaration of Avicenna, Roger Bacon comments: "The naked truth cannot be told. Avicenna well knew that the envy and pride of his rivals, and the folly of the multitude forced him to speak like all the world in his published works, and he knew that he could only think the pure doctrine of Science for the few." The 'pure' doctrine of Avicenna was a pure pantheism—God was identified with the revolving spheres. Bacon expressly rejected this identification without ever knowing what Avicenna's last word was.

Students flocked to schools wherever the desired instruction was provided, as indeed, they always had done. In the sixth century 'Lismore's learned isle,' off the bleak Scottish coast of Oban, was visited by scholars from every part of Europe. In the twelfth, the Moorish universities held some students from countries as distant as England as well as many from Italy and France. To seek for the situations of the foci of learning in different centuries would be a curious inquiry. The excursion would extend from Turkistan to Tunis and Toledo.

Consider also the narrations of the voyages of travelers that began to be current. Benjamin of Tudela (1173) visited regions so distant as Samarkand and India. Jean Carpin, the Franciscan, was sent (1246) by Pope Innocent IV. on a mission to the Tartars, and Rubruquis (1253) to the same people by St. Louis. Marco Polo returned from China and India in 1295. Sir John Mandeville's travels in the orient (in the middle of the fourteenth century) were recorded by him in three languages and were copied everywhere in Europe. Consider, also, that well traveled trade routes existed throughout the nearer east and that the products of all the orient were familiar to the cities of Italy and southern France. The minds of men were opened by the recitals of the experiences of returning travelers. Abbey schools and great universities were everywhere to be found. The learning of the time was within the reach of multitudes.

What the mathematical courses in the English universities were, even in the sixteenth century, is illustrated by a curious passage from the Oxford lectures of Sir Henry Savile (1549–1622): "By the grace of God, gentlemen hearers, I have performed my promise; I have redeemed my pledge. I have explained, according to my ability the definitions, postulates, axioms and the first eight propositions of the Elements of Euclid"—eight propositions! Dante in the *Convito* gives the classic scheme of studies in European universities slightly modified to agree with the nine heavens moved by angels or intelligences, the supreme sphere resting in God himself.

LIBERAL ARTS	*Trivium*	Grammar	Moon	Angels
		Dialectic	Mercury	Archangels
		Rhetoric	Venus	Thrones
	Quadrivium	Arithmetic	Sun	Dominions
		Music	Mars	Virtues
		Geometry	Jupiter	Principalities
		Astrology	Saturn	Powers
PHILOSOPHY	*Physics and Metaphysics*	Starry Heaven		Cherubim
	Moral Science	Crystalline Heaven		Seraphim
	Theology	Empyrean		God.

About the end of the fifteenth century a revolt against the Aristotle of the Arab commentators took form in Italy. On April 4, 1497, the first lecture from the original Greek text was given at the University of Padua. The 'vain glosses' of the Arabs were decried by the most distinguished among the teachers of the sixteenth century. Hippocrates and Galen were infallible only in Greek. In 1552 the preface to an edition of Averroës declared: "Our ancestors could find nothing ingenious in philosophy or medicine unless it came from the Moors. Our own age, on the other hand, trampling Arab science under foot, admires and accepts only what comes directly from the treasury of Greece; it adores the Greeks only; it will have only Greeks for masters; he who knows not Greek, knows nothing." The Arab Aristotle became 'a poisoner; an obscurantist; the executioner of the human race, who has destroyed the world with his pen as did Alexander with his sword.' The new school conquered in the end, but not without a long struggle.

In Petrarch's time the doctrines of Aristotle had taken on an aridity from the Arab commentators that cried for a living spirit to replace it.

"Petrarch deserves the name of 'the first modern man' in that he first introduced to the Latins the fine feeling of antique culture, the source of all our civilization. * * * It was he who first rediscovered the secret of that noble, generous and liberal comprehension of life which disappeared when the barbarians triumphed over the ancient world."

When Arab philosophy was finally overthrown in the early part of the seventeenth century (we may fix the date at the death of Cremonini in 1631) the liberty of opinion that then prevailed in the northeast of Italy vanished completely. The day of conflict was over. The reign of orthodoxy began anew. The final defeat of the Arabs was, on the one hand, a sign of the victory of experimental science; and on the other, it cleared the way for a rigid orthodoxy.

During the period when the struggle between the Arab and the Greek Aristotle was in full progress it was inevitable that liberty of opinion should prevail. At its end two consequences necessarily followed, as has just been said: The essential validity of the methods of experimental science had been vindicated, and scholars understood that a new era had begun. This was the era illuminated by Galileo's early researches. On the other hand, the Greek Aristotle had conquered. The liberty which comes of conflict was no longer permitted. Orthodoxy founded itself on the new interpretations and reigned firmly and severely. To the people at large the end of the conflict marked the overthrow of speculative heresy, not the winning of a new world to science. The pantheistic idealism of Averroës and the Arabs lingered on in a few minds. Cardan, Pomponazzi and Jordano Bruno were tinged by it. But in the church orthodoxy ruled.

During the early centuries of the christian era no one was concerned to vindicate the claim of the church of Rome to primacy. The bishop of Rome was the successor of St. Peter; his church was the mother of all the churches; it was situated at the capital of the empire. These were its sufficient titles. About the year 500 'apostolic canons' were collected which afterwards grew into the canon-law. Precepts from the Bible, extracts from the writings of the fathers, decrees of church councils, letters (decretals) of the Roman bishops, formed the body of a distinctive law of the church. But in the schools of Italy the memory of the civil law of the empire had never wholly died out. Early in the twelfth century Irnerius was lecturing in Bologna on the *Corpus Juris* of Justinian, and from such studies the university arose, just as the University of Paris grew from the teaching of Abelard. A pupil of Irnerius lectured at Oxford. The universities of Paris and Oxford were, however, chiefly concerned with theology and with general culture—with the *quadrivium* or group of higher scientific studies.

The teachings of Bologna (in law) and of Salerno (in medicine) were more special. They necessarily implied an acquaintance with classic writers and with the history of the empire. It was inevitable that the question of the legal status of the church should be discussed. When and how was it recognized by the empire? What were its legal sanctions? Upon what grounds were the canon and the civil law to be reconciled? These were soul-stirring questions which the church subsequently answered in its own way. With the answers we have no concern. The civil law dealt with every one of the personal and social relations of mankind; it had to do with the whole life of civil society; its principles were not immediately related to the principles underlying the body of the canon law.

The origins of what we call the revival of learning must be sought in the discussions that inevitably arose from the comparison of principles so different, and the consequent necessity of an appeal to the original writings of authors of classic times. The renaissance had its formal beginnings in the Italian schools of the early years of the twelfth century.

The history of the first half of the thirteenth century is a proof that the leaven of a revival was then working at Oxford, at Paris, in Robert of Lincoln, in Roger Bacon, at other places, and in many other companies of men. Long years before the savants of the renaissance, Bacon urged the study of the dead languages, of philosophy, of mathematics, of classic literature. Centuries before Luther he pointed out the errors of the Vulgate, and of the fathers of the church. The way was prepared for Petrarch, though in fact he only appeared a full century later. What is the reason of this sudden check to a vigorous and healthy movement? No single cause was more efficient than the rehabilitation of Aristotle as the apostle of orthodoxy towards the year 1250. The advent of 'the first modern man' was delayed for a hundred years, and the later renaissance for three centuries. The wars of the fourteenth century drowned European learning in blood. The history of the promising beginnings of a real revival of learning in the twelfth and thirteenth centuries is not yet written, and the share that the scientific thought of Bacon and his contemporaries had in such a revival has been strangely undervalued. Science, as one of the motive forces of the whole movement, has been neglected. It is the rarest thing to find in the indexes of professed histories of the renaissance the name of any scientific man—even that of Copernicus almost never appears.

The earliest stir of the renaissance was in Italy. Petrarch was the first great man of the new world, as Dante was the last of the old. Germany, the seat of the Holy Roman Empire, felt the impulse quickly on account of its close connection with Italy, and each one of its semi-independent courts was a focus favorable to the new spirit.

The discoveries of Columbus in 1492 were a mighty aid in freeing men's thoughts from the shackles of prescription and custom. The voyages of Vasco da Gama to India (1497–99) and of Magellan around the world (1519–21) came to confirm the larger view and to excite curiosity and hope. New things are within our reach; search and find—these were the lessons of the time. They were lessons for all mankind. Even the peasant heard of the new wonders and felt himself more a man. The philosopher, in his study, was incited to new efforts. A new spirit was born throughout civilized Europe.

To estimate an epoch, something must be known of its arts and inventions. During the middle ages gunpowder, clocks, telescopes, parchment, paper, the mariner's compass were invented or adopted; mathematics received great developments—especially algebra and trigonometry; perspective was studied and perfected; experimental chemistry, not yet a science, was cultivated; surgery was brought to an equal standing with medicine; music, as we know it, began with the notation of Guido d'Arezzo; counterpoint was developed into a doctrine; optics and acoustics were greatly improved and the foundations of mechanics were laid; manufactures of all kinds made great progress, notably those of glass and steel; the art of printing opened literature to all the world —the poor and the rich alike.

If we pass to the field of art there are notable matters to be chronicled. All the basilicas of Italy, all the mosques of the Arabs, all the Byzantine churches, all the Gothic cathedrals are of this period. Santa Sophia dates from A. D. 532, St. Mark's from 1052, Notre Dame from 1163, the Cathedral of York from 1171, St. Peter's from 1450. Of the great painters, Cimabue was born in 1240, Giotto in 1276, Van Eyck in 1366, Botticelli in 1447, Leonardo in 1452, Dürer in 1470, Michel Angelo in 1474, Titian in 1477, Raphael in 1483, Correggio in 1494, Holbein in 1495, Tintoretto in 1512, Veronese in 1532. The dates, set down almost at random, cover a thousand years, but the epoch of great progress was from the twelfth to the sixteenth century. When we thus sum up what was accomplished in five hundred years, the period is seen to be full to overflowing. Its interests did not lie in the direction of science—its ideal was not comfort. At the beginning of the dark ages the problem of Europe was to tame the hordes of barbarians who had possessed themselves of the lands—to contrive workable compromises between the customs, laws, ideals, institutions of northern and southern races. Given the point of starting the progress is not slow. The advancement of Europe from the sixth to the sixteenth century is an amazing phenomenon and no one can study it closely without a sense of wonder that so much was achieved.

We who breathe a different air must never forget that the doctors of the church cared little for science, as such, and everything for religion. In the *Summa* of St. Thomas Aquinas there is but one chapter that deals with scientific matters. Moreover, we must always carefully distinguish between the opinion of the philosophers and that of the multitude. The mass of men then, as now, thought little of philosophical matters and took their opinions ready-made. Real tolerance in philosophy is a product of real experience. Princes like Al Mamun and Alfonso X. patronized learning in a large and liberal way. The crowd of doctors, poets, artists, physicians, astronomers, at such courts lived in a harmony which was enforced upon them by their very situation. Outside the courts there was envy and malice among the excluded theologians, a sullen opposition among the people. What men do not understand they suspect as heretical. There is scarcely a moslem or a christian doctor of the middle ages who did not bear the reputation of magician among the common people. Medicine, astrology, alchemy were, almost necessarily, regarded as magical arts. To a populace that sincerely believed in ubiquitous devils all science was suspect.

Considerations of this sort should make us very tolerant of the blunders of our brothers of past time. It is so easy for any one of us to make a list of the follies, errors and crimes of his own century, and so hard to find excuses for them, that it should give us pause in distributing indiscriminating blame to the men of the middle ages as is often done in books of the warfare-of-science-and-theology sort. Among us, as of old, the ignorant are the most harsh. To us, as to the middle ages, the phrase *Tout comprendre c'est tout pardonner* applies in its fullest force and scope.

During the whole of the middle ages there was never a time when a philosopher was not free to put forth his scientific conclusions hypothetically—as theories to account for observed phenomena. He could not, however, directly attack religion, or even roughly handle received opinion on religious matters. At many epochs the first breath of heresy was fatal. Our own age is not very tolerant of attacks upon cherished beliefs. It is in a great degree its indifference to a certain class of inquiries that gives us our present liberty. Had Copernicus lived, his doctrine would not have given rise to scandal in the church, because it was put forth as a distinctly scientific opinion quite detached from theological suggestions. It was not until 1616 that his book was placed upon the index, and then only as a consequence of the personal enmities that Galileo's bitter satires had excited. If Roger Bacon had been willing to follow the methods of Copernicus the long miseries of his life would have been spared and the world might have been saved from three centuries of wandering in devious and ill-directed paths. If Galileo had done the same he would have lived in peace; we should have owed our present freedom to another martyr.

It is the custom of our minds to escape difficulties by accepting symbols to stand for ideas, types to stand for men, and we stand in danger of losing realities in the types and symbols. The sculpture of the Greeks is summarized to us by a couple of names; but there were many great sculptors in Greece beside Phidias and Praxiteles. The astronomy of the sixteenth and seventeenth centuries can show a large list of noted names; but it is epitomized in Copernicus, Tycho, Kepler and Galileo. It is commonly taken for granted that Copernicus burst forth from darkness and made a new epoch. He stands, indeed, for a new epoch; but he was no less the product of his time than Darwin, another *Bahnbrecher*. There was great activity among astronomers in the decade just preceding the publication of his great book in 1543. Copernicus was the child of universities; the schools of Italy which he frequented for years were alive with inquiry. The epoch for a revision of accepted theory had arrived. It was the encouragement of his friends and scholars that brought about the promulgation of his theories, all of which were fully comprehended by them, before even a line had been printed. Had Copernicus never been born there is no doubt that the heliocentric theory would have been announced before the sixteenth century reached its end. Tycho's observations contained it implicitly. It could not possibly have escaped the eager search of Kepler.

Tycho, again, stands as the type of the men who saw that a multitude of accurate places of the heavenly bodies must be accumulated before any adequate theory of their motions could be formulated. The Moors of Spain, the Arabs of Bagdad, the Turkis of Samarkand grasped the same fundamental idea, and other astronomers in Italy and in Germany were in the same path before Tycho.

Who shall say how much Kepler owed to his master, Moestlin, to whom he is never weary of attributing the suggestions which finally culminated in his splendid discoveries?

Galileo's great achievements in astronomy were largely due to the telescope, which he was the first to use, although it was invented by others. His greatest gift to science is his theory of mechanics, but even here Leonardo da Vinci had already gone far on the true way, and his contemporary, Stevinus, developed the whole subject independently and with equal insight. Galileo was surrounded by men of his own class if not of his own stature.

We, in our turn, may accept these four great men—Copernicus, Tycho, Kepler, Galileo—as types; but we must never forget that they did not stand alone. Each one of them shone with brilliant and intrinsic light, but each one was, also, in some degree, the mirror of his age, concentrating and diffusing the reflections of lesser lights by whom he was surrounded. What he received from them as mist, he returned in rain, as has been finely said of the inspiration of an orator by his audience.

Of this group of four, two are veritable epoch-makers—the first and the last. After the book of Copernicus was understood, the world was no longer the same. Its center had been changed. The sun and not the earth ruled our system. The planets and the stars became the sun's ministers, not ours. Man, *nodus et vinculum mundi,* was discrowned and disenthroned. It was the doctrine of Copernicus that changed the face of the world.

To realize the momentous change time was necessary. It was Galileo who spoke the emphatic word. The predictions of Copernicus were confirmed by the telescope. The new doctrines were explained and enforced so that no escape was possible. It was Galileo and not Copernicus who convinced the reluctant spirits of his day. The work of one was continued in the other. Not until the time of Newton was the message fully credited. It was not welcomed until our own day.

To the men of the middle ages the world was a little space shut tight within a wheelwork of revolving spheres. It was compendious, complete, ingenious, like a toy in a crystal box. Beyond the outer shell nothing existed. The heavens were incorruptible. No change could occur in the whole system, save on the earth alone. The universe was created for the sole use of man. It was small and finite. To us, the awful infinitudes of space are only to be faintly imagined after a series of conceptions, each one so overwhelming that it fades after the briefest instant of realization. Human attention can not grasp the whole series in one view. Each one of the myriad stars is a sun like our own, subjected, as it is, to prodigious physical alterations and catastrophies. Each one is, perhaps, surrounded by a train of planets, like those we know, that must forever remain invisible to our vision. The condition of every celestial body is perpetually changing in a long progress of evolution. Each separate star is situated as far from every other as our own sun from the very nearest of them all. Every star is in motion. The sun, so mighty and all-powerful to us, is but a feeble light among thousands of millions of others scattered so sparsely throughout the never-ending expanse that centuries are needed even for their light to traverse the intervening spaces. In the feeble light of that sunbeam, vital to us, the earth, our mother, shines like the merest mote. Its past is limited, its future insecure. With its finite history the fate of mankind is bound up.

We must not forget that the modern view of the universe is very different from that of Copernicus. Before his day the earth was motionless in the center of the world. After it the earth was in perpetual motion about the sun. Copernicus conceived the sun as fixed. But under Newton's law of universal gravitation there can be no fixed bodies. All are in motion. Our sun with its train of planets is speeding through space towards a goal as yet unknown. Newton's law of gravitation banished rest from the universe. To Copernicus as to Ptolemy rest was the natural state to which all bodies tended. They moved only when perpetually urged. The science of mechanics founded by Galileo and Newton changed all this. The real reformation of science dates from the acceptance of the new conception.

LIFE IN OTHER WORLDS.

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THE question 'whether life exists in any other worlds than our own' is one in which very many persons feel an interest, and about which much has been said and written; but if the man of ordinary education has any ideas on the subject, they are generally mistaken; and even scientists are prone to regard it too exclusively in the light of their particular science, and thus to conceive and propagate fallacies which might be easily avoided.

Of course no absolute answer to the question can be given until perchance some hitherto undreamt-of means shall be discovered for the observation of distant worlds. We can hardly forward the matter by mere speculation on general grounds, such as the law of probabilities, or the relative position of worlds in the universe. Nevertheless there is one method by which we can at least guard ourselves against erroneous speculation, and prepare the way for discovery when the opportunity comes; and that method is, to find out the conditions on which terrestrial life depends, and then to search other worlds and find if possible whether they provide similar or parallel conditions.

Though the ultimate nature of life is as yet unknown to us, its secrets are being gradually unraveled by research; and it becomes more and more apparent that the phenomena of life are but special and intricate developments of physical action. The most prominent and perhaps most fundamental characteristic of life is what may be called the *energy traffic,* or the function of trading in energy; and the phenomena of assimilation, growth, movement, etc., are the outward and visible signs of this traffic. Living substance possesses in the highest degree the property of absorbing radiant energy, as heat or light, storing it in a potential form, and subsequently expending it in active forms such as motion, mechanical work, heat and electricity.

Actions of this kind are not unknown in the inorganic world. For example, the atmosphere and ocean absorb the energy of light and heat from the sun, store it temporarily and convert it subsequently into the energy of wind and wave, lightning and thunder. But in living substance there exists a more finely coordinated energy-trading system, evolved out of the chemical capacities of a small number of elements acting under the physical conditions which prevail on our planet.

The energy traffic depends, no doubt, on causes at present unknown to us; and some biologists are wont to personify these causes as a 'vital force,' an influence (sometimes regarded as external) which modifies the behavior of matter and energy without affecting their quantity. But as we can not exclude the probability of similar directing and modifying influences in the inorganic world, it is best provisionally to regard the causes of life as present alike in living and not-living substances—conspicuous in living substance because coordinated, but hardly observed in not-living substance, owing to incoordination. If a simile be needed, it may be found in the behavior of light: for certain properties of light, though ever present, become evident only when coordinated by polarization; and polarization, be it noted, is a purely physical action.

While every element present in living substance may assist in the work, the energy-traffic is carried on chiefly amongst the four elements, nitrogen, oxygen, carbon and hydrogen. Nitrogen is remarkable for the instability of its chemical compounds—the readiness with which they change their composition—and there is little doubt that on this property depends the extreme sensitiveness of living substance. Carbon and hydrogen have the property of combining together to build up complex compounds, with great storage of potential energy; whereas the same compounds during their oxidation expend their energy in the form of mechanical work, heat, etc. The energy traffic consists of two alternating phases: (1) the *accumulation* of energy, or 'anabolic' phase, which is always coincident with deoxidation and the formation of complex chemical compounds: and (2) the *dispersion* of energy, or 'catabolic' phase, coincident with oxidation of the complex substances, which are thereby converted into simpler substances, as carbonic acid and water. In these processes nitrogen is intimately concerned: it is believed to act as the carrier, taking up each element or group of elements and passing it on in a new state of combination.

All the energy of life is derived ultimately from the sun. A little of this comes indirectly through lightning, which in passing through the air forms ammonia and oxides of nitrogen. These, being carried by rain into the ground, are the constant source of nitrogen for vegetable, and indirectly for animal life. A much larger quantity of energy is well known to be taken direct from the sunshine by plants and used in their anabolic processes. This energy is appropriated by animals in their food; and whether in the vegetable or in the animal, it assists in many alternations of anabolism and catabolism before it is completely dispersed.

The range of temperature suited to terrestrial life is comparatively narrow. All vital actions are suspended temporarily, some permanently, if subjected to a temperature near the freezing point; while the highest that most organisms can bear lies somewhere between 35° and 45° Centigrade (95° and 113° Fahrenheit). Only the spores of certain bacteria can survive boiling. It is therefore probable that if the general temperature of the earth's surface rose or fell 40° (a small amount relatively), the whole course of life would be changed, even perchance to extinction. The record of the fossiliferous rocks shows us that for countless millions of years a large portion of the earth's surface has had a temperature much the same as it now has; it is even probable that the surface temperature never greatly exceeded 40° C., though the interior was, and is, very hot.

Water plays an indispensable part in both the environment and the internal chemistry of life. It forms more than half the weight of most living things; and all the actively living parts of animals and plants (*e. g.*, the nuclei and protoplasm of cells) consist of water holding the other ingredients in solution or suspension.

Every one of the conditions above mentioned (supply of energy, particular elements, range of temperature, abundance of water) is essential to life— *i. e.*, such life as is known to us; and it is difficult to avoid the conclusion that this life is really the outcome of the conditions existing on our earth, and that only in worlds with identical conditions can identical life exist.

It is quite odd how, in spite of the advance of biological science and the acceptance of the principles of evolution, the notion still prevails that life in other worlds is similar to that of our earth. We find astronomers searching for the absorption bands of chlorophyll in the spectrum of Mars; marks on planets are described as probable vegetation; some worlds are supposed to be uninhabitable because they have no atmosphere, others because the temperature is too high for the existence of 'protoplasm.' All this indicates a very contracted view of the nature of life. Chlorophyll, respiration, vegetable, animal and protoplasm are earthly phenomena which may exist nowhere else: their place may be taken in other worlds by other phenomena no less wonderful. What we know of terrestrial life gives us reason to think that the same principles which produce life under earthly conditions may produce life of a different type under different conditions; *e. g.*, where the temperature is different, and a different set of elements are available.

It must be freely admitted that we do not know what elements could take the place of nitrogen, carbon, etc., under conditions differing from those on our earth. All speculations concerning this question have been based on misconceptions of the functions of the elements in life. We may only venture so far as to say that certain elements suggest possibilities of energy traffic by reason of the varied character of their compounds: such are phosphorus, sulphur, iodine and iron. Other elements, such as aluminium and silicon, are remarkable for the monotony of their known chemical actions. . . .

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In order that any world may support life comparable with the life that we know, the following conditions, among others, are necessary, namely, (1) A supply of radiant energy which is intermittent or variable, (2) one or more elements which (like nitrogen) are very sensitive to changes of energy, and (3) one or more elements which (like carbon and hydrogen) are capable of alternately accumulating and dispersing energy by means of opposite chemical changes.

Since popular ideas as to the physical conditions of other worlds are generally hazy and often far from correct, it may not be amiss to recount such particulars as astronomical research has revealed in the members of the solar system.

In looking for a world where the conditions are most like our own, we naturally turn first to Venus. Her size and gravitation are nearly the same as those of the earth, and her atmosphere may therefore be expected to have a similar density and to hold approximately the same gases. As she is nearer the sun, the general temperature would be considerably higher, and the equatorial region might be too hot for our life; but there might nevertheless be a suitable temperature nearer the poles. But our speculations are damped by a suspicion, strong but not fully confirmed, that Venus has no day and night, but always keeps the same side toward the sun. If this is really the case, then the sunny side must be always burning hot and quite dry, while the opposite side must be always encased in ice—nay more, in a mixture of ice and solidified atmospheric gases. The life of such a world must be very different from any that we know.

After Venus, Mars is the planet whose conditions seem most to resemble those of our world. But there are far greater differences than are generally supposed. Mars is so small that he can not provide much heat from within, and so far from the sun that he receives comparatively little heat from without. His gravitation is so slight that the atmosphere is rare and nearly cloudless, and therefore heat must be readily lost by radiation. Thus on theoretical grounds Mars should be intensely cold: in fact his surface should be constantly in the condition of the highest mountain-tops of our world, only receiving less heat than they do from the sun. At such low temperature and pressure, water could never exist in the liquid form, though it might be solid or gaseous. But water is very possibly absent from Mars. Dr. Johnstone Stoney has calculated, by application of the dynamic theory of gases, that any water vapor introduced into the atmosphere of that planet would escape into space, the gravitation being there insufficient to retain it. Professor G. H. Bryan, calculating from slightly different data, questions Dr. Stoney's conclusions; but at all events Mars's gravitation is very near the dividing line between the ability and inability to retain water. If water is absent from Mars, then the polar caps and other seeming evidence of its presence must be due to some other fluid or gas, having heavier molecules and lower freezing and boiling temperatures. Dr. Stoney himself holds that carbon dioxide would give the appearances of vapor, frost and snow, which are seen with the telescope; and there are still heavier gases which might be imagined to be present. In any case, the conditions seem quite incompatible with life of our earthly type.

As already hinted, the atmosphere of a world depends on its gravitation. Gases tend to diffuse into space, unless retained by adequate attraction. Our earth can hardly retain so light and mobile a gas as hydrogen; Mars may have difficulty in retaining the less mobile vapor of water; but the gravitation of the moon is too slight to retain any known gas, hence she has no atmosphere and no water. Yet this is not sufficient reason for assuming the absence of life. The surface of the moon is usually considered to have been for a long time in an inert state. If it had been so, the accumulation of meteoric stones and dust during ages would have covered it with a uniform veil. Instead of this, the surface presents much variety of tint and texture, indicating a still continuing geological activity; and some changes in its markings are said to have been observed in recent years. Professor Lapworth, regarding it with a geologist's eye, feels convinced that the moon is an active and living world. The geological activity may be the result of the extremes of temperature which are produced by the regular alternation of a half-month's sunshine and a half-month's darkness. At the same time such extremes might awaken to vital activity elements which behave as dead on this earth.

In contrast to the moon are the very large planets, Jupiter and Saturn. Owing to the high gravitation, the atmosphere of such planets is very dense, and so loaded with opaque particles that we can not see through it to the body of the planet within. But though the body is beyond our scrutiny, we can infer that it is very hot, even at the surface; for if the solar system was formed (as is assumed) by condensation of a nebula, the heat of condensation must be proportionately greater and longer retained in a large world than in a small one. Thus for the purposes of life on these great planets the energy radiating from within may be available, and indeed may largely exceed the energy received from the sun at so great a distance. The satellites of these planets may resemble our moon, except that they receive much less energy from the sun.

Of Uranus and Neptune we know very little; but their large size leads us to suppose that their physical conditions may have some resemblance to those of Jupiter and Saturn.

What can we say of the possibility of life in the sun? The visible surface or photosphere has a temperature so high that even iron exists there as a gas, and almost all chemical compounds known to us may be dissociated. The deeper parts are doubtless far hotter still, with chemical possibilities or impossibilities beyond our comprehension. In fact the chemistry of the sun is of so different an order from any that we have experience of, that we can not reconcile it with any of our notions of life. But if such a vast fund of energy can run to waste without producing life except in distant planets, there must be in nature an extravagance such as almost to justify those persons who imagine our own world to be the only one bearing life, and the whole universe to be made for man.

These few particulars, which we have learned concerning the physical conditions prevailing in other worlds of our solar system, are distinctly against the probability of their possessing life similar to that existing in this world. If they contain life, even life depending on the same principles, it must be quite different in its manifestations, and not easily recognizable with the telescope. If any germ of life should escape from this world and land upon another member of the solar system, it must pretty certainly perish for want of the necessary conditions. The same might be said of a germ from another world landing on our earth—if indeed we have any right to speak of a 'germ' from another world, since the word is geomorphic, and actually assumes that similarity which we hold to be improbable in life under different conditions.

Whether any members of other solar systems resemble our own in physical conditions is naturally a matter of pure speculation; but there is no *a priori* impossibility, since the spectroscope shows that many of the fixed stars contain the same elements as our sun, and have about the same temperature.

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We are considering only such life as depends on the same principles as earthly life. We may admit the possibility of other kinds of life, having nothing in common with such life as we know, but at present we have no grounds for speculation concerning them. Keeping within the bounds of legitimate induction, we are led to the following conclusions:

1. If life is essentially a function of the elements nitrogen, oxygen, carbon and hydrogen, acting together, then it can probably occur only on exceptional worlds, with conditions closely resembling those of our own earth. Such conditions are not present in any other world in our solar system, nor can they be expected to occur frequently in members of other systems.

2. On the other hand, if different conditions can awaken a capacity for exalted energy traffic among other elements than those just named, then the universe seems to provide immense possibilities of life, whose variety and magnificence may far exceed anything that we can imagine.

THE NEW WEST POINT.

By WILLIAM J. ROE,
NEW YORK.

IN the year 1802, by act of Congress, the United States Military Academy was established at West Point on the Hudson River. The experience of Washington during the war of the revolution with the militia of the several states and with raw volunteers was convincing as to the necessity for a permanent military establishment, and especially for the creation of a considerable body of officers sedulously trained in the art of war. The sentiments of the people then, and for many years after, were not favorable to the formation of a standing army, and it was not until the many and serious reverses of the land forces in the 'war of 1812' that any progress was made at West Point in the way of educating officers for their country's service. In the year 1817,—James Monroe being president and George Graham of Virginia secretary of war, Sylvanus Thayer, of Massachusetts, became superintendent of the academy, and at once began a system of instruction and discipline so complete and admirable as to have been maintained in almost the minutest detail to the present day. General Thayer remained at the head of the academy until 1833.

During the period between the close of the war with Great Britain and 1846, the sole opportunity for the graduates of West Point to prove their value was upon the frontier as it then was, the Rocky Mountains and the 'Plains' in contest with hostile Indians. In this sort of warfare there was more room for the display of the forester's and trapper's craft and experience than for the exercise of tactics or 'grand-strategy,' and the consequence was that again the people grew impatient with the appropriations for the academy's maintenance. By this time a numerous body of officers had been graduated, and the idea of a thousand or more men with a life tenure of office and something akin to 'special privilege' and European exclusiveness did not find favor with either 'democrats' or 'republicans.' About this time it was in fact seriously contemplated to abolish the academy altogether. It is more than probable that this would have been done by congress, if at this juncture the Mexican war had not suddenly burst upon the country. We have, it must be confessed, but little to be proud of as to the origin of this war, or to the aggressive and not wholly unscrupulous terms that were finally forced upon Mexico; but the war accomplished at least one good result by demonstrating the merit and necessity of trained leaders. With a little army of only a few thousands, officered almost wholly by West Point graduates, Winfield Scott marched from the Gulf to the Valley of the City of Mexico, gaining victory after victory, to finally dictate the terms of peace from 'the Halls of Montezuma.'

The change of sentiment among the people as to 'graduated cadets' was instantaneous, and from that day no thought has found expression adverse to the interests of educating and maintaining a considerable body of competent officers.

The reasons for the people's change of sentiment are not to be found alone in the proved ability of West Point men in campaigning, or in any superior valor in action. Others than graduates have shown great skill in strategy, and the volunteer has always been easily his

THE FIRST ACADEMY.

equal in courage and endurance, with perhaps that moral advantage of not being a 'hireling soldier.' It is that through now a full century the record of the graduates of West Point has been spread before the country, and has been found to be on the average so exceedingly high as to be a matter not only of congratulation, but astonishment. There are West Point men who have gone badly astray; some have been promptly cashiered out of the service; others have fled with ill-gotten spoils beyond a 'process,' and others yet have had short shrift in a penitentiary. There are such, but they are marvelously few. Not only in the army, but in civil life, the standard of honor and of integrity has been and is marvelously high.

This has come, not that among the four thousand graduates the same blood does not run and the same influences work for good or ill as among a similar number of others; if they are on the average more high-minded, more duteous in every department of life, it is that the penalty for departure from the straight and narrow path is so extremely swift and terrible. What is true in this respect in the army and in business affairs is true perhaps to a greater extent in the academy itself, and there indeed it is that the foundations of probity in after life are laid. For four long years—with one brief furlough the third year—the West Point cadet seldom if ever leaves the academy at all; collegians have long vacations; the cadet has none; youths in training for business may spend much time with their families; the student at West Point has no such opportunities. Again it is not with him as with others in trade or at most educational institutions, that he is 'under masters.' There are professors and instructors, a commandant and 'tactical officers,' but as to discipline and all matters of moral obligation, the corps of cadets *governs itself*. From the cadet adjutant and captains to the corporals, and even men-in-the-ranks 'on duty,' each cadet is bound by the strongest of obligations to report violations of regulations. That which would have been called in the large school which I attended in early youth 'telling tales,' is here not only permissible, but an essential part of the academic discipline. Instruction in science, tutelage in the war-course; these go hand in hand; but far more efficient for real and vital education is the constant presence of the spirit of self-training and self-conquest in the molding of true character.

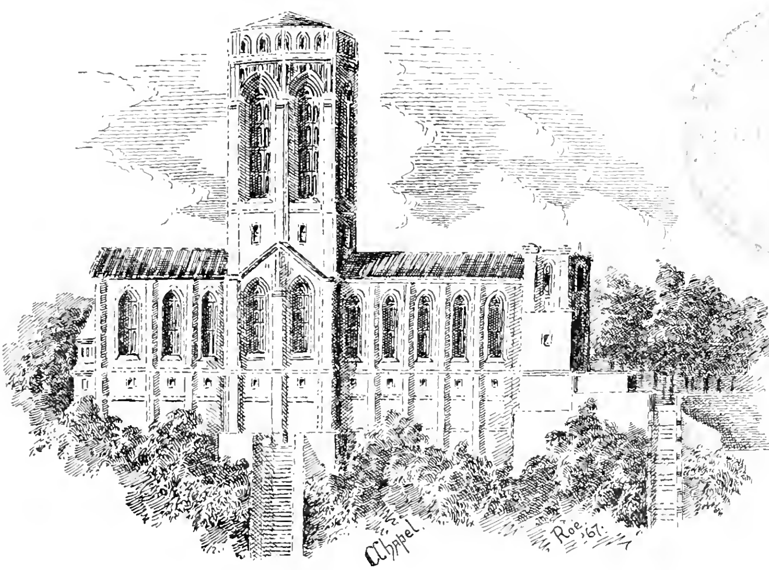
Other institutions outrank the military academy in perhaps all branches of strictly scientific education; some of the refinements of high culture are neglected, and literary excellence is ignored; but as a school of the art of living it is incomparable, as a school of the science of character it is unique.

At the close of the war between the states our regular army was left in a somewhat disorganized condition. In the process of re-organization and increase, there came into the service a very considerable number of commissioned officers who had earned a sort of right to retention in the new army by reason of exceptionally good service as volunteeers. Many of these new appointments had been high in rank—some even generals—who now were content to act as mere file-closers. Some of these were political appointments, and the most inefficient were in due time weeded out; but by far the majority were men of long experience in the field, well worthy of their commissions.

At the time of the breaking out of the Spanish war it was these men, appointments either from the army or from civil life, who by the natural process of seniority had arrived at the highest rank, and it was chiefly upon them that the responsibility rested of commanding troops in the ensuing campaigns. The record of these men is so open and so recent that it appears unnecessary to particularize. They made many mistakes, but on the whole their actions were marked with singular skill, and the results that they achieved were remarkably successful.

Such having been the case, it would not perhaps have been unnatural if the veterans of the civil war had been rather disposed to magnify their own opportunities, even possibly to the extent of discrediting the advantages of West Point training. This, however, has not been the case; the most successful of leaders who had come up 'from the ranks' have united in deploring for themselves the lack of certain elements, hardly to be described and to be gained only in early youth, and to advocate most strenuously the training that the academy affords.

This influence, which has been quite unanimous, combined with the popular feeling consequent upon our sudden rise as a 'world-power,' has determined congress to increase largely the capacity of West Point, and to remodel wholly the *material* of the institution. For this pur-



THE CHAPEL.

pose the sum of five million dollars has been appropriated, and, after a competition between ten prominent firms of architects, the award of excellence in general design has been made to Cram, Goodhue and Ferguson, of Boston.

The work of remodeling the academy is necessarily tri-fold: it naturally resolves itself into the architectural, the pictorial, and, inevitably, the practical. At present the buildings of the academy, constructed as they have been at various periods and by authority of men of various degrees of artistic feeling, are more or less ill-assorted and incongruous; several are fine examples of architecture; the cadet barracks highly appropriate in treatment, and the cadet mess-hall exquisitely designed. But—not to be invidious—at least, there are 'others.' The Cullum Memorial building is quite worthy in its way and standing alone; but its Polonian fairness serves only to 'swear at' the grim granite, buttressed and embattled, across the plain. By the side of the Memorial (as if it had laid an egg) is the officers' mess—that also not bad architecturally, but a little, just a little, one feels, out of keeping. The hotel, of course, is a bad blot on the landscape, and some other matters need remedying. Let us be patient as well as brutally frank—they are all going to be remedied if the government will permit the architects to 'build up the system.'

No mere panaceas for the accident of incongruity; touches here and there modifying or obscuring or obliterating something hideous or something merely obtrusive, saving sacredly all that can or ought to be saved out of the chaos: never replacing anything really beautiful by something even more beautiful even to propitiate uniformity, and above all guarding jealously the spirit of old associations, always at 'arms-port' to cry, 'Who comes there?' to him—even to a friend, without the academy or within, who can not give the countersign, 'Propriety,' or seeks to substitute 'Utility.'

What a superb foundation these artist souls may build upon! A level square mile, terre-plein whose barbette views throw glances riverward many miles north and south, a steep scarp of primeval rock plunging down sheer to the glacis of water below; outlying works of precipitous hills, piled terrace upon terrace to the highest peak crowned with the gray vestiges of Fort Rufus Putnam.

Not alone the traditions of the military academy invite the artisan and the architect to his best efforts, but here are older historic associations yet to stimulate also the poet. To the planning of such work as is here contemplated some measure of fine frenzy must mingle with the dull prosaic details of necessity or expediency.

The general plans and such details as have been elaborated show conclusively how grand the scope of alteration, how admirably existing conditions are to be utilized, and the natural features are to be availed of. In its material phases West Point may be easily separated into three distinct periods: that of the early academy, of the old north and south barracks—of the academy as it was when Edgar Allan Poe was a cadet, where Whistler stood higher in drawing than in chemistry, and where Grant and Lee, Sherman and Longstreet got their education. Then came the time of the present barracks, Elizabethan, stately, well appointed. It was erected in 1851. The old academic building was built in 1838, and was replaced by the present modern structure in or about 1890. The third period is that about to be inaugurated.

In the construction of the New West Point the present academic building will be retained; the site of the old chapel being utilized for additional academic accommodations; the new chapel—decidedly the most ornate and conspicuous of the new buildings—lifted upon a spur of the hills overlooking the plain. The barracks also will be kept, with material additions and changes needed for the housing of the increased number of cadets. To the north of the Cullum Memorial and balancing the officers' mess-hall will be located a building for use as bachelors' quarters, of the same Georgian style of architecture.

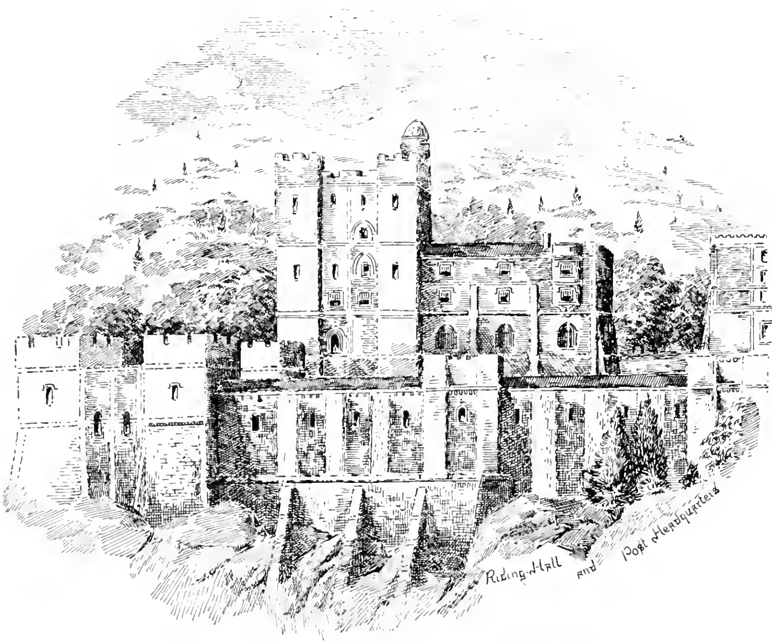
The enmity of styles, as far as possible, will be propitiated, one blending with the other, without actually mingling, masses of foliage serving to keep a measure of peace between them. Where the hotel now stands it is proposed to erect the quarters of the superintendent, the present battle monument duplicated on the right of what may be termed the major axis of the scenic system. The avenue now existing vistas upon the center of academic life, while other avenues will be made to radiate from here, across the plain, sweeping down the hillside.

The approach to the academy will probably be completely altered; the landing either from railway or boats being made not only commodious but imposing. Access to the high level will be as now by means of a gently winding ramp, while a large passenger elevator will conduct to a public square, to the restaurant and hotel; these being located where they will be apart from the real activities of either academic or military life, and yet conducing more readily to the convenience and comfort of visitors. From the south, the post will be approached through elaborate arched gateways, with appropriate towers, the strongest emphasis being placed upon this prime avenue, while between the two sections of the academy will be a monumental arch, to be adorned with statues and memorials.

As seen from the river the riding-hall, greatly enlarged, will be the most imposing of structures, rising as it will from the perpendicular crags, growing out of them and seeming a part of them, buttressed on front and flank and crowned with a line of battlements. Above will rise the fine elevation of the post headquarters, which will form also a striking background from the southern approach.

The dominant style of the construction will be the Gothic, not American architecture as it has grown pliant and flexible from the studiously archeological, but suggestive of the ascendant impulses of formality of former British models. The material will be generally stone, treated with greater or less elaboration, according to the value pictorially of the buildings, due harmony being preserved or achieved by judicious alterations in effect. Several of the minor structures will be of red brick in Flemish bond, trimmed with stone.

Perhaps the most difficult problem was that of the judicious enlargement of the cadet barracks, to accommodate double or more the number of cadets for which the present barracks was built. The difficulty was the greater because of the limited space apparently at command. The steep hill on the south seemed an obstacle to additions in that direction, while the gymnasium on the west occupied ground that could otherwise have been used. Previous to the submission of the work to competition, there was a studied examination of the entire subject of enlargement by a board of officers detailed for the purpose, and one of the professors at the academy—Professor Larned of the department of drawing—made a special study and comprehensive re-

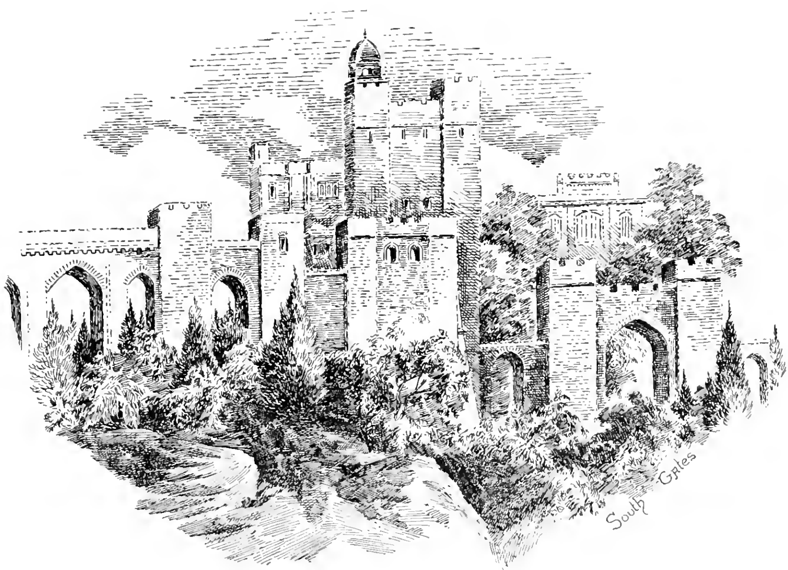


RIDING HALL AND POST HEADQUARTERS.

port. Among the officers there was developed considerable difference of opinion and these divergent views have been set forth in a majority and minority report. The enlargement of barracks was a point upon which the difference of views was especially pronounced; in effect the problem that the architects were called upon to solve was, or seemed to be, solely to decide whether the barrack buildings should be extended on a line parallel to the west side of the plain, or whether a closed quadrangle should be formed by a series of so-called divisions south of the present sally-port and upon the line now that of the southerly side of the 'area-of-barracks.'

The successful architects, adopting neither of these suggestions, have happily (at least so it seems to an old graduate) hit upon an expedient by which all the advantage of expansion is gained, and without loss—even much gain in the way of structural effect. Practically the present barrack building is left intact, a few simple exterior changes excepted, the advantage of a spacious quadrangle is retained, while sufficient dormitories, light, airy and well swept by prevailing breezes, are provided. Instead of the present inadequate lodging an administration building is planned, not only serviceable but calculated to increase greatly the effect of unity with variety.

In the comprehensive system thus designed, the requirements of the future have not been unheeded. The probabilities of still greater



South Gates.

expansion than any now contemplated sedulously and with rare judgment have been pointed out. By the removal of the gymnasium to another suitable locality, the barracks could be prolonged to the westward, furnishing quarters for nearly three hundred more cadets in addition to the present large increase in the corps; the natural amphitheater at the foot of the hill back of the line of professors' quarters on the plain suggests the erection of a stadium for athletics—baseball, cricket, football and the like. The natural slope could there easily be so managed as to give seating for six thousand spectators. The removal of the cavalry and artillery ground to the southerly end of the reservation was recommended by the officers' board, and this feature will be incorporated in the design.

It is not to disparage the earnest efforts of preceding administrations of either the academy or the war department to say that heretofore little has been done in the way of symmetry of proportion or in fact of even enlightened systematic utility. Such flagrant solecisms of economy as that the post quartermaster's offices, the post office and the meat market should be huddled together in the same vicinity, will now be completely remedied. Hitherto appropriations have been too limited in amount and too rigidly doled out in detail by civilian 'watch dogs' of trivial parsimonies. Now at last the way seems tolerably clear by which the several functions of the post shall be grouped in order of the importance: first, that which is military, afterwards, and adjoining, that which is scholarly, and then, separate and apart, all other and subsidiary functions—supplying and purveying of goods, reception and entertaining of guests; all will be no longer scattered or occupying the most eligible positions, but grouped together and in exactly their right locality.

The plans as already outlined are in scope and arrangement as nearly perfect as practical ingenuity could devise. It is greatly to be hoped that in carrying out so thorough a reformation, they who are charged with the duty may remain unhampered by an authority supreme in the state, but which has in manifold instances in the past proved its woeful incapacity to deal with technical needs or more deplorably yet, with the demands of art. The mistake at Annapolis will probably not be here repeated; but the New West Point will be made to burgeon out of the old; the revolutionary relics retained with all their hallowed associations unimpaired, and the sacred traditions of the academy held inviolate.

A LABORATORY FOR THE STUDY OF MARINE ZOOLOGY IN THE TROPICAL ATLANTIC.*

BY DR. ALFRED GOLDSBOROUGH MAYER.

MANY able naturalists have discussed the question of the advisability of establishing a marine biological laboratory for research within the West Indian region, and the advocacy of the idea by Huxley and Lancaster is a matter of recent memory. While none of these discussions has resulted in the establishment of a permanent laboratory they have served a useful purpose in keeping alive the interest of

TRACK OF LOGGERHEAD TURTLE (*T. caretta*) MADE IN CRAWLING UP THE BEACH TO LAY ITS EGGS. LOGGERHEAD KEY, TORTUGAS.

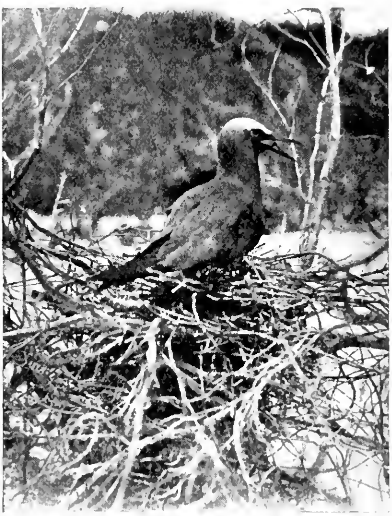
biologists, and also in proving that it is very difficult to bring about a combination of colleges or learned societies which will lead to the establishment of such a station.

Indeed the realization of the establishment of such a laboratory might be considered well-nigh hopeless were it not for the recent creation of the Carnegie Institution. If it be the aim of this institution to maintain researches which no existing agencies have been able to

* With illustrations by permission of the Museum of the Brooklyn Institute of Arts and Sciences.

perform it would appear that an excellent opportunity is presented in the possibility of establishing such a laboratory.

Each of our universities and learned societies represents a more or less well-defined and consequently narrow clientage, while the Carnegie Institution alone is truly national in its scope and influence. Also while our national scientific bureaus must devote their energies chiefly to the solution of practical problems, the Carnegie Institution alone may devote even the major proportion of its funds to the advancement of pure science. As no permanent laboratory for research in marine zoology exists in the West Indian region the Carnegie Institution would have an absolutely free hand in determining the situation, scope and destiny of such a station.



NODDY GULL (*A. stolida*) UPON ITS NEST, BIRD KEY, TORTUGAS, WHERE SEVERAL THOUSAND OF THESE BIRDS NEST ANNUALLY.

The present movement appears to have been initiated by two articles in *Science* advocating the establishment of such a laboratory at the Tortugas, Florida. Considerable discussion ensued; the chief questions being those of the most suitable site for the station, its auspices, and the character of its work. Opinions upon these important points were expressed by fifty naturalists, such as Barton, M. A. Bigelow, R. P. Bigelow, Chapman, H. L. Clarke, J. F. Clarke, Conklin, Dall, Davenport, Dean, Dodge, Duerden, Edwards, Evermann, Gill, Hargitt, Herrick, L. O. Howard, Jennings, H. P. Johnson, D. S. Jordan, V. L. Kellogg, Kingsley, Lillie, Lucas, McBride, McMurrich, Metcalf, Mills, Minot, Montgomery, Morgan, Neal, Nutting, Ortmann, C. H. Parker, R. Rathbun, Richards, Ritter, Rolfs, Sedgwick, Springer, R. M. Strong, Treadwell, Verrill, H. B. Ward and four others. It is evident that a large number of our most active biologists have interested themselves in the project.

Twenty of those who have expressed any opinion upon the question of site have favored more or less strongly the placing of the laboratory at the Tortugas; six recommend Jamaica; three Porto Rico; two the Gulf Coast; two the Bahamas; the Isle of Pines, Miami, Florida, and the Bermudas each one.

Although the number of naturalists who have advocated the placing of the laboratory at Jamaica is small, their opinion is evidently worthy of highest respect when we consider that among them are such investigators as Barton, H. L. Clark, Conklin, Duerden and Morgan. The advantages claimed for Jamaica are a healthful climate, the best of social conditions, a rich *land* and *fresh-water* as well as marine fauna and flora, and the accessibility of the island. The land flora and fauna of Jamaica are stated on good authority to be the richest of the Antilles, while the coral reefs and marine fauna, although possibly

THE PARADE GROUND OF FORT JEFFERSON, DRY TORTUGAS, SEEN THROUGH ONE OF THE CASEMATES.

not so rich as those of the Tortugas, are said to be remarkably varied. Unfortunately none of the gentlemen who advocate Jamaica have been at the Tortugas, and it is therefore impossible for them to make any direct comparison between the marine faunæ of the two places.

The advocates of the Tortugas, Florida, claim that here we find by far the *richest pelagic fauna* of the tropical Atlantic which is driven upon the shores by the prevailing winds from the Gulf Stream.

The Tortugas reefs, while not so rich in corals, are richer in fishes and invertebrates than are those of the Bahamas and probably of other West Indian Islands. The nearness of the Pourtales plateau would give the station an enviable opportunity for deep-sea dredging, while the remarkable purity of the ocean water surrounding the Tortugas would provide the laboratory with an almost unique advantage in the rearing of larvæ, and prosecution of physiological work. The Tortugas is now a naval coaling station, and a naval surgeon is stationed at Fort Jefferson, which is in telegraphic connection with Key West. A large naval tug makes two regular trips each week to and fro between Key West and the Tortugas, completing the journey in less than six hours. The climate is rendered cool by the small land area and the almost constant breeze. There are no sand flies and practically no mosquitoes on Bird and Loggerhead keys, while the few mos-

Gulf-Weed and Marine Animals cast upon the Beach of Loggerhead Key, Tortugas, by a Gale of seven hours' Duration.

quitoes at Fort Jefferson could be eradicated by screening the cisterns. The quarantine station has been removed, and the place is most healthful on account of its isolation.

With the exception of several species of gulls, numerous migrating birds and a few insects, the land fauna of the Tortugas is uninteresting, and the flora is limited to the few plants which can cling to beaches of coral sand. In these respects Jamaica is incomparably superior to the Tortugas. The social conditions, and opportunity for the study of a diversified land and fresh-water fauna and flora in Jamaica are far superior to those which may be enjoyed at the Tortugas. On the other hand, the Tortugas has a far richer pelagic and certainly equally good littoral fauna, the purest of ocean water, and it affords the best situation in the world from which to study the life and conditions of the Gulf Stream. To students from the middle west the Tortugas are more accessible than is Jamaica.

The discussion has at least succeeded in establishing the fact that the Bahamas are on the whole inferior to the Tortugas, for despite their good coral reefs, their pelagic and littoral faunæ are relatively poor. Nutting who directed one of the most successful biological expeditions ever sent to the Bahamas, is emphatic in declaring the superiority of the Tortugas. The prevalent winds prevent the floating life of the Gulf Stream from reaching the Bahamas, whereas they con-

THE QUEEN'S STAIRWAY, NASSAU, BAHAMAS. A cut through æolian rock.

stantly drift the pelagic creatures of the stream upon the Tortugas.

Next to Jamaica, Porto Rico appears to be the favorite among the Antilles; the southern shore, Mayaguez, and Culebra Island being especially recommended. Judging from the published results of the *Fish Hawk* expedition of 1898–99 under the auspices of the United States Fish Commission, the littoral fauna is remarkably good, although I am informed on excellent authority that the pelagic hauls of the expedition were poor. The social conditions of Porto Rico appear to be not so good as those of Jamaica, and its land fauna and flora are said to be poorer than those of the English island, but there are certain advantages in having the station established upon land possessed by the United States. This also applies to the Isle of Pines, which has been ably recommended by J. Fred Clarke.

The marine fauna of the Tortugas is greatly superior to that of the Florida mainland or Gulf Coast. Moreover, while the ocean water surrounding the Tortugas is of the purest the shore waters of Florida and the Gulf of Mexico are often charged with silt, and sullied with the drainage from mangrove swamps to such a degree as to be rapidly fatal to pelagic life. The littoral fauna of the mainland shores is

Beach Rock at Mastic Point, Andros Isd., Bahamas. A typical sea-worn rocky beach composed of agglutinated fragments of shells, corals, etc.

inferior to that of the Tortugas, and the greater heat, mosquitoes and occasional epidemics of mainland places render them undesirable.

The fauna of Bermuda is subtropical and consequently poorer than that of the Bahamas, Tortugas or West Indies. Judging from the results accomplished by Fewkes and others the pelagic life appears to be even poorer than that of the Bahamas, although the expeditions under Verrill have demonstrated that the littoral fauna is very rich.

Summing up, the question of site appears to have been narrowed down to a choice between the Tortugas and one of the Antilles, the favorite island being Jamaica. Before this question can be definitely settled some competent naturalist who is already familiar with the fauna and flora of one of these places should investigate the other with a view to drawing a just comparison between them. It is remarkable that no biologist familiar with either one of these situations has ever studied at the other.

Concerning the scope and auspices of the laboratory all the correspondents are agreed that it should be national in character, and that every possible aid should be given to all competent students, both in the prosecution of their studies and in the *publication of results.*

Although a tropical laboratory may well remain open during the entire year, the most available months for study are May 1 to August 1. This is the period of calms, which follows the trade wind period of the winter and precedes the hurricane season of the autumn. During late spring and early summer months one may safely go out to sea in small sail boats, and may wade and collect on the windward sides of the reefs, an advantage rarely enjoyed during the winter, when the almost constant trade wind lashes the ocean into foam. There is yet another advantage gained by selecting the summer months for study, for this is the period when numerous larvæ and young forms appear; and few realize who have not been there that there is almost as much difference between the faunæ of summer and winter in the tropical ocean as there is along our own temperate shores. With the exception of the Siphonophoræ, almost all forms of pelagic life are much more numerous in spring and summer than during the winter months. These remarks apply especially to the Tortugas and Bahamas, where the calm period is well marked.

This appeal for this laboratory may seem to some to be worthy of but little attention; for abstract laws and facts having little or no bearing upon the practical things of life would chiefly concern its thought, but who may dare to predict the outcome of the study of pure science? Polarized light by means of which we now analyze our sugars, the principles underlying the working of the dynamo, telegraph and telephone; the great law of evolution and the germ theory of disease were all discovered and made known by men who had in mind only the advancement of the sum of human knowledge totally apart from practical results or the acquisition of wealth. Our national progress vast in material has been insignificant in abstract science, yet underlying all practical applications are the laws which men who have studied nature for the simple love of her ways have found. Too much of our energy is withdrawn from the study of cardinal principles, and too much devoted to the application of established laws to the serving of mere practical ends. Let us have at least one laboratory devoted exclusively to *research* in science, both pure and applied, and let its course be free from criticism if it be so fortunate as to lead to the discovery of laws even if no money be made thereby.

THE PARENT-STREAM THEORY OF THE RETURN OF SALMON.

By President DAVID STARR JORDAN,
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IT has been generally accepted as unquestioned, by packers and fishermen, that the salmon of the Pacific (king salmon, red salmon, silver salmon, humpback salmon and dog salmon) all return to spawn to the very stream in which they were hatched. As early as 1880, the present writer placed on record his opinion that this theory was unsound. In a general way, most salmon return to the parent stream, because when in the sea the parent stream is the one most easily reached. The channels and runways which directed their course to the sea may influence their return trip in the same fashion. When the salmon is mature, the spawning season approaching, it seeks fresh water. Other things being equal, about the same number will run each year in the same channel. With all this, we find some curious facts. Certain streams will have a run of exceptionally large or exceptionally small red salmon. The time of the run bears some relation to the length of the stream: those who have farthest to go start earliest. The time of running bears also a relation to the temperature of the spawning grounds—where the waters cool off earliest, the fish run soonest.

The supposed evidence in favor of the parent stream theory may be considered under three heads:* (1) Distinctive runs in various streams, (2) return of marked salmon, (3) introduction of salmon into new streams followed by their return.

Under the first head it is often asserted of fishermen that they can distinguish the salmon of different streams. Thus the Lynn Canal red salmon are larger than those in most waters, and it is claimed that those of Chilcoot Inlet are larger than those of the sister streams at Chilcat. The red salmon of Red Fish Bay on Baranof Island (near Sitka) are said to be much smaller than usual, and those of the neighboring Necker Bay are not more than one third the ordinary size. Those of a small, rapid stream near Nass River are more wiry than those of the neighboring large stream. The same claim is made for the different streams of Puget Sound, each one having its characteristic run. In all this there is some truth and

* See an excellent article by H. S. Davis in the *Pacific Fisherman* for July, 1903.

perhaps more exaggeration. I noticed that the Chilcoot fish seemed deeper in body than those at Chilcat. The red salmon becomes compressed before spawning, and the Chilcoot fishes having a short run spawn earlier than the Chilcat fishes, which have many miles to go, the water being perhaps warmer at the mouth of the river which flows farthest from the parent ice-fields. The riper fishes run up the shorter river. In Bristol Bay, according to Dr. Gilbert, the great runs ascend sometimes one river, sometimes another. Perhaps some localities may meet the nervous reactions of small fishes while not attracting the large ones. In Necker Bay a few full-grown salmon run besides the little ones. A few dwarf individuals, two and three year olds, ripened prematurely, run in every salmon stream. These little fishes are nearly all males. Mr. H. S. Davis well observes that 'until a constant difference has been demonstrated by a careful examination of large numbers of fish from each stream taken *at the same time,* but little weight can be attached to arguments of this nature.'

It is doubtless true as a general proposition that nearly all salmon return to the region in which they were spawned. Most of them apparently never go far away from the mouth of the stream or the bay into which it flows. It is true that salmon are occasionally taken well out at sea and it is certain that the red salmon runs of Puget Sound come from outside the Straits of Fuca. There is, however, evidence that most species rarely go so far as that. When seeking shore, they usually reach the original channels.

In 1880, the writer, studying the king salmon of the Columbia, used the following words, which he has not had occasion to change:

> It is the prevailing impression that the salmon have some special instinct which leads them to return to spawn in the same spawning grounds where they were originally hatched. We fail to find any evidence of this in the case of the Pacific coast salmon, and we do not believe it to be true. It seems more probable that the young salmon hatched in any river mostly remain in the ocean within a radius of twenty, thirty or forty miles of its mouth. These, in their movement about in the ocean may come into contact with the cold waters of their parent rivers, or perhaps of any other river, at a considerable distance from the shore. In the case of the quinnat and the blueback, their 'instinct' seems to lead them to ascend these fresh waters, and in a majority of cases these waters will be those in which the fishes in question were originally spawned. Later in the season the growth of the reproductive organs leads them to approach the shore and search for fresh waters, and still the chances are that they may find the original stream. But undoubtedly many fall salmon ascend, or try to ascend, streams in which no salmon was ever hatched. In little brooks about Puget Sound, where the water is not three inches deep, are often found dead or dying salmon, which have entered them for the purpose of spawning. It is said of the Russian River and other California rivers, that their mouths, in the time of low water in summer, generally become entirely closed by sand-bars, and that the salmon, in their eagerness to ascend them, frequently fling themselves entirely out of water on the beach. But this does

not prove that the salmon are guided by a marvelous geographical instinct which leads them to their parent river in spite of the fact that the river can not be found. The waters of Russian River soak through these sand-bars, and the salmon instinct, we think, leads them merely to search for fresh waters. This matter is much in need of further investigation; at present, however, we find no reason to believe that the salmon enter the Rogue River simply because they were spawned there, or that a salmon hatched in the Clackamas River is more likely, on that account, to return to the Clackamas than to go up the Cowlitz or the Des Chûtes.

Attempts have been made to settle this question by marking the fry. But this is a very difficult matter, indeed. Almost the only structure which can be safely mutilated is the adipose fin, and this is often nipped off by sticklebacks and other meddling fish. The following experiments have been tried, according to Mr. Davis:

In March, 1896, 5,000 king salmon fry were marked by cutting off the adipose fin, then set free in the Clackamas River. Nearly 400 of these marked fish are said to have been taken in the Columbia in 1898 and a few more in 1899. In addition a few were taken in 1898, 1899 and 1900 in the Sacramento River, but in much less numbers than in the Columbia. In the Columbia most were taken at the mouth of the river where most of the fishing was done, but a few were in the original stream, the Clackamas. It is stated that the fry thus set free in the Clackamas came from eggs obtained in the Sacramento—a matter which has, however, no bearing on the present case.

In the Kalama hatchery on the Columbia River, Washington, 2,000 fry of the quinnat or king salmon were marked in 1899 by a V-shaped notch in the caudal fin. Numerous fishes thus marked were taken in the lower Columbia in 1901 and 1902. A few were taken at the Kalama hatchery, but some also at the hatcheries on Wind River and Clackamas River. At the hatchery on Chehalis River six or seven were taken, the stream not being a tributary of the Columbia, but flowing into Shoalwater Bay. None were noticed in the Sacramento. The evidence shows that the most who are hatched in a large stream tend to return to it, and that in general, most salmon return to the parent region.

There is no evidence that a salmon hatched in one branch of a river tends to return there rather than to any other. Experiments of Messrs. Rutter and Spaulding in marking adult fish at Karluk would indicate that they roam rather widely about the island before spawning. A spawning fish set free in Karluk River was found three days later at Red River, sixty miles away on the opposite side of Kadiak Island.

The introduction of salmon into new streams may throw some light on this question. In 1897 and 1898, 3,000,000 young king salmon fry were set free in Papermill Creek near Olema, California. This is a small stream flowing into the head of Tomales Bay, and it had never previously had a run of salmon. In 1900, and especially in 1901, large quinnat salmon appeared in considerable numbers in this stream. One specimen weighing about sixteen pounds was sent to the present writer for identification. These fishes certainly returned to the parent stream, although this stream was one not at all fitted for their purpose.

But this may be accounted for by the topography of the Bay. Tomales Bay is a long and narrow channel, about twenty miles long and from one to five in width, isolated from other rivers, and with but one tributary stream. Probably the salmon had not wandered far from it; some may not have left it at all. In any event, a large number certainly came back to the same place.

That the salmon rarely go far away is fairly attested. Schools of king salmon play in Monterey Bay, and others chase the herring about in the channels of southeastern Alaska. A few years since, Captain J. F. Moser, in charge of the *Albatross,* set gill nets for salmon at various places in the sea off the Oregon and Washington coast, catching none except in the bays.

Mr. Davis gives an account of the liberation of salmon in Chinook River, which flows into the Columbia at Baker's Bay:

It is a small, sluggish stream and has never been frequented by Chinook salmon, although considerable numbers of silver and dog salmon enter it late in the fall. A few years ago the state established a hatchery on this stream, and since 1898 between 1,000,000 and 2,000,000 Chinook fry have been turned out here annually. The fish are taken from the pound-nets in Baker's Bay, towed into the river in crates and then liberated above a dike which prevents their return to the Columbia. When ripe, the salmon ascend to the hatchery, some two or three miles further up the river where they are spawned.

The superintendent of the hatchery, Mr. Nic Hansen, informs me that in 1902, during November and December, quite a number of Chinook salmon ascended the Chinook River. About 150 salmon of both sexes were taken in a trap located in the river about four miles from its mouth. At first thought it would appear that these were probably fish which, when fry, had been liberated in the river, but unfortunately there is no proof that this was the case. According to Mr. Hansen, the season of 1902 was remarkable in that the salmon ran inshore in large schools, a thing which they had not done before for years. It is possible that the fish, being forced in close to the shore, came in contact with the current from the Chinook River, which, since the stream is small and sluggish, would not be felt far from shore. Once brought under the influence of the current from the river the salmon would naturally ascend that stream, whether they had been hatched there or not.

The general conclusion, apparently warranted by the facts at hand, is that the Pacific salmon, for the most part, do not go to a great distance from the stream in which they are hatched, that most of them return to the streams of the same region, a majority to the parent stream, but that there is no evidence that they choose the parental spawning grounds in preference to any other, and none that they will prefer an undesirable stream to a favorable one for the reason that they happen to have been hatched in the former.

Mr. John C. Callbreath, of Wrangel, Alaska, has long conducted a very interesting but very costly experiment in this line. About

1890, he established himself in a small stream called Jadgeska on the west coast of Etolin Island, tributary to McHenry Inlet, Clarence Straits. This stream led from a lake, and in it a few thousand red salmon spawned, besides multitudes of silver salmon, dog salmon and humpback salmon. Making a dam across the stream, he helped the red salmon over it, destroying all the inferior kinds which entered the stream. He also established a hatchery for the red salmon, turning loose many thousand fry each year for about twelve years. This was done in the expectation that all the salmon hatched would return to Jadgeska in about four years. By destroying all individuals of other species attempting to run, it was expected that these would become extinct so far as the stream is concerned.

The result of this experiment has been disappointment. After twelve years or more there has been no increase of red salmon in the stream, and no decrease of humpbacks and other humbler forms of salmon. Mr. Callbreath draws the conclusion that salmon run at a much greater age than has been supposed—perhaps at the age of sixteen years, instead of four. A far more probable conclusion is that the salmon set free by him have joined other bands bound for more suitable streams. It is indeed claimed that since the establishment of Callbreath's hatchery on Etolin Island, there has been a notable increase of the salmon run in various streams of Prince of Wales Island on the opposite side of Clarence Straits. But this statement, while largely current among the cannerymen, and not improbable, needs verification.

We shall await with much interest the return of the millions of young salmon hatched in 1902, and turned loose in Naha stream. We may venture the prophecy that while a large percentage will return to Loring, many others will enter Yes Bay, Karta Bay, Moira Sound and other red salmon waters along the line of their return from Dixon Entrance or the open sea.

HERTZIAN WAVE WIRELESS TELEGRAPHY. VI.

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It remains then to consider some of the questions connected with practical Hertzian wave telegraphy and the problem of the limitation of communication. These matters at the present moment very much occupy the public attention, and many conflicting opinions are expressed concerning them.

It may be observed at the outset that the difficulty of dealing with the subject as freely as many desire is that Hertzian wave telegraphy is no longer merely a subject of scientific investigation, but has developed into a business and involves therefore other interests than the simple advancement of scientific knowledge. We can, however, discuss in a general manner some of the scientific problems which present themselves for solution. The first of these is the independence of communication between stations. It is desirable, at the outset, to clear up a little misunderstanding. There is a great difference between preventing the reception of communication when it is not desired by the recipient and preventing it when it is the object of the latter to overhear if he can. It is therefore necessary to distinguish between isolation and overhearing. We may say that a station is *isolated* when it is not affected by Hertzian waves other than those it desires to receive; but that a station *overhears* when it can, if it chooses, pick up communications not intended for it, or can not help receiving them against its will.

This distinction is a perfectly fair one. Any telegraph or telephone wire can be tapped, if it is desired, but unless there is some fault on the line, no station will receive a message against its desires. Moreover, it may be noted that there are penalties attaching to tapping a telegraph wire, and at present there are none connected with the misappropriation of an ether wave.

We shall therefore consider in the first place the methods so far proposed for preventing any given receiver from being affected by Hertzian waves sent out from other stations, except that of those from which it is desired to receive them. The first method is that which has been called the method of *electrical syntony,* and consists in adjusting the electrical capacity and inductance of the various open and closed circuits of the receiving and transmitting stations to be put in communication so that they have the same electrical time-period.*

In the Cantor Lectures before the Society of Arts in 1900, on electrical oscillations and electric waves, the author has discussed at length the conditions under which powerful electrical oscillations can be set up in a circuit. It was there shown that every electric circuit having capacity and inductance has a particular or natural time-period of electrical oscillation depending on the product of these qualities, and that, to accumulate powerful electrical oscillations in it, the electromotive impulses on it must be delivered at this rate. Illustrations were drawn from mechanics, such as the examples furnished by vibrating pendulums and springs, and from acoustics, as illustrated by the phenomena of resonance, to show that small or feeble blows or impulses delivered at the proper time intervals have a cumulative effect in setting up vibrations in a body capable of oscillation. It is a familiar fact that if we time our blows, we can achieve that which no single blow, however powerful, can accomplish in throwing into vibration a body such as a pendulum, which is capable of oscillation under the action of a restoring force. Precisely the same is true of an electric circuit. We have already seen that the receiving aerial has an alternating electromotive force set up in it by the impact of the successive electric waves sent out from the transmitter. It must, however, be remembered that the transmitter sends out a series of trains of waves, not by any means a continuous train, but one cut up into groups of probably ten to fifty waves, each separated by intervals of silence, long, compared with the duration of a single train of waves.

If, however, by a suitable adjustment of capacity and inductance, we make the natural time-period of oscillation of the receiving aerial circuits agree with those of the transmitting aerial, within certain limits the former will only be receptive for waves of the frequency sent out by the transmitter. It is quite easy to illustrate this principle by numerous experiments. It can be done by means of an apparatus devised by Dr. Georg Seibt for showing in an interesting manner the syntonization or tuning of two electric circuits. This consists of two bobbins, each consisting of one layer of insulated wire wound on a wooden rod (see Fig. 22). Each of these bobbins has a certain electrical capacity with respect to the earth, when considered as an insulated conductor, and it has also a certain inductance. If therefore electromotive impulses are applied to one end of the bobbin at regular intervals, electrical oscillations will be set up in it, and, as already explained, if these are

* The capacity of an electrical circuit corresponds to the elastic pliability, or what is commonly called the elasticity, of a material substance, and the inductance to mass or inertia. Hence capacity and inductance are qualities of an electric circuit which are analogous to the elasticity and inertia of such a body as a heavy spring.

timed at a certain rate, the bobbin will act like a closed organ pipe to air impulses and oscillations of potential will be accumulated at the opposite end, which have much greater amplitude than the impressed oscillations at the end at which they are applied. We can make the existence of the amplitude oscillations of potential evident by attaching to one end of the bobbin a vacuum tube, which will be illuminated thereby, or by terminating it by a pointed piece of wire, so that an electrical brush can be formed at the point, if the potential variations have sufficient amplitude. We arrange also another closed oscillation circuit consisting of two Leyden jars and a variable inductance coil and a pair of spark balls which are connected to an induction coil. In this manner we can set up oscillations in the discharge circuit of these Leyden jars, and we can vary the time period by altering the inductance and the capacity. If we denote the capacity of the jars in the microfarads by the letter C and the inductance in centimeters of the discharge circuit of the jars by the letter L, it can then be shown that the number of oscillations per second denoted by n is given by the expression:*

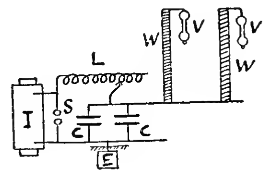


FIG. 22. SEIBT'S APPARATUS FOR EXHIBITING ELECTRIC RESONANCE. *I*, induction coil; *S*, spark gap; *CC*, condensers; *L*, variable inductance; *E*, earth plate; *WW*, wire spirals; *VV*, vacuum tubes.

$$n = \frac{5,000,000}{\sqrt{CL}}.$$

If now we adjust the Leyden jar circuit to a particular rate of oscillation, we have between the terminals of the jar or condenser an alternating difference of potential or electromotive force. If we connect one side of the jars to the earth and the other side to the foot of one of the spirals or bobbins above described, we shall find perhaps that the vacuum tube at the other end is not rendered luminous. When, however, we adjust the inductance in the discharge circuit of the jar to a certain value to make the frequency of the condenser oscillations agree with the natural time period of the bobbin terminated by the vacuum tube, this latter at once lights up brilliantly. Again, if we connect both these bobbins at the same time to the discharge circuit of the Leyden jar, we shall find that we can make an adjustment of the inductance of that circuit, such that either of the bobbins at pleasure can be made to respond and be set in electrical vibration, as shown by the illumination of the vacuum tube at its upper end or by an electrical

* See Cantor Lectures, on 'Electrical Oscillations and Electric Waves,' delivered before the Society of Arts, London, November 26, December 4, 10, 17, 1900. Lecture I., page 12, of reprint.

brush being formed at the terminal. In making this adjustment of inductance, we are *tuning,* as it is called, the Leyden jar discharge circuit to the resonating bobbin. A very small variation of the inductance of the jar circuit causes the vacuum tube to change in luminosity. If, however, the natural time periods of these bobbins do not lie very far apart, then a faint luminosity will make its appearance in both the vacuum tubes. Supposing therefore that we connect to the oscillating circuit of the jar a number of bobbins having different time-periods of oscillation, like organ-pipes, and supply them all with one common alternating electromotive force. Those bobbins whose natural time-period is very different to that of the oscillating circuit or impressed electromotive force will not respond, but those bobbins of which the natural time-period lies near to, even if not quite exactly the same as, that of the impressed electromotive force will give evidence of being set in oscillation. A very violent electromotive force will cause them all to respond to some slight extent, no matter whether the period of that impulse is tuned to their common period precisely or not.

At this point questions arise of great practical importance. A matter which has been in dispute in connection with practical Hertzian wave telegraphy is how far this electrical tuning is a sufficient solution of the practical problem of isolation. It is not denied that experiments such as those made with Seibt's apparatus can be shown on a small scale; and, on a still larger scale, Mr. Marconi gave to the author in September, 1900, a demonstration in practical telegraphic work of sending two independent Hertzian wave messages and receiving them on two independent receivers attached to the same aerial.

Since that date much experience has been gained and large power stations erected, and a statement has been frequently made that syntony is no protection against interference when one of the stations is sending out very powerful waves. The contention has been raised that large power stations producing electric waves will therefore play havoc with Hertzian wave telegraphy on a smaller scale, such as the ship to shore and intermarine communication. Under these circumstances, it appeared to the author important to subject the matter to a special test, and Mr. Marconi therefore offered to give a demonstration, with this object, in support of the opinion that he has expressed positively that waves from his power stations do not interfere with the working of his ship installations. This matter is vital to the whole question of practical Hertzian wave telegraphy, for the ship to shore communication is of stupendous importance; and if Mr. Marconi had done nothing else except render this possible and effective, he would have earned, as he has done, the gratitude of humanity for all time. Accordingly, the author embraced the opportunity of making some careful tests to settle the question, whether the powerful waves sent out from a station such as Poldhu did or did not affect the exchange of messages between ship and shore stations in proximity, equipped with Marconi apparatus of a suitable type.

These experiments were carried out on the eighteenth of March last, at Poldhu, in Cornwall, and a program was arranged by the author of the following kind. Close to the Poldhu station is an isolated mast, which was equipped by Mr. Marconi with a Hertzian wave apparatus, similar to that he places on ships. Six miles from Poldhu is the Lizard receiving station, with which ships proceeding up or down the English Channel communicate. It was arranged that a series of secret messages, some of them in cipher, should be delivered simultaneously at certain known times, both to the power station at Poldhu and to the small adjacent ship station; and it was arranged that these messages should be sent off simultaneously, the operators being kept in ignorance up to the moment of sending as to the nature of the messages. At the Lizard, Mr. Marconi connected two of his receiving instruments to the aerial, one of them tuned to the waves proceeding from the power station at Poldhu, and the other to those proceeding from the small ship station. At the appointed time, these two sets of messages were received simultaneously in the presence of the author, each message being printed down independently on its own receiver; and Mr. Marconi read off and interpreted all these messages perfectly correctly, not having known before what was the message that was about to be sent. In addition to this, precautions were taken to prove that the power station at Poldhu was really emitting waves sufficiently powerful to cross the Atlantic and not being made to sing small for the occasion. To assist in proving this, the messages sent out from the power station were also received at a station at Poole, two hundred miles away, and the assistant there was instructed to telegraph back these messages by wire as soon as he received them. These messages came back perfectly correctly, thus demonstrating that the power station was sending out power waves. The whole program was carried out with the greatest care to avoid any mistakes on the part of the assistants, and provided an absolute demonstration of the truth of Mr. Marconi's assertion that the waves from one of his power stations, such as Poldhu, do not in the least degree interfere with the transmission and reception of messages between ship and shore, effected by means of certain forms of Marconi apparatus for producing and detecting waves of a different wave length.* This complete independence of transmission, however, is entirely due to the employment of a receiving circuit of a certain type in Mr. Marconi's receivers. It does not at all follow that receiving circuit of any kind, even a Marconi receiver not especially arranged, set up in proximity to a power station would not be affected. This,

* A fuller account of these experiments was given by the author in a letter to the London *Times* published on April 14, 1903.

however, is not an important matter. Far more important is it to show, as has been shown, that practically perfect isolation can be achieved if it is desired.

It must be noted, however, that, although the fact that electric circuits have a natural time-period of oscillation of their own is a scientific principle which carries us a considerable way towards a solution of what is called syntonic Hertzian wave telegraphy, it is not in itself alone in every respect an entire solution of the practical problem. The degree to which it is a solution depends to a considerable extent upon the nature of the detecting device, or kumascope, which we are employing. The coherer, or Branly filings tube, has the peculiarity that its passage from a nonconductive to a conductive condition follows immediately when the difference of potential between its ends is made sufficiently great. In other words, if the tube is acted upon by a sufficient electromotive force, it is not necessary that electromotive force should be repeated at intervals to make this particular form of kumascope responsive. Again, if we consider the nature of the oscillations which are sent out from any transmitting aerial, we find that each group of oscillations corresponding to a single spark consists of waves gradually decreasing in amplitude. In other words, the first wave of the group is the strongest, and the decay in amplitude is often very rapid. Supposing, then, we construct a simple receiver consisting of an aerial having inserted in its circuit a sensitive Branly filings tube. Such a receiver is almost entirely non-syntonic; that is to say, it is affected by any wave passing over it which is sufficiently powerful. We may look upon it that if the first wave of the series is sufficiently powerful to affect the kumascope, the conductive change takes place whether or not the first wave is followed by others. Accordingly, it is perfectly certain that if a transmitter is sending out trains of waves of any period, a simple combination of coherer and aerial will be influenced, if it is placed near enough to the transmitter. On the other hand, it is possible to combine a kumascope of a certain type with a receiving aerial and other circuits in such a manner that when the waves that reach it are feeble it shall not respond at all unless those waves have very nearly a time period of a certain value.

At this stage, it may be perhaps well to explain a little in detail what is meant by an easily responsive circuit, and, on the other hand, by an irresponsive circuit, or, as we may call it, a *stiff* circuit. Supposing that we consider an aerial consisting of a simple straight wire having small capacity and small inductance, such a circuit admits of being sent into electrical oscillation, not only by waves of its own natural time-period, but by the sudden application of any violent electromotive impulse. If, on the other hand, we bestow upon the circuit in any way considerable inductance, we then obtain what may be called a stiff or irresponsive circuit, which is one in which electrical oscillations can be accumulated only by the prolonged action of impulses tuned to a particular period.

A mechanical analogue of this difference may be found in considering the different behavior of elastic bodies to mechanical blows. Take, for instance, a piece of elastic steel and fix the bottom end in a vise. The steel strip may be thrown into vibration by deflecting the upper end. It has, however, a very small mass, and therefore any violent blow or blows, even although not repeated, will set it in oscillation. If, however, we add mass to it by fixing at the other end a heavy weight, such as a ball of lead, and at the same time make the spring stiffer, we have an arrangement which is capable of being sent into considerable oscillation only by the action of a series of impulses or blows which are timed at a particular rate.

Returning then to the electrical problem, we see that in order to preserve a kumascope or wave detector from being operated on by any vagrant wave or waves having a period very different to an assigned period, it must be associated with an electrical circuit of the kind above called a stiff circuit.

We will now consider the manner in which the problem has been practically attacked by Mr. Marconi, Dr. Slaby, Sir Oliver Lodge and others, who have invented forms of receiver and transmitter, which are syntonic or sympathetic to one another.

Some of the methods which Mr. Marconi has devised for the achievement of syntonic wireless telegraphy were fully described by him in a paper read before the Society of Arts on May 17, 1901.*

On referring to his paper, it will be seen that in one form his transmitter consists of an aerial, near the base of which is inserted the secondary circuit of an oscillation transformer or transmitting jigger. One end of this secondary circuit is attached to the aerial and the other end is connected to the earth through a variable inductance coil. The primary circuit of this oscillation transformer is connected in series with a condenser, consisting of a battery of Leyden jars, and the two together are connected across to the spark balls which close the secondary circuit of an induction coil, having the usual make and break key in the primary circuit. Mr. Marconi so adjusts the induction of the aerial and the capacity of the condenser, or battery of Leyden jars, that the two circuits, consisting respectively of this battery of Leyden jars and the primary circuit of the transformer, and on the other hand of the capacity of the aerial and the inductance in series with it, and that of the secondary circuit of the transformer have the same time period. In other words, these two inductive circuits are tuned together. At the receiving end, the aerial is connected in series with a variable inductance and with the primary circuit of another oscillation transformer,

* See *Journal of the Society of Arts*, Vol. XLIX., p. 505. 'Syntonic Wireless Telegraphy,' by G. Marconi.

the second terminal of which is connected to the earth. The secondary circuit of this last oscillation transformer is cut in the middle and is connected to the terminals of a small condenser. The outer terminals of this secondary circuit are connected to the metallic filings tube or other sensitive receiver and to a small condenser in parallel with it (see Fig. 23). The terminals of the condenser which is inserted in the mid-

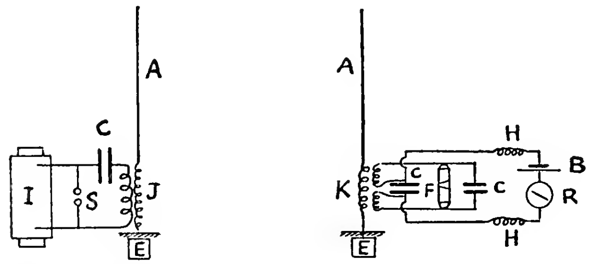


FIG. 23. MARCONI TRANSMITTER AND RECEIVER. *I*, induction coil; *A*, aerial; *E*, earth plate; *HH*, choking coils; *S*, spark gap; *J*, transmitting jigger; *K*, receiving jigger; *R*, relay *C*, condenser; *F*, filings tube; *B*, battery. Many practical details are omitted.

dle of the secondary circuit of the oscillation transformer are connected through two small inductance coils with a relay and a single cell. This relay in turn actuates a Morse printer by means of a local battery. The two circuits of the oscillation transformer are tuned or syntonized to one another, and also to the similar circuit of the transmitting arrangement. When this is the case, the transmitter affects the coresonant receiving arrangement, but will not affect any other similar arrangement, unless it is within a certain minimum range of distance. Owing to the inductance of the oscillation transformer forming part of the receiving arrangements, the receiving circuit is, as before stated, very stiff or irresponsive; the sensitive tube is therefore not acted upon in virtue merely of the impact of the single wave against the aerial, but it needs repeated or accumulated effects of a great many waves, coming in proper time, to break down the coherer and cause the recording mechanism to act. An inspection of the diagram will show that as soon as the secondary electromotive force in the small oscillation transformer or jigger of the receiving instrument is of sufficient amplitude to break down the resistance of the coherer, the local cell in circuit with the relay can send a current through it and cause the relay to act and in turn make the associated telegraphic instrument record or sound.

Mr. Marconi described in the above-mentioned paper some other arrangements for achieving the same result, but those mentioned all depend for their operation upon the construction of a receiving circuit on which the time-period of electrical oscillations is identical with that of a transmitting arrangement. By this means he showed experiments during the reading of his paper, illustrating the fact that two pairs of transmitting and receiving arrangements could be so syntonized that each receiver responded only to its particular transmitter and not to the other.

With arrangements of substantially the same nature, he made experiments in the autumn of 1900 between Niton, in the Isle of Wight, near Bournemouth, a distance of about thirty miles, in which independent messages were sent and received on the same aerial.

Dr. Slaby and Count von Arco, working in Germany, have followed very much on the same lines as Mr. Marconi, though with appliances of a somewhat different nature. As constructed by the General Electric Company, of Berlin, the Slaby-Arco syntonic system of Hertzian telegraphy is arranged in one form as follows: The transmitter consists of a vertical rod like a lightning conductor, say 100 or 150 feet in height. At a point six or nine feet above the ground, a connection is

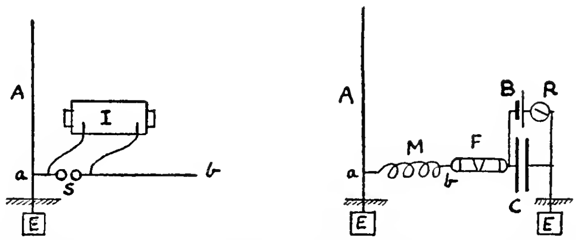


FIG. 24. SLABY-ARCO SYNTONIC TRANSMITTER AND RECEIVER. *I*, induction coil; *M*, multiplier; *B*, battery; *A*, aerial; *F*, filings tube; *R*, relay; *E*, earthplate; *C*, condenser.

made to a spark ball (see Fig. 24), and the corresponding ball is connected through a variable inductance with one terminal of a condenser, the other terminal of which is connected to the earth. The two spark balls are connected to an induction coil, or alternating current transformer, and by variation of the inductance and capacity the frequency is so arranged that the wave-length corresponding to it is equal to four times the length of that portion of the aerial which is above the spark ball connection. The method by which this tuning is achieved is to insert in the portion of the aerial below the spark balls, between it and the earth, a hot wire ammeter of some form. It has already been shown that in the case of such an earthed aerial, when electrical oscillations are set up in it, there is a potential node at the earth and a potential antinode or loop at the summit, if it is vibrating in its fundamental manner; also, there is a node of current at the summit of the aerial and an antinode at the base. This amounts to saying that the amplitude of the potential vibrations is greatest at the top end of the aerial, and the amplitude of the current vibrations is greatest at the bottom or earthed end. Accordingly, the inductance and capacity of the lateral branch of the transmitter is altered until the hot wire ammeter in the base of the aerial shows the largest possible current.

The corresponding receiver is constructed in a very similar manner.

A lightning conductor or long vertical rod of the same height as the transmitting aerial is set up at the receiving station, and at a point six or nine feet from the ground a circuit is taken off, consisting of a wire loosely coiled in a spiral, the length of which is nearly equal to, although a little shorter than, the height of the vertical wire above the point of connection. The outer end of this loose spiral is connected to one terminal of the coherer tube, and the other terminal of the coherer is connected to the earth through a condenser of rather large capacity. The terminals of this last condenser are short-circuited by a relay and a single cell. When the adjustments are properly made, it is claimed that the receiver responds only to waves coming from its own syntonized or tuned transmitter. In this case, the length of the receiving aerial above the point of junction with the coherer circuit is one quarter the length of the wave. A variation of the above arrangements consists in making this lateral circuit equal in length to one half of a wave, and connecting the coherer to its center through a condenser to the earth. The outer end of this lateral circuit is also connected to the earth (see Fig. 24).*

Dr. Slaby claims that this arrangement is not affected by atmospheric electricity, and that the complete and direct earthing of the aerial and also in the second arrangement, of the receiver of the outer end of the lateral conductor, conduces to preserve the receiver immune from any electrical disturbances except those having a period to which it is tuned.

A method has also been arranged by him for receiving on the same aerial two messages from different transmitting stations, simultaneously. In this case, two lateral wires of different lengths are connected to the receiving aerial, and to the outer end of each of these is connected a coherer tube, the other end of which is earthed through a condenser. One of these lateral wires is made equal or nearly equal in length to the aerial and the other is made longer to fulfil the following condition.† If we call H the height of the receiving aerial above point of junction of the lateral wires, then the length of one lateral wire is made equal to H, and the height of the aerial is adjusted to be equal to one quarter of the wave-length of one incident wave. The other lateral wire may then be made of a length equal to one third of H and it will then respond to the first odd harmonic of that wave, of which the fundamental is in syntony with the vertical wire. By suitably choosing the relation between the wave lengths of the two transmitting stations, it is possible to receive in this manner two different

* See German Patent Specifications, Class 21a, No. 7,452 of 1900 and also No. 8,087 of 1901.

† See German Patent Specification, Class 21a, No. 7,498 of 1900, applied for November 9, 1900. The above-mentioned patent is subsequent in date to Mr. Marconi's experiments on the same subject.

messages at the same time on the same aerial. Subsequently to the date of the above-mentioned demonstration of multiplex wireless telegraphy by Mr. Marconi, an exhibition of a similar nature was given by Professor Slaby in a lecture given in Berlin on December 22, 1900.*

Both the above described syntonic systems of Mr. Marconi and Dr. Slaby are 'earthed' systems, but arrangements for syntonic telegraphy have been devised by Sir Oliver Lodge and Professor Braun, which are 'non-earthed.'

Sir Oliver Lodge and Dr. Muirhead have devised also syntonic systems. According to their last methods, the syntonic transmitting and receiving arrangements are as shown in Fig. 25.† On examining the

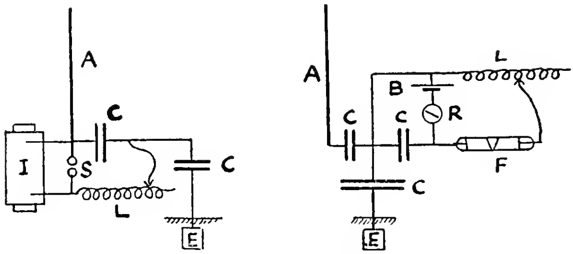


FIG. 25. LODGE-MUIRHEAD SYNTONIC RECEIVER. *I*, induction coil; *S*, spark gap; *A*, aerial; *C*, *C*, condensers; *E*, earth plate; *R*, relay; *L*, variable inductance; *F*, filings tube; *B*, battery.

diagrams, it will be seen that the secondary terminals of the induction coil are, as usual, connected to a pair of spark balls, and that these spark balls are connected by a condenser and by a variable inductance. One terminal of the condenser is earthed through another condenser of large capacity, and the remaining terminal of the first condenser is connected to an aerial. It should therefore be borne in mind in dealing with electrical oscillations that a condenser of sufficient capacity is practically a conductor, and an inductance coil of sufficient inductance is practically a non-conductor. Hence the insertion of a large capacity in the path of the aerial wire is no advantage whatever and makes no essential difference in the arrangement. In order to obtain any powerful radiation, the length of the aerial or sky wire, as they call it, must be so adjusted that its length is one quarter the wave length corresponding to the oscillation circuit, consisting of the condenser and variable inductance.

The receiving arrangement consists of a similar sky wire or aerial earthed through a condenser of large capacity and having in the portion above this last condenser another condenser of similar capacity. At the earthed side of this last condenser a connection is made to a resonant circuit, consisting of a variable inductance, and another con-

* See *Electrician*, January 18, 1900, Vol. XLVI., p. 475. Also reprint of a paper of Professor A. Slaby, 'Abgestimmte und mehrfache Funkentelegraphie.'

† See British Specification, No. 11,348 of 1901.

denser and a sensitive metallic filings tube of the Branly type; also a portion of this resonant circuit is shunted by another consisting of a battery and telegraphic relay, as shown in the diagram. The circuit, including the coherer, is tuned to its own aerial and also to that of the transmitting circuit, and under these circumstances trains of waves thrown off at the transmitting aerial will sympathetically affect the receiving aerial.

There is nothing in the arrangement which specially calls for notice. It is simply a variation of other known forms of syntonic transmitter and receiver, and possesses all the advantages and disadvantages attaching to such electrical syntonic methods.

Professor Braun's syntonic system, the receiver and transmitter of which have been described, is also in one form a non-earthed system. Innumerable other patentees have taken out patents for devices which are modifications in small degree of the above arrangements.

It may be well to note at this point the disadvantages that are possessed by any form of coherer as a telegraphic kumascope in connection with proposed arrangements for the isolation of Hertzian wave stations. All the detectors of the coherer type really depend for their actuation upon electromotive force; that is to say, upon the application to the terminals of the detector of a certain electromotive force. Although there may be no sharp and defined critical electromotive force, yet, nevertheless, as a matter of fact, if the electromotive force applied exceeds a certain value, then the detector passes suddenly from one state of conductivity to another. It may be of great conductivity, as in the case of the Branly coherer, or of lesser conductivity, as in the case of the so-called anticoherers, of which the Schäfer kumascope may be taken as a type. Accordingly, when these instruments are subjected to a train of waves, each individual group of which is damped, their operation is largely governed by the fact that if the first wave or oscillation set up in the receiving circuit is powerful enough to break down the coherer, then the receiving mechanism acts, no matter whether the first impulse is followed by others or not.

In comparison with so-called coherers, those depending upon the changes in the magnetization of iron by electrical oscillations certainly have an advantage, because this is a process which requires the application of alternating electric currents decreasing in strength for a certain time; and it is found therefore that the magnetic receivers do not require to be associated with such a stiff or irresponsive resonant circuit to confine their indications to oscillations or waves of one definite period, and that they lend themselves much more perfectly to the work of 'tuning' or syntonizing stations than do those kumascopes depending upon the contact or coherer principle.

We may then glance at the alternative solutions of the problem offered by other investigators. M. Blondel has proposed to effect the syntonization of two stations, not by syntonizing the receiver for the exceedingly high frequency oscillations of the individual electric waves, but to syntonize it for the much lower frequency, corresponding to that of the intervals between the groups of waves. Thus, for instance, if an ordinary simple transmitting aerial is set up, the production of sparks between the spark balls results in the emission of short trains of waves, each of which may consist of half a dozen or more individual waves, the time of production of the whole group being very small compared with the interval between the groups. M. Blondel proposes, however, to syntonize the receiver, not for the high frequency period of the waves themselves, which may be reckoned in millions per second, but for the low frequency period between the groups of waves, which is reckoned in hundreds per second. Thus, for instance, if sparks are made at the rate of fifty or a hundred per second, they can be made to actuate the telephone receiver and so produce in the telephone a sound corresponding to a frequency of 50 or 100. In other words, to make a low musical note or hum. This continuous sound can be cut up, by means of a key placed in the primary circuit of the transmitting arrangement, into long or short periods, and hence the letters of the alphabet signal.

M. Blondel's arrangements comprise a Mercadier's monotone telephone and either a coherer or a particular form of vacuum tube as a kumascope. On August 16, 1898, M. Blondel deposited with the Academy of Sciences in Paris a sealed envelope containing a description of his improvements in syntonic wireless telegraphy, which was opened on May 19, 1900.* The arrangement of the receiving apparatus was as follows: A single battery cell keeps a condenser charged until the kumascope is rendered conductive by the oscillations coming down the aerial; and under these circumstances the condenser discharges through the telephone and causes a tick to be heard in it. If the trains of waves are at the rate of 50 or 100 per second, these small sounds run together into a musical note, and this continuous hum can be cut up into long and short spaces, in accordance with the Morse alphabet signals. The telephone must not be an ordinary telephone, capable of being influenced by any frequency, but be one which responds only to a particular note, and under these conditions the receiving arrangement is receptive only when the trains of waves arrive at certain regular predetermined intervals, corresponding with the tone to which the telephone is sensitive.

* See *Comptes Rendus,* May 21, 1900; *Rapports du Congrès International d'Electricité,* Paris, 1900, p. 341.

THE BRIGHT SIDE OF RUSSIAN IMMIGRATION.

By Dr. ALLAN McLAUGHLIN,

U. S. PUBLIC HEALTH AND MARINE-HOSPITAL SERVICE.

A LARGE proportion of the immigrants giving Russia as their birthplace crowd into the tenements of the east side of New York City and furnish operatives for the sweat shops and material for all the charitable organizations in the city.

These immigrants are so prominently in the public eye that we hear a great deal about the alarming and deplorable increase in Russian immigration. The casual newspaper reader does not find out that from Russia we receive five distinct racial elements and that only one of the five races tends to congregate in New York City, the other four being distributed among the mines, farms and factories in nearly every state in the union. So much is published about the sweat shop and the tenement that the reader is apt to lose sight of the fact that we receive a great many very desirable immigrants from Russia.

Fifty years ago the question of what constituted a desirable immigrant was a vexed one and many claimed that no such thing as a desirable immigrant existed. Time has modified the views of the extremist and proved that an immigrant with a good physique, willing to work and obey the law, has a definite economic value. This is especially true if he is between the ages of fifteen and forty-five years and is an unskilled laborer. Three races stand out preeminently among the races of Russia as furnishing a very large proportion of desirable immigrants. They are the Russian-German, Lithuanian and Finn.

The following table shows the immigration from Russia during 1902, arranged by races, and shows the relative standing of these races in some of the essential factors of desirability:

Race.	Number Landed.	Per Cent. Between Ages of 14 and 45.	Per Cent. Unskilled Laborers.	Per Cent. Remaining in New York.
Russian-German	8,542	75	90	5
Finn.......................	13,854	90	86	12
Lithuanian	9,975	91	86	15
Pole.........................	33,859	88	82	20
Hebrew	37,846	67	13	68

Russian-Germans.

The term 'Russian-German' sounds paradoxical, but it in reality describes the racial status of this people more accurately than any other designation.

Germans have been landlords in the Russian Baltic provinces since the days of the old German order of crusaders, The Sword Brothers of Livonia. German artisans were imported and enjoyed the favor of the Great Peter, and German farmers took advantage of the breaking up of the large Polish estates after the insurrection of 1863 to establish themselves upon much of the best farming land in Poland. But none of these different divisions of the German race in Russia concerns us in our consideration of the Russian-German immigrant. He has a history entirely his own and has no more connection with other isolated colonies of Germans in Russia than he has with the Russian, from whom he holds himself religiously aloof.

Anne, daughter of Peter the Great, married the Duke of Holstein Gottorp, a German prince, and their son, who was crowned Peter III., was thus half German. Peter III. married a German princess, Sophia, of Anhalt Zerbst, who later deposed him and became sole ruler of the country, taking the name of Catherine II. The Ukraine, or country north of the Black Sea, which was the most fertile part of Russia, had never been consistently cultivated. This magnificent 'black mold belt,' one of the finest wheat-raising regions in the world, could only be kept from the Tartar hordes by the employment of the Cossacks as a protection. The Cossacks effectually prevented further Tartar raids, but were not farmers; and to develop this fine country Catherine offered special inducements to German settlers.

These inducements included the use of their own schools and the practise of their own religion, exemption from military service and some other special privileges. Many Germans took advantage of their countrywoman's liberal offer. As a result there are to-day in southern Russia in the governments immediately north of the Black Sea thousands of Germans who speak only German, who are in religion Lutherans and who are by far the most prosperous agricultural class in Russia.

The present Tsar has withdrawn the privileges granted by the Empress Catherine, has sought to replace the German schools by Russian, and the Lutheran religion by the Greek orthodox church; but he has only succeeded in exiling from Russia thousands of these German farmers, who come as immigrants to America with the proceeds of their Russian farms in their pockets and the courage of the pioneer in their hearts.

The Finns.

The Finns belong to the Ugro-Finnic or Uralo-Altaic stock and are akin to the Magyar and Laplander. About a dozen different tribes of this Ugro-Finnic stock are recognized; they are scattered over northern and central Russia and Siberia.

It must be remembered that the classification of Finnic peoples is made from a philological view-point, without regard to the influence great or slight which surrounding races may have exerted on the racial type. Otherwise it would often be hard to believe that the Finnish immigrant was of the same race as the Lapp, Magyar or Volga Finn.

The Finns are said to have lived on the Volga in the seventh century and to have been driven north in the eighth century to their present home. They were conquered and christianized in the twelfth century by the Swedes, who occupied and ruled the country for more than five hundred years. In the wars between Sweden and Russia, Finland was often the battleground, and finally by treaty in 1809 Sweden ceded the grand duchy of Finland to Russia.

The Finnish constitution of 1772 afforded ample protection to the liberties of the people. It insured practical autonomy in internal affairs and provided that the Finnish army could not be required to serve outside of Finland. Alexander I. guaranteed to Finland the preservation of its laws, constitution and religion, and this pledge has been renewed by each succeeding ruler, including the present Tsar, Nicholas II., who however has broken his pledge. The condition of the Finns under their own constitution has been much better than that of any other subjects of the Tsar. Serfdom never existed in their country and five ninths of the land was owned by peasants. The policy of Russianization pursued by Tsar Nicholas II. since 1898 has practically set aside the constitution and reduced the grand duchy of Finland to the status of an ordinary Russian province.

Since 1863 Russia has attempted to eliminate Swedish influence by fostering the growth of the native language and literature. Now, however, the Finnish language is placed under the ban and the removal of high officials of Finland's educational system and the substitution of Russians in their places at Helsingfors and other educational centers may be considered an indication of the coming suppression of the Finnish language in the schools.

The majority of our Finnish immigrants come from near the coast, and in this locality the Swedish influence upon the people is shown most markedly by the frequent great variation from the recognized Finnish type. It is difficult in some cases to differentiate them from the Swedes and it is rare to find among these immigrants the broad head, flat features, yellow skin, obliquely set eyes, or other characteristics of the Ugro-Finnic type. They are tall and well proportioned, sometimes with fair complexions, sometimes with a queer combination of the characteristics of Finn and Swede. Eighty per cent. of the Finns are engaged in agricultural pursuits. They are honest, industrious and energetic; and it is a very rare occurrence to find an illiterate Finn.

Lithuanians.

The Lithuanian people, according to their traditions and the researches of some eminent ethnologists, were probably the first of the Aryan race to settle in Europe. Their first European home seems to have been in the valley of the Danube in the country now known as Bulgaria. The valley of the Danube was the natural highway of invasion used by the fierce Asiatic tribes in their incursions westward. Wars of the Romans against the Dacians and successive invasions of Goth and Hun forced the Lithuanians to seek a new home out of the path of invasion and conflict.

They migrated northward, probably during the third and fourth centuries, and following the valley of the Vistula spread out over territory extending from the mouth of the Vistula to the shore of Lake Peipus and southward to the great marshes of Pinsk. Their early history is necessarily hazy, depending upon tradition and scientific deduction. From the tenth century their history is fairly clear and about this time we find the Lithuanian nation divided into three main branches, viz., Borussians, Letts and Samoghitians.

The Borussians, who occupied territory in the vicinity of Königsberg, East Prussia, soon fell under German influence and lost their political existence, leaving only their name corrupted into Prussia.

The Letts occupied the country now known as the Baltic provinces of Russia. They mixed with and dominated the Livs and Esths (Finnish tribes occupying Livonia and Esthonia) and with these tribes became subject to a German religious order with a military organization known as the Sword Brothers of Livonia.

The Samoghitians, or Lithuanians proper, occupied territory south of the Baltic provinces. There they formed an independent state and resisted successfully all efforts of German crusader, Slav and Tartar to subjugate them. In the fourteenth century the king of Lithuania ruled the country occupied to-day by Poles, Lithuanians and white Russians. In 1386 Yagello, king of Lithuania, married Yadviga, queen of Poland, was baptized into the Latin church and crowned king of Poland. Lithuania during this reign reached the zenith of her power and extended her dominions to the River Moskwa on the east and to the Black Sea on the south. The union with Poland was nominal at this time, but a real union took place in 1569 when, by the treaty of Lublin, Lithuania ceased to exist politically. From that time to the present the history of Lithuania has been that of Poland.

The absorption of the Livs and other Finnish elements by the Letts has made that branch of the Lithuanian race more or less of a mixed type. The Borussians, or Lithuanians of Prussia, rarely emigrate.

The uninviting nature of the country occupied by the Samoghitians or Lithuanians proper and its inaccessibility, owing to vast tracts of marsh and forest land, helped to preserve the racial characteristics, and the Samoghitian is to-day a distinct type bearing no resemblance to surrounding races. A typical Lithuanian has the features of a Greek and the complexion of a Norseman. They are tall and splendidly proportioned, towering over their Slavic neighbors. The stature and fine physique of the Russian Imperial Guard are due to the fact that it is recruited almost entirely in the Lithuanian provinces. Their fair complexion, long face and clear-cut features make them readily distinguishable from the Slavs, whose squat figures and wide faces are accentuated by the contrast. Their language is very old and primitive and is said to resemble Sanskrit so closely that Lithuanian peasants can understand Sanskrit phrases. Their written literature is very scanty, but their unwritten popular folk-lore is rich in idyllic and lyric songs and poetry of a pastoral variety and melancholy tone. They are very proud of their ancestry and resent being considered Slavs. They claim with pride that most of Poland's great men, Kosciusko, Chodkiewicz, Sienkewicz and others were Lithuanians. Their occupation is agriculture. The land owners have always been Polish or German and business is carried on by Jews and Germans.

Few words are necessary to convince one of the desirability of the Russian-German. He has the industry, thrift and sterling honesty that have made his brother Germans from the Fatherland welcome and successful in this country. He is a picturesque figure clad in sheepskin garments, which add to his appearance of splendid physique. He represents the best type of the agricultural immigrant who comes here to make a home in the far west with the necessary money in his pocket to buy land and give him his start.

The Finns are also an agricultural or pastoral people, and if they possess less money than the Russian-Germans their sturdy physique and willingness to work make their success certain in this country. They work on farms in the northern central states and have been valuable as laborers in the development of the mines of northern Michigan and Wisconsin. The ability of the Finns to withstand the rigors of a northern climate, and their well-known thrift and industry, have suggested the possibility of their being valuable in the agricultural and mining development of Alaska. A colony of Finns in Canada has been very successful in wheat raising on the shores of Great Slave Lake, a latitude once considered scarcely habitable for white men.

The Lithuanians are also agricultural or pastoral in occupation, but in this country are largely employed as laborers in the mines of Pennsylvania and other mining states. Their rugged physique fits them for this rough work, and so long as the industrial demand for unskilled labor keeps up so long will the Lithuanian be valuable as the best type of this class of immigrants.

A careful study of the statistics of immigration and of economic and social conditions in this country will convince any one that there is little to fear from such races as the Russian-German, Finn and Lithuanian properly inspected under our present laws; and that future legislation aiming to cut down the number of undesirable immigrants must be directed toward debarring the competitive and parasitic classes which now crowd our great cities.

THE INFLUENCE OF BRAIN-POWER ON HISTORY.

By Sir NORMAN LOCKYER,
ROYAL COLLEGE OF SCIENCE.

SOME years ago, in discussing the relations of scientific instruction to our industries, Huxley pointed out that we were in presence of a new 'struggle for existence,' a struggle which, once commenced must go on until only the fittest survives.

It is a struggle between organized species—nations—not between individuals or any class of individuals. It is, moreover, a struggle in which science and brains take the place of swords and sinews, on which depended the result of those conflicts which, up to the present, have determined the history and fate of nations. The school, the university, the laboratory and the workshop are the battlefields of this new warfare.

But it is evident that if this, or anything like it, be true, our industries can not be involved alone; the scientific spirit, brain-power, must not be limited to the workshop if other nations utilize it in all branches of their administration and executive.

It is a question of an important change of front. It is a question of finding a new basis of stability for the Empire in face of new conditions. I am certain that those familiar with the present states of things will acknowledge that the Prince of Wales's call, 'Wake up,' applies quite as much to the members of the government as it does to the leaders of industry.

What is wanted is a complete organization of the resources of the nation, so as to enable it best to face all the new problems which the progress of science, combined with the ebb and flow of population and other factors in international competition, are ever bringing before us. Every minister, every public department, is involved, and this being so, it is the duty of the whole nation—king, lords and commons—to do what is necessary to place our scientific institutions on a proper footing in order to enable us to 'face the music' whatever the future may bring. The idea that science is useful only to our industries comes from want of thought. If any one is under the impression that Britain is only suffering at present from the want of the scientific spirit among our industrial classes, and that those employed in the state service possess adequate brain-power and grip of the conditions

* From the address of the president of the British Association for the Advancement of Science, Southport, 1903.

of the modern world into which science so largely enters, let him read the report of the Royal Commission on the War in South Africa. There he will see how the whole 'system' employed was, in Sir Henry Brackenbury's words applied to a part of it, '*unsuited to the requirements of an Army which is maintained to enable us to make war.*' Let him read also, in the address of the president of the Society of Chemical Industry, what drastic steps had to be taken by Chambers of Commerce and 'a quarter of a million of working men' to get the Patent Law Amendment Act into proper shape, in spite of all the advisers and officials of the Board of Trade. Very few people realize the immense number of scientific problems the solution of which is required for the state service. The nation itself is a gigantic workshop, and the more our rulers and legislators, administrators and executive officers possess the scientific spirit, the more the rule of thumb is replaced in the state service by scientific methods, the more able shall we be, thus armed at all points, to compete successfully with other countries along all lines of national as well as of commercial activity.

It is obvious that the power of a nation for war, in men and arms and ships, is one thing; its power in the peace struggles to which I have referred is another; in the latter, the source and standard of national efficiency are entirely changed. To meet war conditions, there must be equality or superiority in battleships and army corps. To meet the new peace conditions there must be equality or superiority in universities, scientific organizations and everything which conduces to greater brain-power.

The present condition of the nation, so far as its industries are concerned, is as well known, not only to the Prime Minister, but to other political leaders in and out of the Cabinet, as it is to you and to me. Let me refer to two speeches delivered by Lord Rosebery and Mr. Chamberlain on two successive days in January, 1901:

Lord Rosebery spoke as follows:

> . . . The war I regard with apprehension is the war of trade which is unmistakably upon us. . . . When I look round me I cannot blind my eyes to the fact that so far as we can predict anything of the twentieth century on which we have now entered, it is that it will be one of acutest international conflict in point of trade. We were the first nation of the modern world to discover that trade was an absolute necessity. For that we were nicknamed a nation of shopkeepers; but now every nation wishes to be a nation of shopkeepers, too, and I am bound to say that when we look at the character of some of these nations, and when we look at the intelligence of their preparations, we may well feel that it behooves us not to fear, but to gird up our loins in preparation for what is before us.

Mr. Chamberlain's views were stated in the following words:

> I do not think it is necessary for me to say anything as to the urgency and necessity of scientific training. . . . It is not too much to say that the

existence of this country, as the great commercial nation, depends upon it. . . . It depends very much upon what we are doing now, at the beginning of the twentieth century, whether at its end we shall continue to maintain our supremacy or even equality with our great commercial and manufacturing rivals.

All this refers to our industries. We are not suffering because trade no longer follows the flag as in the old days, but because trade follows the brains, and our manufacturers are too apt to be careless in securing them. In one chemical establishment in Germany, 400 doctors of science, the best the universities there can turn out, have been employed at different times in late years. In the United States the most successful students in the higher teaching centers are snapped up the moment they have finished their course of training, and put into charge of large concerns, so that the idea has got abroad that youth is the password of success in American industry. It has been forgotten that the latest product of the highest scientific education must necessarily be young, and that it is the training and not the age which determines his employment. In Britain, on the other hand, apprentices who can pay high premiums are too often preferred to those who are well educated, and the old rule-of-thumb processes are preferred to new developments—a conservatism too often depending upon the master's own want of knowledge.

I should not be doing my duty if I did not point out that the defeat of our industries one after another, concerning which both Lord Rosebery and Mr. Chamberlain express their anxiety, is by no means the only thing we have to consider. The matter is not one which concerns our industrial classes only, for knowledge must be pursued for its own sake, and since the full life of a nation with a constantly increasing complexity, not only of industrial, but of high national aims, depends upon the universal presence of the scientific spirit—in other words, brain power—our whole national life is involved.

The present awakening in relation to the nation's real needs is largely due to the warnings of men of science. But Mr. Balfour's terrible Manchester picture of our present educational condition * shows that the warning which has been going on now for more than fifty years has not been forcible enough; but if my contention that other reorganizations besides that of our education are needed is well founded, and if men of science are to act the part of good citizens in taking their share in endeavoring to bring about a better state of things, the question arises, has the neglect of their warnings so far been due to the way in which these have been given?

* "The existing educational system of this country is chaotic, is ineffectual, is utterly behind the age, makes us the laughing-stock of every advanced nation in Europe and America, puts us behind, not only our American cousins, but the German and the Frenchman and the Italian."—*Times*, October 15, 1902.

Lord Rosebery, in the address to a Chamber of Commerce from which I have already quoted, expressed his opinion that such bodies do not exercise so much influence as might be expected of them. But if commercial men do not use all the power their organization provides, do they not by having built up such an organization put us students of science to shame, who are still the most disorganized members of the community?

Here, in my opinion, we have the real reason why the scientific needs of the nation fail to command the attention either of the public or of successive governments. At present, appeals on this or on that behalf are the appeals of individuals; science has no collective voice on the larger national questions; there is no organized body which formulates her demands.

During many years it has been part of my duty to consider such matters, and I have been driven to the conclusion that our great crying need is to bring about an organization of men of science and all interested in science, similar to those which prove so effective in other branches of human activity. For the last few years I have dreamt of a Chamber, Guild, League, call it what you will, with a wide and large membership, which should give us what, in my opinion, is so urgently needed. Quite recently I sketched out such an organization, but what was my astonishment to find that I had been forestalled, and by the founders of the British Association!

At the commencement of this address I pointed out that one of the objects of the Association, as stated by its founders, was 'to obtain a more general attention to the objects of science and a removal of any disadvantages of a public kind which impede its progress.'

Every one connected with the British Association from its beginning may be congratulated upon the magnificent way in which the other objects of the Association have been carried out, but as one familiar with the Association for the last forty years, I can not but think that the object to which I have specially referred has been too much overshadowed by the work done in connection with the others.

A careful study of the early history of the association leads me to the belief that the function I am now dwelling on was strongly in the minds of the founders; but be this as it may, let me point out how admirably the organization is framed to enable men of science to influence public opinion and so to bring pressure to bear upon governments which follow public opinion. (1) Unlike all the other chief metropolitan societies, its outlook is not limited to any branch or branches of science. (2) We have a wide and numerous fellowship, including both the leaders and the lovers of science, in which all branches of science are and always have been included with the utmost catholicity—a condition which renders strong committees possible on any subject. (3) An annual meeting at a time when people can pay attention to the deliberations, and when the newspapers can print reports. (4) The possibility of beating up recruits and establishing local committees in different localities, even in the King's dominions beyond the seas, since the place of meeting changes from year to year, and is not limited to these islands.

We not only, then, have a scientific parliament competent to deal with all matters, including those of national importance, relating to science, but machinery for influencing all new councils and committees dealing with local matters, the functions of which are daily becoming more important.

The machinery might consist of our corresponding societies. We already have affiliated to us seventy societies with a membership of 25,000; were this number increased so as to include every scientific society in the Empire, metropolitan and provincial, we might eventually hope for a membership of half a million.

I am glad to know that the Council is fully alive to the importance of giving impetus to the work of the corresponding societies. During this year a committee was appointed to deal with the question; and later still, after this committee had reported, a conference was held between this committee and the corresponding societies committee to consider the suggestions made, some of which will be gathered from the following extract:

In view of the increasing importance of science to the nation at large, your committee desire to call the attention of the council to the fact that in the corresponding societies the British Association has gathered in the various centers represented by these societies practically all the scientific activity of the provinces. The number of members and associates at present on the list of the corresponding societies approaches 25,000, and no organization is in existence anywhere in the country better adapted than the British Association for stimulating, encouraging and coordinating all the work being carried on by the seventy societies at present enrolled. Your committee are of opinion that further encouragement should be given to these societies and their individual working members by every means within the power of the association; and with the object of keeping the corresponding societies in more permanent touch with the association they suggest that an official invitation on behalf of the council be addressed to the societies through the corresponding societies committee asking them to appoint standing British Association sub-committees, to be elected by themselves with the object of dealing with all those subjects of investigation common to their societies and to the British Association committees, and to look after the general interests of science and scientific education throughout the provinces and provincial centers. . . .

Your committee desire to lay special emphasis on the necessity for the extension of the scientific activity of the corresponding societies and the expert knowledge of many of their members in the direction of scientific education. They are of opinion that immense benefit would accrue to the country if the corresponding societies would keep this requirement especially in view with the object of securing adequate representation for scientific education on the education committees now being appointed under the new Act. The educational section of the association having been but recently added, the corresponding societies have as yet not had much opportunity for taking part in this branch of the association's work; and in view of the reorganization in education now going on all over the country your committee are of opinion that no more opportune time is likely to occur for the influence of scientific organizations to make itself felt as a real factor in national education. . . .

I believe that if these suggestions or anything like them—for some better way may be found on inquiry—are accepted, great good of science throughout the Empire will come. Rest assured that sooner or later such a guild will be formed because it is needed. It is for you to say whether it shall be, or form part of, the British Association. We in this Empire certainly need to organize science as much as in Germany they find the need to organize a navy. The German Navy League, which has branches even in our Colonies, already has a membership of 630,000, and its income is nearly 20,000*l.* a year. A British Science League of 500,000 with a sixpenny subscription would give us 12,000*l*, a year, quite enough to begin with.

I for one believe that the British Association would be a vast gainer by such an expansion of one of its existing functions. Increased authority and prestige would follow its increased utility. The meetings would possess a new interest; there would be new subjects for reports; missionary work less needed than formerly would be replaced by efforts much more suited to the real wants of the time. This magnificent, strong and complicated organization would become a living force, working throughout the year, instead of practically lying idle, useless and rusting for 51 weeks out of the 52 so far as its close association with its members is concerned.

If this suggestion in any way commends itself to you, then when you begin your work in your sections or general committee see to it that a body is appointed to inquire how the thing can be done. Remember that the British Association will be as much weakened by the creation of a new body to do the work I have shown to have been in the minds of its founders as I believe it will be strengthened by becoming completely effective in every one of the directions they indicated, and for which effectiveness we their successors are indeed responsible. The time is appropriate for such a reinforcement of one of the wings of our organization, for we have recently included education among our sections.

There is another matter I should like to see referred to the committee I have spoken of, if it please you to appoint it. The British Association, which as I have already pointed out is now the chief body in the Empire which deals with the totality of science, is, I believe, the only organization of any consequence which is without a charter, and which has not His Majesty the King as patron.

I suppose it is my duty after I have suggested the need of organization to tell you my personal opinion as to the matters where we suffer most in consequence of our lack of organization at the present time.

Our position as a nation, our success as merchants, are in peril chiefly—dealing with preventable causes—because of our lack of completely efficient universities, and our neglect of research. This research has a double end. A professor who is not learning can not teach properly or arouse enthusiasm in his students; while a student of anything who is unfamiliar with research methods, and without that training which research brings, will not be in the best position to apply his knowledge in after life. From neglect of research come imperfect education and a small output of new applications and new knowledge to reinvigorate our industries. From imperfect education come the unconcern touching scientific matters, and the too frequent absence of the scientific spirit, in the nation generally from the court to the parish council.

I propose to deal as briefly as I can with each of these points.

I have shown that so far as our industries are concerned, the cause of our failure has been run to earth; it is fully recognized that it arises from the insufficiency of our universities both in numbers and efficiency, so that not only our captains of industry, but those employed on the nation's work generally, do not secure a training similar to that afforded by other nations. No additional endowment of primary, secondary or technical instruction will mend matters. This is not merely the opinion of men of science; our great towns know it, our ministers know it.

It is sufficient for me to quote Mr. Chamberlain:

> It is not every one who can, by any possibility, go forward into the higher spheres of education; but it is from those who do that we have to look for the men who, in the future, will carry high the flag of this country in commercial, scientific and economic competition with other nations. At the present moment, I believe there is nothing more important than to supply the deficiencies which separate us from those with whom we are in the closest competition. In Germany, in America, in our own colony of Canada and in Australia, the higher education of the people has more support from the government, is carried further, than it is here in the old country; and the result is that in every profession, in every industry, you find the places taken by men and by women who have had a university education. And I would like to see the time in this country when no man should have a chance for any occupation of the better kind, either in our factories, our workshops or our counting-houses, who could not show proof that, in the course of his university career, he had deserved the position that was offered to him. What is it that makes a country? Of course you may say, and you would be quite right, 'The general qualities of the people, their resolution, their intelligence, their pertinacity, and many other good qualities.' Yes; but that is not all, and it is not the main creative feature of a great nation. The greatness of a nation is made by its greatest men. It is those we want to educate. It is to those who are able to go, it may be, from

the very lowest steps in the ladder, to men who are able to devote their time to higher education, that we have to look to continue the position which we now occupy as, at all events, one of the greatest nations on the face of the earth. And, feeling as I do on these subjects, you will not be surprised if I say that I think the time is coming when governments will give more attention to this matter, and perhaps find a little more money to forward its interests (*Times*, November 6, 1902).

Our conception of a university has changed. University education is no longer regarded as a luxury of the rich which concerns only those who can afford to pay heavily for it. The Prime Minister in a recent speech, while properly pointing out that the collective effect of our public and secondary schools upon British character can not be overrated, frankly acknowledged that the boys of seventeen or eighteen who have to be educated in them 'do not care a farthing about the world they live in except in so far as it concerns the cricket-field or the football-field or the river.' On this ground they are not to be taught science, and hence, when they proceed to the university, their curriculum is limited to subjects which were better taught before the modern world existed, or even Galileo was born. But the science which these young gentlemen neglect, with the full approval of their teachers, on their way through the school and the university to politics, the civil service or the management of commercial concerns, is now one of the great necessities of a nation, and our universities must become as much the insurers of the future progress as battleships are the insurers of the present power of states. In other words, university competition between states is now as potent as competition in building battleships, and it is on this ground that our university conditions become of the highest national concern and, therefore, have to be referred to here, and all the more because our industries are not alone in question.

Chief among the causes which have brought us to the terrible condition of inferiority as compared with other nations in which we find ourselves are our carelessness in the matter of education and our false notions of the limitations of state functions in relation to the conditions of modern civilization.

Time was when the navy was largely a matter of private and local effort. William the Conqueror gave privileges to the Cinque Ports on the condition that they furnished fifty-two ships when wanted. In the time of Edward III., of 730 sail engaged in the siege of Calais, 705 were 'people's ships.' All this has passed away; for our first line of defense we no longer depend on private and local effort.

Time was when not a penny was spent by the state on elementary education. Again, we no longer depend upon private and local effort. The navy and primary education are now recognized as properly calling upon the public for the necessary financial support. But when we pass from primary to university education, instead of state endowment we find state neglect; we are in a region where it is nobody's business to see that anything is done.

We in Great Britain have thirteen universities competing with 134 state and privately endowed in the United States and 22 state endowed in Germany. I leave other countries out of consideration for lack of time, and I omit all reference to higher institutions for technical training, of which Germany alone possesses nine of university rank, because they are less important; they instruct rather than educate, and our want is education. The German State gives to one university more than the British Government allows to all the universities and university colleges in England, Ireland, Scotland and Wales put together. These are the conditions which regulate the production of brain-power in the United States, Germany and Britain respectively, and the excuse of the government is that this is a matter for private effort. Do not our Ministers of State know that other civilized countries grant efficient state aid, and further, that private effort has provided in Great Britain less than 10 per cent. of the sum thus furnished in the United States in addition to state aid? Are they content that we should go under in the great struggle of the modern world because the ministers of other states are wiser, and because the individual citizens of another country are more generous, than our own?

If we grant that there was some excuse for the state's neglect so long as the higher teaching dealt only with words, and books alone had to be provided (for the streets of London and Paris have been used as class rooms at a pinch), it must not be forgotten that during the last hundred years not only has knowledge been enormously increased, but things have replaced words, and fully equipped laboratories must take the place of books and class rooms if university training worthy of the name is to be provided. There is much more difference in size and kind between an old and a new university than there is between the old caravel and a modern battleship, and the endowments must follow suit.

What are the facts relating to private endowment in this country? In spite of the munificence displayed by a small number of individuals in some localities, the truth must be spoken. In depending in our country upon this form of endowment, we are trusting to a broken reed. If we take the twelve English university colleges, the forerunners of universities unless we are to perish from lack of knowledge, we find that private effort during sixty years has found less than 4,000,000*l.*, that is, 2,000,000*l.* for buildings and 40,000*l.* a year income. This gives us an average of 166,000*l.* for buildings and 3,300*l.* for yearly income.

What is the scale of private effort we have to compete with in regard to the American universities?

In the United States, during the last few years, universities and colleges have received more than 40,000,000*l.* from this source alone; private effort supplied nearly 7,000,000*l.* in the years 1898–1900.

Next consider the amount of state aid to universities afforded in Germany. The buildings of the new University of Strassburg have already cost nearly a million; that is, about as much as has yet been found by private effort for buildings in Manchester, Liverpool, Birmingham, Bristol, Newcastle and Sheffield. The government annual endowment of the same German university is more than 49,000*l.*

This is what private endowment does for us in England, against state endowment in Germany.

But the state does really concede the principle; its present contribution to our universities and colleges amounts to 155,600*l.* a year; no capital sum, however, is taken for buildings. The state endowment of the University of Berlin in 1891–2 amounted to 168,777*l.*

When, then, we consider the large endowments of university education both in the United States and Germany, it is obvious that state aid only can make any valid competition possible with either. The more we study the facts, the more statistics are gone into, the more do we find that we, to a large extent, lack both of the sources of endowment upon one or other or both of which other nations depend. We are between two stools, and the prospect is hopeless without some drastic changes. And first among these, if we intend to get out of the present slough of despond, must be the giving up of the idea of relying upon private effort.

That we lose most where the state does least is known to Mr. Chamberlain, for in his speech, to which I have referred, on the University of Birmingham, he said: "As the importance of the aim we are pursuing becomes more and more impressed upon the minds of the people, we may find that we shall be more generously treated by the state."

Later still, on the occasion of a visit to University College School, Mr. Chamberlain spoke as follows:

"When we are spending, as we are, many millions—I think it is 13,000,000*l.*—a year on primary education, it certainly seems as if we might add a little more, even a few tens of thousands, to what we give to university and secondary education" (*Times,* November 6, 1902).

To compete on equal grounds with other nations we must have more universities. But this is not all—we want a far better endowment of all the existing ones, not forgetting better opportunities for research on the part of both professors and students. Another crying need is that of more professors and better pay. Another is the reduction of fees; they should be reduced to the level in those countries which are competing with us, to say, one fifth of their present rates, so as to enable more students in the secondary and technical schools to complete their education.

In all these ways, facilities would be afforded for providing the highest instruction to a much greater number of students. At present there are almost as many *professors and instructors* in the universities and colleges of the United States as there are *day students* in the universities and colleges of the United Kingdom.

Men of science, our leaders of industry, and the chiefs of our political parties all agree that our present want of higher education—in other words, properly equipped universities—is heavily handicapping us in the present race for commercial supremacy, because it provides a relatively inferior brain-power which is leading to a relatively reduced national income.

The facts show that in this country we can not depend upon private effort to put matters right. How about local effort?

Any one who studies the statistics of modern municipalities will see that it is impossible for them to raise rates for the building and up-keep of universities.

The buildings of the most modern university in Germany have cost a million. For up-keep the yearly sums found, chiefly by the state, for German universities of different grades, taking the incomes of seven out of the twenty-two universities as examples are:

		£
1st Class	Berlin	130,000
2nd Class	Bonn, Göttingen	56,000
3rd Class	Königsberg, Strassburg	48,000
4th Class	Heidelberg, Marburg	37,000

Thus if Leeds, which is to have a university, is content with the 4th class German standard, a rate must be levied of 7*d.* in the pound for yearly expenses, independent of all buildings. But the facts are that our towns are already at the breaking strain. During the last fifty years, in spite of enormous increases in ratable values, the rates have gone up from about 2*s.* to about 7*s.* in the pound for real *local* purposes. But no university can be merely a local institution.

What, then, is to be done? Fortunately, we have a precedent admirably in point, the consideration of which may help us to answer this question.

I have pointed out that in old days our Navy was chiefly provided by local and private effort. Fortunately for us, those days have passed away; but some twenty years ago, in spite of a large expenditure, it began to be felt by those who knew that in consequence of the increase of foreign navies, our sea-power was threatened, as now, in consequence of the increase of foreign universities, our brain-power is threatened.

The nation slowly woke up to find that its enormous commerce was no longer insured at sea, that in relation to foreign navies our own had been suffered to dwindle to such an extent that it was no longer capable of doing the duty which the nation expected of it even in time of peace. At first, this revelation was received with a shrug of incredulity, and the peace-at-any-price party denied that anything was needed; but a great teacher arose;* as the facts were inquired into the suspicion changed into an alarm; men of all parties saw that something must be done. Later, the nation was thoroughly aroused, and with universal agreement the principle was laid down that, cost what it might to enforce our sea-power, our Navy must be made and maintained of a strength greater than those of any two possibly contending powers. After establishing this principle, the next thing to do was to give effect to it. What did the nation do after full discussion and inquiry? A bill was brought in in 1888, and a sum of 21,500,000*l.* was voted in order, during the next five years, to inaugurate a large ship-building program, so that Britain and Britain's commerce might be guarded on the high seas in any event.

Since then we have spent 120,000,000*l.* on new ships, and this year we spend still more millions on still more new ships. If these prove insufficient to safeguard our sea-power, there is no doubt that the nation will increase them, and I have not heard that anybody has suggested an appeal to private effort.

How, then, do we stand with regard to universities, recognizing them as the chief producers of brain-power and therefore the equivalents of battleships in relation to sea-power? Do their numbers come up to the standard established by the Admiralty principle to which I have referred? Let us attempt to get a rough-and-ready estimate of our educational position by counting universities as the Admiralty counts battleships. I say rough and ready because we have other helps to greater brain-power to consider besides universities, as the Admiralty has other ships to consider besides ironclads.

In the first place, let us inquire if they are equal in number to those of any two nations commercially competing with us.

In the United Kingdom, we had until quite recently thirteen. Of these, one is only three years old as a teaching university and another is still merely an examining board.

* Captain Mahan, of the U. S. Navy, whose book, 'On the Influence of Sea-power on History,' has suggested the title of my address.

† These are Oxford, Cambridge, Durham, Victoria, Wales, Birmingham, London, St. Andrews, Glasgow, Aberdeen, Edinburgh, Dublin and Royal University.

In Germany there are twenty-two universities; in France, under recent legislation, fifteen; in Italy, twenty-one. It is difficult to give the number in the United States, because it is clear, from the tables given in the Report of the Commissioner of Education, that some colleges are more important than some universities, and both give the degree of Ph.D. But of universities in title we have 134. Among these, there are forty-six with more than fifty professors and instructors, and thirteen with more than 150. I will take that figure.

Suppose we consider the United States and Germany our chief commercial competitors, and apply the Admiralty principle. We should require, allowing for population, eight additional universities at the very lowest estimate.

We see, then, that instead of having universities equaling in number those of two of our chief competitors together, they are by no means equal to those of either of them singly.

After this statement of the facts, any one who has belief in the importance of higher education will have no difficulty in understanding the origin of the present condition of British industry and its constant decline, first in one direction and then in another, since the tremendous efforts made in the United States and Germany began to take effect.

If, indeed, there be anything wrong about the comparison, the error can only arise from one of two sources; either the Admiralty is thoughtlessly and wastefully spending money, or there is no connection whatever between the higher intelligence and the prosperity of a nation. I have already referred to the views of Mr. Chamberlain and Lord Rosebery on this point; we know what Mr. Chamberlain has done at Birmingham; we know the strenuous efforts made by the commercial leaders of Manchester and Liverpool; we know, also, the opinion of men of science.

If while we spend so freely to maintain our sea-power our export of manufactured articles is relatively reduced because our competitors beat us in the markets of the world, what is the end of the vista thus opened up to us? A Navy growing stronger every year and requiring larger votes to guard our commerce and communications, and a vanishing quantity of commerce to guard—a reduced national income to meet an increasing taxation!

The pity is that our government has considered sea-power alone; that while so completely guarding our commerce it has given no thought to one of the main conditions on which its production and increase depend: a glance could have shown that other countries were building universities even faster than they were building battleships; were, in fact, considering brain-power first and sea-power afterwards.

Surely it is my duty as your president to point out the danger ahead if such ignoring of the true situation should be allowed to continue. May I express a hope that at last, in Mr. Chamberlain's words, 'the time is coming when governments will give more attention to this matter'?

The comparison shows that we want eight new universities, some of which, of course, will be colleges promoted to university rank and fitted to carry on university work. Three of them are already named: Manchester, Liverpool, Leeds.

Let us take this number and deal with it on the battleship condition, although a modern university on American or German models will cost more to build than a battleship.

If our present university shortage be dealt with on battleship conditions, to correct it we should expend *at least* 8,000,000*l.* for new construction, and for the pay-sheet we should have to provide (8 × 50,000*l.*) 400,000*l.* yearly for personnel and up-keep, for it is of no use to build either ships or universities without manning them. Let us say, roughly, capitalizing the yearly payment at 2½ per cent., 24,000,000*l.*

At this stage, it is important to inquire whether this sum, arrived at by analogy merely, has any relation to our real university needs.

I have spent a year in making inquiries, as full as I could make them, of friends conversant with the real present needs of each of the universities old and new; I have obtained statistics which would fill a volume, and personally I believe that this sum at least is required to bring our university system up to anything like the level which is insisted upon both in the United States and in Germany. Even Oxford, our oldest university, will still continue to be a mere bundle of colleges, unless three millions are provided to enable the university properly so-called to take her place among her sisters of the modern world; and Sir Oliver Lodge, the principal of our very youngest university, Birmingham, has shown in detail how five millions can be usefully and properly applied in that one locality, to utilize for the good of the nation the enthusiasm and scientific capacity which are only waiting for adequate opportunity of development.

How is this money to be raised? I reply without hesitation, *duplicate the Navy Bill of* 1888–9; do at once for brain-power what we so successfully did then for sea-power.

Let 24,000,000*l.* be set apart from one asset, our national wealth, to increase the other, brain-power. Let it be assigned and borrowed as it is wanted; there will be a capital sum for new buildings to be erected in the next five or ten years, the interest of the remainder to go towards increased annual endowments.

There need be no difficulty about allocating money to the various institutions. Let each university make up its mind as to which rank of the German universities it wishes to emulate. When this claim has been agreed to, the sums necessary to provide the buildings and teaching staff of that class of university should be granted without demur.

It is the case of battleships over again, and money need not be spent more freely in one case than in the other.

Let me at once say that this sum is not to be regarded as practically gone when spent, as in the case of a short-lived ironclad. *It is a loan* which will bear a high rate of interest. This is not my opinion merely; it is the opinion of those concerned in great industrial enterprises and fully alive to the origin and effects of the present condition of things.

I have been careful to point out that the statement that our industries are suffering from our relative neglect of science does not rest on my authority. But if this be true, then if our annual production is less by only two millions than it might have been, having two millions less to divide would be equivalent to our having forty or fifty millions less capital than we should have had if we had been more scientific.

Sir John Brunner, in a speech connected with the Liverpool School of Tropical Medicine, stated recently that if we as a nation were now to borrow ten millions of money in order to help science by putting up buildings and endowing professors, we should get the money back in the course of a generation a hundredfold. He added that there was no better investment for a business man than the encouragement of science, and that every penny he possessed had come from the application of science to commerce.

According to Sir Robert Giffen, the United Kingdom as a going concern was in 1901 worth 16,000,000,000*l.*

Were we to put aside 24,000,000*l.* for gradually organizing, building and endowing new universities, and making the existing ones more efficient, we should still be worth 15,976,000,000*l.*, a property well worth defending by all the means, and chief among these brain-power, we can command. If it be held that this, or anything like it, is too great a price to pay for correcting past carelessness or stupidity, the reply is that the 120,000,000*l.* recently spent on the navy, a sum five times greater, has been spent to correct a sleepy blunder, not one whit more inimical to the future welfare of our country than that which has brought about our present educational position. We had not sufficiently recognized what other nations had done in the way of ship building, just as until now we have not recognized what they have been doing in university building.

Further, I am told that the sum of 24,000,000*l.* is less than half the amount by which Germany is yearly enriched by having improved upon our chemical industries, owing to our lack of scientific training. Many other industries have been attacked in the same way since, but taking this one instance alone, if we had spent this money fifty years ago, when the Prince Consort first called attention to our backwardness, the nation would now be much richer than it is, and would have much less to fear from competition.

Suppose we were to set about putting our educational house in order, so as to secure a higher quality and greater quantity of brain-power, it would not be the first time in history that this has been done. Both Prussia after Jena and France after Sedan acted on the view:

"When land is gone and money spent,
Then learning is most excellent."

After Jena, which left Prussia a 'bleeding and lacerated mass,' the King and his wise counselors, among them men who had gained knowledge from Kant, determined, as they put it, 'to supply the loss of territory by intellectual effort.'

What did they do? In spite of universal poverty, three universities, to say nothing of observatories and other institutions, were at once founded, secondary education was developed, and in a few years the mental resources were so well looked after that Lord Palmerston defined the kingdom in question as 'a country of damned professors.'

After Sedan, a battle, as Moltke told us, 'won by the school-master,' France made even more strenuous efforts. The old University of France, with its 'academies' in various places, was replaced by fifteen independent universities, in all of which are faculties of letters, sciences, law and medicine.

The development of the University of Paris has been truly marvelous. In 1897–8, there were 12,000 students, and the cost was 200,000*l.* a year.

But even more wonderful than these examples is the 'intellectual effort' made by Japan, not after a war, but to prepare for one.

The question is, shall we wait for a disaster and then imitate Prussia and France? or shall we follow Japan, and thoroughly prepare by 'intellectual effort' for the industrial struggle which lies before us?

Such an effort seems to me to be the first thing any national or imperial scientific organization should endeavor to bring about.

SHORTER ARTICLES AND DISCUSSION.

THE AURORA BOREALIS OF AUGUST 21.

To THE EDITOR: I have been much interested in the account given by Dr. A. F. A. King of the unusual aurora observed by him on the twenty-first of August at York Harbor, Maine (POPULAR SCIENCE MONTHLY, Vol. LXIII., pp. 563–4), because I also observed it the same evening from a point near Baddeck, Cape Breton Island, Nova Scotia.

My attention was called to the display about 8:45 P.M., Halifax time (this would be about 7:45 P.M. by eastern standard time, which I presume is the time used by Dr. King). There was then nothing unusual about the aurora.

I went out of doors especially for the purpose of ascertaining whether any auroral arch was visible extending from east to west across the zenith; for I observed such a phenomenon here two or three years ago (but without the comet-like appendages described by Dr. King) and have been on the lookout since for its reappearance. Certainly no such arch was visible here at 8:45 P.M. on August 21, and the whole display seemed then to be on the wane. Shortly after 9:00 P.M. only a diffused glow remained in the northern sky above a bank of auroral cloud.

During the course of the night I observed the aurora occasionally to see if there was any change, but noticed nothing unusual until 12:45. The arch might have appeared between 9:00 P.M. and 12:45 without my noticing it, as intervals of at least an hour separated my observations. I can say positively that it did not appear between 12:45 and 2:30 A.M., as I was out of doors continuously watching the sky during that time. From 9:00 P.M. till after midnight I noticed nothing more than the usual faint glow in the north; but happening to glance out of the window at 12:45 I was startled by the tremendous activity then displayed. The maximum was reached about 1:00 A.M., and by 2:00 A.M. the display was practically over. At 2:30 A.M., I returned indoors and made a record of my observations, from which I quote the following extract:

> . . . Looking out about 12:45 (a quarter to one A. M., Saturday) great activity was manifest. The whole northern sky was ablaze, pulsations of light streamed upwards from the horizon as though light phosphorescent clouds were being blown along by a hurricane. Upon going out I found that faint auroral clouds covered the whole sky even to the south. Faint pulsations of light in the south appeared to be streaming north while the northern streamers streamed south.
>
> Observing attentively, there seemed to be a luminous streaming upwards from the horizon all around, converging—not at the *zenith*—but at a point of the sky which I should think would be opposite the sun. I was powerfully impressed by the idea that these were parallel rays directed away from the sun, rendered convergent by perspective.
>
> At the point opposite the sun a considerable space—roughly circular in outline—seemed to be generally free from luminous cloud effects, except when a suffused glow would come and cover the space—a momentary glow without stream effect. Towards the circular space the stream effects were centrally directed all round, being most marked in the northern and northwestern sky, where the stream effects were vivid—luminous pulsations like light smoke driven by a hurricane. The stream effects were much less marked in the western, southern and eastern sky. Light glows would appear, but only by at-

tention could the stream effects be distinguished. I am certain, however, that they were there and that the direction was upwards towards this anti-helial (?) position everywhere.

The appearances noted were highly suggestive of luminous matter of some sort streaming past the earth on all sides with tremendous velocity in a direction away from the sun—the parallel streams being rendered apparently convergent by perspective.

The aurora, however, is believed to be a strictly terrestrial phenomenon in the nature of an electrical discharge in the higher regions of the atmosphere; although good grounds exist for supposing that there is some intimate connection between great auroral displays on the earth and disturbances going on in the sun.

In this connection it would be interesting to know where Borelli's comet was at the time. It was then rapidly nearing its closest approach to the sun.

ALEXANDER GRAHAM BELL.

BEINN BHREAGH, NEAR BADDECK, NOVA SCOTIA, September 26, 1903.

MR. COOK ON EVOLUTION, CYTOLOGY, AND MENDEL'S LAWS.

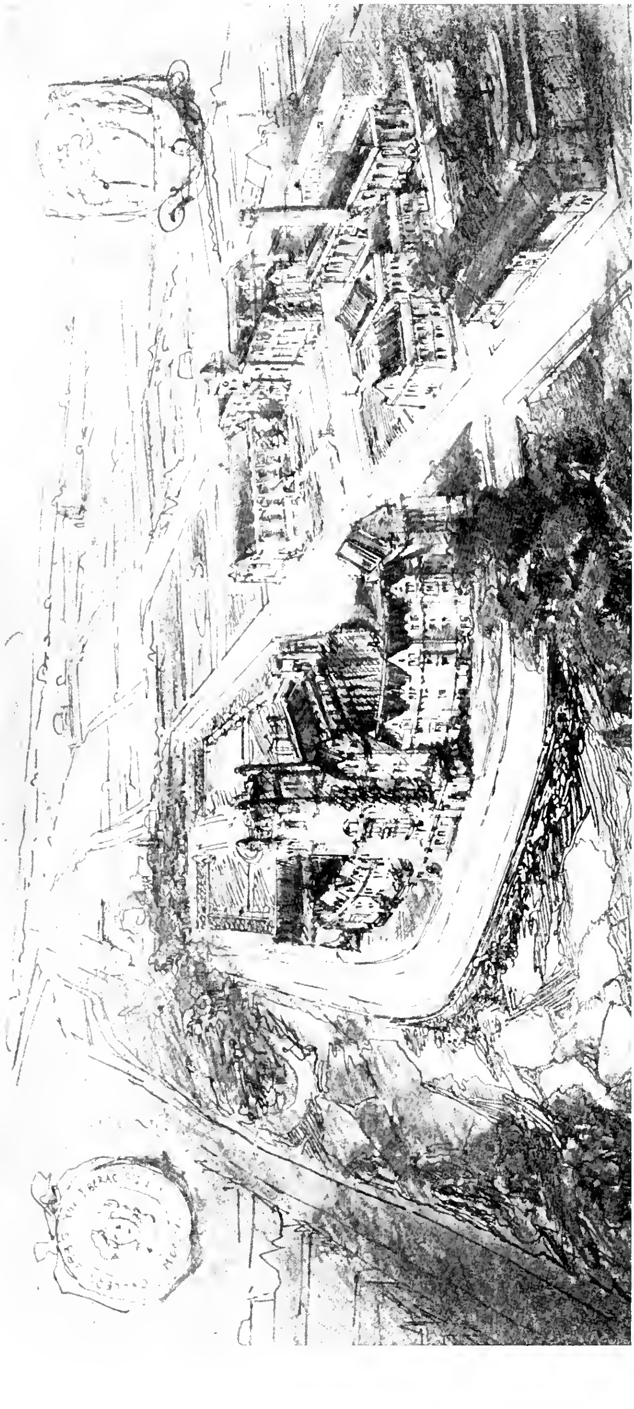
TO THE EDITOR: Owing to my absence in Europe, Mr. O. F. Cook's article, published under the above title in the July number of the POPULAR SCIENCE MONTHLY, has only now come to my attention. Mr. Cook's somewhat drastic criticism of the suggestion regarding Mendelian inheritance, made in my article in the issue of *Science* for December 19, 1902, takes a prominent place in his essay and relates to a question of wide biological interest. I, therefore, ask space to point out that he failed to grasp the nature of the suggestion; and unfortunately the confusion was worse confounded by his misquotation, of course unintentional, of my own statement in such a way as to make me seem to commit the very error that is the object of his criticism, though I myself had expressly warned against such an error in a paper read before the Washington meeting of the American Association last December!

Mr. Cook's objection to the suggestion, as he understood it and as he quoted it, is perfectly correct, and the man of straw thus set up by his own hand is properly overthrown. Assuredly, to maintain that the reducing division in the maturation of the germ-cells 'leads to the separation of paternal and maternal elements and their ultimate isolation' *as* 'separate germ-cells' (this as quoted by Mr. Cook, italics mine) involves, as he points out, the *reductio ad absurdum* that the individual could not show characters individually traceable to more than two grandparents; for this form of statement implies that purely paternal or maternal *groups* of chromosomes are separated by the division, to be isolated as such in the gametes, the latter being thus rendered pure in respect to parentage. But this, of course, was not my meaning, nor was it what I said. Mr. Cook failed to perceive that my statement referred, not to the parental *groups*, but to the members of the *individual pairs* of paternal and maternal chromosomes. What I said was the isolation of the paternal and maternal elements, not '*as*' but '*in*' separate germ-cells; and the elements thus separated from each other were specifically designated as 'the members of each pair.' I regret that Mr. Cook did not read with greater attention; for my phraseology was carefully chosen, the untenability of the view which is erroneously ascribed to me having been clearly pointed out by Mr. Sutton when he first brought his suggestion to my attention, and since fully considered by him in an article on 'The Chromosomes in Heredity' published in the *Biological Bulletin* for last April. It is only fair to add that since Mr. Cook accuses me, as he does Mr. Cannon, of a failure to understand the Mendelian principle, it is probable that his misinterpretation arose from the association in his mind of my communication with Mr. Cannon's paper on 'A Cytological Basis of Mendel's Law,' where unfortunately the error in question was not avoided. This paper I first saw after its publication.

In point of fact the cytological evidence on which Sutton based his suggestion leaves quite undecided the question whether any definite order is followed in the grouping of the chromosome-pairs in the equatorial plate, and places no obstacle in the way of assuming that their position is a matter of chance, *i. e.*, that paternal and maternal chromosomes may lie indifferently toward either pole, and that consequently all combinations of paternal and maternal chromosomes may be produced in the gametes. To employ Sutton's graphic illustration: if the number of chromosomes be taken as 8 and designated as A, a, B, b, C, c, D, d (large letters denoting paternal chromosomes and small ones the corresponding maternal), the chromosome-pairs in the equatorial plate might, so far as the cytological evidence shows, present any or all the groupings $\frac{ABCD}{abcd}$, $\frac{abCD}{ABcd}$, $\frac{aBcD}{AbCd}$ and so on, which gives a possibility of 16 different combinations in the gametes and of 256 in the zygotes or offspring. If the number of chromosomes be 24 (a very common number), the number of possible combinations in the gametes becomes more than 4,000 and in the zygotes nearly 17,000,000 (Sutton). The assumption is, therefore, in full harmony with the fact that offspring may show many different combinations of characters individually traceable to four grandparents or a greater number of more remote ancestors.

Despite the immense range of mixed variation and inheritance thus permitted under the assumption, a point of real difficulty, not touched on by Mr. Cook, is the relatively small number of chromosomes as compared with that of transmissible characters; for if the chromosome-hypothesis, as developed by Sutton, be valid, it would seem to follow that each chromosome stands not for one, but for many, characters, and these should form a coherent group in inheritance. Coherent groups of associated characters have, however, been recognized by many observers, including Mendel himself; and in this direction definite evidence for or against the chromosome hypothesis may perhaps be obtained by the comparative study of variation in nearly related species that differ in the number of chromosomes, though this presents a problem of great complexity. Regarding cases of non-conformity to the so-called Mendelian law or principle, Sutton has endeavored to show that they do not invalidate the suggestions given by the cytological work of himself, Montgomery, Cannon and others. They sufficiently indicate, however, that these suggestions do not yet afford a full or positive explanation, but only, in my own former phrase, give a 'clue' which awaits further development and test. It is entirely possible that the clue may prove false, yet even so it may serve to illustrate that 'fertility of false theories' to which Mr. Cook pays his tribute. In the meantime it is to be regretted that a biologist of Mr. Cook's standing should give currency to the statement that 'The notion that heredity, variation and evolution are the functions of special organs or mechanisms of cells has no ascertained basis of fact' (*l. c.*, p. 222). This 'notion' may be true or false, but such an utterance will be truly surprising to any one having some degree of acquaintance with the literature of embryology and cytology.

EDMUND B. WILSON.
COLUMBIA UNIVERSITY,
September 24, 1903.



Bird's-eye View of the Buildings of the College of the City of New York.

THE PROGRESS OF SCIENCE.

THE COLLEGE OF THE CITY OF NEW YORK.

Since 1848 the College of the City of New York and its predecessor, the Free Academy, have carried forward an educational work the importance of which is scarcely appreciated. Yale and Princeton are household words, where the existence of the City College is unknown. Yet the college has rivaled the more prominent institutions both in numbers of students and in the efficiency of the courses of instruction. From the point of view of this journal, it is sufficient to note that at least two members of the National Academy of Sciences are graduates of the college, and that the only living ex-president of the academy was formerly one of its professors. There is reason to believe that September 29, when a new president was installed and the corner-stone of the new buildings was laid, will mark an epoch in the history of the institution, and that it will become one of the chief centers for the educational progress of the future.

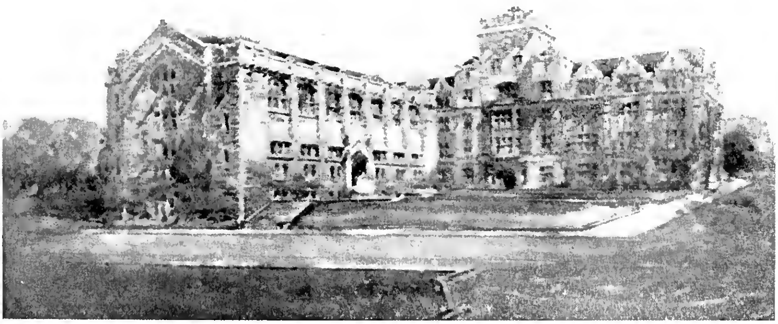
The ceremonies of installation and dedication were themselves imposing. Those who hold that academic processions, gowns and the like are somewhat out of place in a modern democratic community were at least given the pleasure of seeing gowns handed out with an even hand to all, whether or not they possessed academic degrees. The fact of special interest was the representation on the program of republicans and democrats, of protestants, catholics and jews, all uniting in the service of the college without regard to political or denominational differences. Mayor Low spoke immediately after Mr. Shepard, his rival in the contest for the mayorality two years ago, and Ex-President Cleveland followed Senator Depew. Other speeches were made by Governor Odell, the presidents of Columbia, Cornell, Yale and the Johns Hopkins Universities, and by representatives of the trustees, faculty, alumni and students of the college. The new president of the college made an admirable inaugural address, showing full appreciation of the problems before the college and the city.

Dr. John Huston Finley was offered the presidency of the college after a careful search had been made through the whole country for the best attainable man. That one born in Illinois, at the time professor in a university in another state, regarding whose political or religious affiliations no questions were asked, was chosen, shows that municipal institutions can be conducted without local or partisan prejudice. General Webb, who retires from the presidency at the age of sixty-seven years, held the office for twenty-three years. A graduate of West Point and a general in the regular army, he possessed valuable qualifications for the office, but he was not an educational leader. The students were well trained and well drilled, but instructors were assigned to teach subjects with which they were not familiar and investigation was not sufficiently encouraged. The college did not take an important place in the educational and scientific progress of the country. Dr. Finley has the vigorous personality and has had the training and experience fitting him for a college presidency—one of the most responsible and influential, and at the same time one of the most complicated and difficult of positions. As a boy he worked on a farm and in a

DR. JOHN HUSTON FINLEY, PRESIDENT OF THE COLLEGE OF THE CITY OF NEW YORK.

St. Nicholas Terrace Facade — Main Building.

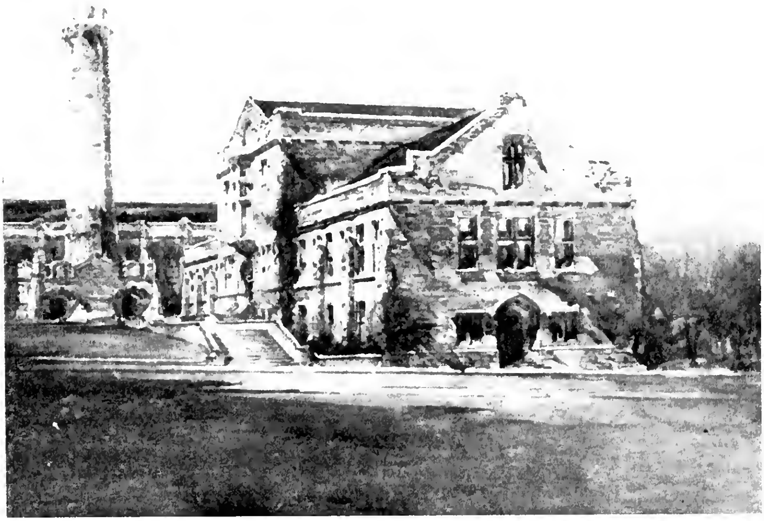
printing office. He was called to the presidency of Knox College five years after graduating from it. He had pursued graduate studies at the Johns Hopkins University and had been secretary of the State Charities Aid



Gymnasium and Sub-Freshman Building.

Association of New York. He resigned the presidency of Knox College after seven years of useful service, and was engaged on the editorial staff of *Harper's Weekly* and *McClure's Magazine*. In 1900 he was called to the professorship of politics at Princeton University. And this wide experience he has gained before the age of forty. From his administration of the college much may be expected.

The new buildings of the college, some illustrations of which are here shown, are worthy not only of the work that the college has done, but also of what may be expected from it. They stand on rising ground a mile north of Columbia University, occupying a somewhat similar site, but not so completely shut in by apartment houses. Gothic architecture, like academic gowns, seems to belong to the past rather than to the future, but a traditional environment carries with it much that is good, and there is perhaps more danger in innovation than in imitation. The architect, Mr. Geo. B. Post, has certainly fitted the buildings admirably to the site and united them to a picturesque whole. It is unfortunate that the modern college and the scientific laboratory have not developed a significant architectual form, but it is useless to complain of the inevitable.



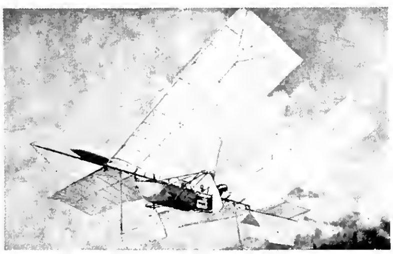
CHEMICAL AND MECHANICAL ARTS BUILDINGS FROM COLLEGE GROUNDS.

It has been indicated that the College of the City of New York may become one of the storm-centers of educational development. In spite of remarks made at the installation ceremonies by several of the speakers, including university presidents, the New York City College is not unique. There are somewhat similar institutions in Philadelphia and Baltimore, and Cincinnati has a municipal university. But the New York institution, coordinate with the great state universities, must lead the way. Here all the questions of the relation of the college to the high school and to the university, of liberal to technical studies, of higher education to the state, of public to semi-private and semi-religious institutions, will become pressing. We do not hesitate to express the opinion that the maintenance of education is as completely a public duty as the maintenance of the courts or of the army, that higher education should no more be left to private initiative than elementary education, and that ultimately all the educational and scientific institutions of New York City will be unified under the control of the people of the city.

AERIAL NAVIGATION.

READERS of THE POPULAR SCIENCE MONTHLY may naturally expect to find here more or less authoritative statements in regard to scientific matters exploited in the newspapers. One of the subjects that has attracted particular attention recently is the aerodrome of Dr. S. P. Langley, secretary of the Smithsonian Institution. The somewhat sensational character of the attempt to fly and the secrecy with which the proceedings are surrounded have naturally excited public curiosity, and the newspapers have found the failure of the machines a good opportunity for jokes, so that we read of 'airships as submarines' and the like.

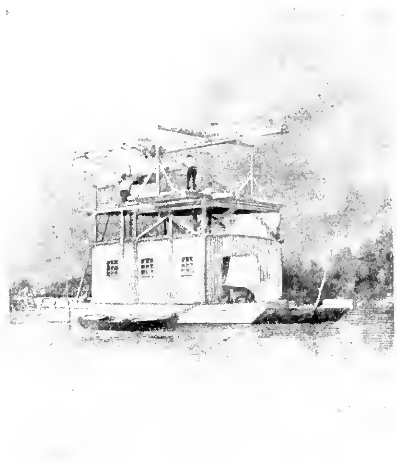
Dr. Langley has carried forward important researches in aerodynamics, and has done more than any one else toward constructing an aeroplane that would fly. After numerous experiments and failures a machine was launched in 1896 that stayed in the air from one to two minutes. We reproduce from the 'Report' of the Smithsonian Institution for 1900, two pictures of this aerodrome, one an imaginary sketch, the other from a photograph taken by Dr. A. Graham Bell. The total length was about 16 feet and the width between the wings about 12 feet. The weight was about 30 pounds, of which one fourth was represented by the machinery, the engines, which could supply one to one and a half horse-power, weighing 26



THE AERODROME AS IT MIGHT APPEAR IN THE AIR.

ounces, and the boiler about 5 pounds.

Dr. Langley has not published a scientific account of his work, but contributed a popular article to *McClure's Magazine* for June, 1897, which he reprinted in the 'Report' of the Smithsonian Institution for 1900, and to this our readers may refer. It appears to us that Dr. Langley takes rather too little credit for his work on aerodynamics and rather too much



THE AERODROME, READY FOR LAUNCHING.

for the practical success of his flying machine. Hundreds of patents for aeroplanes had been taken previously, and toys had been constructed that would fly. The Langley aerodrome was not steered, nor tried in a breeze, nor able to carry any weight, nor kept in the air as long as two minutes. This record has of course been much surpassed by dirigible balloons and perhaps by artificial flight. Aeroplanes can doubtless be made to fly; as Lord Rayleigh, quoting Mr. Maxim, has said, 'it is mainly a question of some time and much money.' Aeroplanes will probably be used for military purposes and for adventure, but not for the ordinary uses of transportation and commerce. Dr. Langley seems to claim too much when he writes in a popular magazine that he has demonstrated the practicability of mechanical flight and that 'the great universal highway overhead is now soon to be opened'; that aerodromes 'may be built to remain days in the air,' 'to travel at speeds higher than any with which we are familiar.'

The secretary of the Smithsonian Institution should be the representative of American science and should be extremely careful not to do anything that may lend itself to an interpretation that will bring injury on the scientific work of the government or of the country. Dr. Langley has stated that for 'the commercial and practical development of the idea it is probable that the world may look to others.' We think that it would have been better if the secretary of the Smithsonian Institution had adhered to this resolution and had not spent large sums on secret experiments for the War Department. He could have placed his scientific knowledge at the disposal of army officers and expert mechanicians, and this would have been better than to attempt to become an inventor in a field where success is doubtful and where failure is likely to bring discredit, however undeserved, on scientific work.

SCIENTIFIC ITEMS.

Professor Alexander Bain, for many years professor of logic in the University of Aberdeen, died on September 17, at the age of eighty-five years. Dr. Bain was the author of an important series of books on psychology, logic and English. His works on 'The Senses and the Intellect,' in 1855, and 'The Emotions and the Will,' in 1859, in many ways laid the foundations of modern scientific psychology.

Dr. W. A. Noyes, of the Rose Polytechnic Institute, has accepted the position of chemist in the National Bureau of Standards.—Professor J. Mark Baldwin, of Princeton University, has been called to organize a graduate department of philosophy and psychology at the Johns Hopkins University.—Dr. T. H. Montgomery, Jr., assistant professor of zoology at the University of Pennsylvania, has been appointed to the professorship of zoology in the University of Texas, vacant by the removal of Professor W. M. Wheeler to the American Museum of Natural History. Dr. Herbert S. Jennings, assistant professor of zoology at the University of Michigan, and now at Naples, has been called to the assistant professorship of zoology at the University of Pennsylvania.

Mr. Robert E. Peary has been given three years' leave of absence from the navy to continue his Arctic explorations. His plan contemplates the construction of a strong wooden ship with powerful machinery, in which he will sail next July to Cape Sabine and, after establishing a sub-base there, force his way northward to the northern shore of Grant Land, where he will spend the winter with a colony of Whale Sound Esquimaux, who will be taken there by him from their homes further south. This winter base will be at or in the vicinity of Cape Columbia or Cape Joseph Henry, situated about the 82d degree of north latitude.

The new medical buildings and laboratories of Toronto University were officially opened on October 1. The opening address was given by Professor Charles S. Sherrington, of Liverpool. Speeches were made by representatives of various institutions, and an address in the evening was made by Professor William Osler, of the Johns Hopkins University. A special convocation was held on October 2, at which the following visitors received the honorary degree of LL.D. from the university: William Williams Keen, Jefferson Medical College, Philadelphia; William Henry Welch, Johns Hopkins University; William Osler, Johns Hopkins University; Russell Henry Chittenden, Yale University; Charles S. Sherrington, University of Liverpool; Henry Pickering Bowditch, Harvard University.

THE POPULAR SCIENCE MONTHLY.

DECEMBER, 1903.

RECENT THEORIES IN REGARD TO THE DETERMINATION OF SEX.

BY PROFESSOR T. H. MORGAN,

BRYN MAWR COLLEGE.

IT was long believed that the sex of the embryo is determined at a relatively late stage in its development, and therefore it seemed probable that external factors must decide whether the embryo is to become a male or a female individual. Many views have been held as to what these external factors are, and from time to time hopes have been held out that it might be possible to regulate, by artificial means, the sex of the developing embryo.

In the last few years opinion has begun to turn in the opposite direction, and several attempts have been made to prove that the sex of the embryo is determined in the egg. That this must be the case in man seemed to be indicated by the fact that 'identical twins' are always of the same sex. There can be little doubt that such twins come from the same egg, and the presumption is strongly in favor of the view that they represent the separated first two cells of the segmenting egg. These twin embryos are enclosed in the same chorion, which further indicates that they have come from one egg. The 'ordinary twins' of man are no more like each other than are any other two children born at different times. The pair of ordinary twins often consists of a male and a female. Since the embryos that give rise to ordinary twins are subjected to practically the same conditions during their uterine life, and are often, as has been said, a male and a female in a pair, it follows that in man the external conditions that affect the egg, after it has left the ovary or after it has been fertilized, do not determine the sex. A similar and even more remarkable fact is known in the case of the armadillo, *Tatusa hybrida* of Paraguay. The eight to eleven young of each birth are always of the same sex. This occurs also, it is said, in another species, *Tatusa novemcinta.* In the latter case it was found by Jehring that all the embryos of one birth are enveloped in a common chorion, although each has its own separate placenta. It is probable that these embryos are the product of a single egg that has become separated during the early stages of segmentation into as many parts as there are embryos produced. That separated blastomeres or cells are capable of giving rise to whole embryos has been demonstrated experimentally in recent years for a number of animals.

The following discovery also bears on the same question. A hymenopterous insect, a chalcid bee, *Encrytus fuscicollis,* lays one or two eggs in the egg of a caterpillar that is to become the host. The egg of the parasite develops inside the body of the young caterpillar, not into a single embryo, as is the rule, but into a chain of embryos. As many as a hundred embryos may come from the same egg, all united in a common amnion. It has been observed that the bees that emerge from the same caterpillar are frequently of the same sex. Thus in twenty-one observations the progeny was in fourteen cases all of the same sex. In the remaining seven cases both males and females appeared. In the former it is probable that only a single egg had been laid in the egg of the butterfly, and in the latter more than one egg may have been deposited.

One of the earliest and most important of the recent memoirs that have attempted to show that the sex of the individual is determined in the egg is that of Cuénot.* This paper deserves first place not only because in point of time it precedes the others to be mentioned, but also because the author has undertaken a considerable number of important experiments that bear on the problem of the determination of sex.

It had been claimed that when young caterpillars are poorly nourished they give rise to a larger number of males, and conversely, when well nourished to a great majority of females. The experiment was first carried out by Landois, and later confirmed by Giard, Treat and Gentry. On the other hand, Riley found that starved caterpillars, as well as those abundantly supplied with nourishment, give both male and female individuals with no greater disproportion in numbers than ordinarily exists. Other observers have recorded similar results. Furthermore, a number of investigators have shown that the sex of the young insect is already determined at the time when it emerges from the egg and even some time before that event. Brocadello's

* *Bulletin Scientifique de la France et de la Belgique,* XXXII., October, 1899.

observation is even more important. He discovered that there are large and small eggs laid by the silk-worm moth, and that the caterpillars emerging from the large eggs are, in the great majority of cases (88 to 95 per cent.), females, while those from the smaller eggs give a corresponding majority of males (88 to 92 per cent.). It is therefore clear that the difference in size corresponds to a difference in the sex of the embryos, and that with sufficient care it would be possible to separate the two sorts of eggs so completely that all of one kind would be females and of the other males. A similar result has been obtained by Joseph in another moth, *Ocneria dispar*. Cuénot states that he has been able to verify completely this statement of Joseph.

How can we explain the apparent contradiction between the results of Landois, Treat and Gentry, and those of Brocadello, Joseph and Cuénot? It is probable that in all cases the facts recorded are correct. Cuénot suggests that in the lots of caterpillars that were poorly nourished there was a large mortality of the young females, so that of those surviving there was a larger percentage of males. If we apply this same view to the case in which abundant feeding gives rise to more females we shall have to assume that here a larger percentage of males are eliminated, but it is not at all evident why this should be the case. Cuénot points out another possible source of error; namely, that in selecting the caterpillars for the experiment the larger ones may have been picked out to be given an abundant diet and the smaller ones for a meager diet. If this had been done consciously, or unconsciously, the results would not be due to the quality of the food, because the young caterpillars that were large were already females (having come from larger eggs), and those that were small were already males (having come from small eggs). It is clear, therefore, that all the early experiments must be repeated and the precaution taken to note the number of caterpillars at the beginning and at the end of the experiment, and the sex of those that die must, if possible, be determined. Care must also be taken that no selection of large and of small individuals takes place. Since, however, it has been so clearly shown by Brocadello and by Cuénot that large eggs become females and small eggs males, it will be desirable in repeating the experiments to take this fact into account, and to attempt to discover if the potentialities of the large and of the small eggs can be changed by external conditions. Here we have a new field for experimental work that will yield results of great interest. The lines are now so definitely drawn, and it is clearly so important to settle this question on as many forms as possible, that it is much to be hoped that in the near future many workers will turn their attention to this important subject.

Cuénot's experiments on certain flies, belonging to four different genera, are of especial interest. In this group also it had been claimed by Lowne that individuals from the large maggots that have been well nourished are nearly always females, while those from small maggots, poorly nourished, are usually males. Cuénot first determined, in the three genera used in his experiments, that normally the number of males and of females is about the same. The results of his experiments, in which the maggots were well fed, were as follows—in *Lucilia cæsar* 49.27 per cent. of females; in *Calliphora vomitoria* 51.02 per cent. of females; and in *Sarcophaga carnaria* 51.62 per cent. of females. It is obvious that the presence of an abundance of food did not produce an excess of females. In another experiment in which the maggots received as small a quantity of food as possible there was great mortality and the pupæ were of diminutive size. The results were as follows—*Lucilia cæsar* 57.92 per cent. of females; *Calliphora vomitoria* 57.92 per cent. of females; and *Curtonerva pabulorum* 26 females and 17 males. It is even more evident from the results of this experiment that starving does not have the effect of producing an increase in the number of males. Several variations of these experiments were made, but the results were always the same. Cuénot also tried to find out if the amount of food taken by the individual during its growth has any effect on the *kinds of eggs* that are produced. The larvæ of *Calliphora vomitoria* were starved from their birth until they pupated. They gave rise to twelve males and five females, whose size was scarcely half that of the normal individuals. These dwarf flies, confined in a cage with sweetened water and meat, laid twenty times. The larvæ that hatched were kept in a well-nourished condition, and gave rise to 359 females and 353 males. The results show that the amount of food supplied to the young maggots had no effect upon the relative number of male and female eggs that they produced. It is true that these animals, when poorly nourished, gave rise to only a few eggs, but the relative number of eggs that became male or female remained the same.

Among the earliest experiments that were carried out to show whether the sex of the individual could be determined by external conditions were those of Born in 1881, and of Yung in 1883 and 1885. Born tried to show that more male frogs develop when the fluid containing the fertilizing spermatozoa is more concentrated, but this conclusion has been shown to be wrong. Born also fed the tadpoles of *Rana temporaria* on a rich diet consisting of water plants and of the flesh of frogs and of tadpoles. A large percentage of females developed which Born attributed to the abundance of food. It was shown, however, by Pflüger in the following year, 1882, that Born's conclusion was erroneous, because, even under normal conditions, female frogs are more numerous. Pflüger found that the normal proportions of females to males is often as high as five to one; and this corresponds also to the proportion sometimes obtained when tadpoles are reared from eggs artificially fertilized.

Yung found that females of *Rana esculenta* are twice as numerous as males, while Cuénot found, on the contrary, in a different locality that there were more males than females.* It is not known whether this disproportion in the sexes is due to the greater mortality of one sex, or whether there are more eggs of one kind than of the other. The results appear to indicate, however, that external conditions do not have a determining influence on sex, and it seems not improbable, although not completely established, that there may be greater mortality among the male tadpoles than among the females in some species and in certain localities.

Cuénot made a few experiments with the eggs of *Rana temporaria*. He points out that his results are open to the same grave criticism as are those of his predecessors in that he did not determine the sex of those that died. In one experiment in which the tadpoles were given an abundant supply of vegetable food they suffered greatly from crowding and from insufficient aeration of the water. Their development was retarded and they remained small. Of the 26 frogs that metamorphosed all were females. In another similar experiment there were 3 females and 4 males. In a third experiment the tadpoles were placed in a large aquarium supplied with cold, running water. No food was given, and the tails of the tadpoles were frequently amputated in order to prolong the larval period. There emerged 57 young frogs, of which 33 were females, 29 males, and one hermaphrodite.

In a fourth experiment the tadpoles were separated into three lots. The first were given a vegetarian diet; the second were given only animal food; and the third were put into a large aquarium whose floor was covered with mud, but no food was present. The tadpoles that died were no doubt eaten by their companions and thus a certain amount of food was probably obtained.

The first and the second lots developed at the same rate, but the tadpoles did not reach a large size owing to the small dimensions of the aquarium. They became frogs after two months. Those of the third lot on the contrary were retarded in their development; they remained small and began to die from hunger after the third month. They were then given animal food; they grew rapidly and metamorphosed a month later, *i. e.*, four months after hatching. The frogs were of small size and showed signs of having been poorly nourished. Of the 35 survivors of this third lot 23 were females and 12 were males. Of the 36 survivors of the second lot (with animal diet) there were 14 females and 22 males. Of the 108 survivors of the first lot (vegetarian

* Boulenger also found in *Pelodytes*, *Pelobates* and *Bufo* an excess of adult males.

fed) there were 51 females and 57 males (and 8 not differentiated). The proportionate number of females to males in all the tadpoles reared in these experiments is not different from that which Cuénot determined in nature. He concludes from his results that the sex of the frog is not influenced by the external conditions (especially of food) to which the tadpoles are subjected.

Pigeons have also furnished some interesting facts in regard to problem of sex. From the time of Aristotle it has been recognized that of the two eggs laid in each batch one generally produces a male and the other a female. Nevertheless numerous exceptions have been recorded in which both individuals were of the same sex. Cuénot himself found in eight sets that in two instances there were two males; in two instances there were two females, and in five instances there was a male and a female.* It has been claimed moreover, and the tradition also goes back to the time of Aristotle, that the first egg laid gives rise to a male and the second to the female. Flourens confirmed this fact for eleven sets, and Cuénot found the same result. The meaning of this is obscure, for it may be that a male egg is first set free, or that the conditions to which the first egg that is laid is subjected are such that it becomes a male. The former interpretation may appear to be the more probable, but it is not conclusively established by the facts.

Although many statistics have been brought together in regard to the determination of sex in man and in other mammals there is no convincing evidence showing that external factors determine the sex of the embryo; and, as has been pointed out, there is strong evidence pointing in the opposite direction.

If we turn now to some of the lower animals we shall find that there are a few indisputable cases in which it has been shown that the sex of the individual is predetermined in the egg. It was discovered by Korschelt that two kinds of eggs are produced by a small worm, *Dinophilus apatris,* and that the larger eggs develop, after fertilization, into females and the smaller into males. The females are about 1.2 mm. long, while the males are only 0.04 mm. long. The males are degenerate in structure; they are less numerous than the females, and live only ten days, whereas the females live a month or more.

A similar difference in the size of the eggs that produce males and females is found in certain rotifers, in *Hydatina senta* for example. In this species there are three kinds of females distinguished by the different kinds of eggs that they lay. One lays large eggs which without fertilization produce females. Another lays small eggs, less rich in yolk than the last, and these eggs, also without being fertilized,

* There is here probably a misprint since 2 + 2 + 5 equal nine.

produce *males*. A third kind of female produces the winter eggs, which are fertilized by the males and give rise to females. In this rotifer the sex of the egg is determined while the egg is still in the ovary, and Nussbaum has made the important discovery that the amount of nourishment taken by a young female, between the time of her emergence from the egg and the deposition of her first egg, determines which kind of eggs she will subsequently produce. If she has been well nourished in this interval she produces eggs that become females, but if poorly nourished she produces male eggs. After the eggs have been once formed no subsequent change of food or of temperature can alter the kind of eggs that are produced. It has not been determined why some females produce parthenogenetic eggs and other females winter eggs that are to be fertilized. Nussbaum thinks that the effect of an early union with a male, combined with insufficient nourishment during the first hours of free life, determine that winter eggs are to be produced.

Amongst crustaceans and insects there are several instances known in which the sex of the individual appears to be connected with certain kinds of eggs. The water fleas, or daphnids, produce during the summer small parthenogenetic eggs with a thin shell which develop into parthenogenetic females,* but under certain conditions males and females appear. The females produce large winter eggs which are fertilized and produce in the following year only female daphnids which start the parthenogenetic summer broods. The sex of the winter eggs is probably determined in the ovary, since the eggs show their characteristic structure before they are set free. The appearance of the male and female generation is supposed to be connected with the change in temperature, or more probably with a change in the amount of food. Under these conditions, as has just been said, eggs that produce males and females are formed. Here it would appear that an external condition determines the appearance of the male and of a different kind of female.

Similar facts are known for the aphids, or plant-lice. If conditions are favorable, *i. e.*, if they are kept warm and have an abundance of succulent food, they continue indefinitely producing wingless parthenogenetic females. But if the food becomes scarce or dry, then winged males and females arise from the parthenogenetic eggs; these unite, and the fertilized winter eggs are laid. From these eggs the wingless parthenognetic females arise in the following spring.

The life history of *Phyloxera vitifolii*, which is parasitic on the

* Lenssen claims that the parthenogenetic female eggs do not give off a polar body, and that the male eggs give off only a single polar body. Whether this difference may have any relation to the sex of the individual will be discussed later.

roots of the grape, is as follows: A series of parthenogenetic wingless females succeed each other, until at the end of June the last generation of these produces, parthenogenetically, winged females that are capable of migrating. These also produce parthenogenetic eggs of two kinds, small ones from which winged males develop, and larger ones from which winged females arise.* Union of the sexes now takes place and each female lays one egg which gives rise in the following spring to the parthenogenetic wingless female that lives on the root of the grape vine.

We come now to the much discussed case of the hive bee. There are here three kinds of individuals: the queen which lays all the eggs; the workers, which are immature females and do not reproduce at all, and the drones or males which fertilize the eggs of the queen.

It has long been believed that when an egg of the queen is fertilized it gives rise to a female (either queen or worker according to the kind of food given to the young maggot), but if not fertilized the egg gives rise to a male. It has been generally assumed, in accordance with this belief, that all the eggs are alike and will produce males if they are not fertilized, but females if they are fertilized. It is known moreover that the cells of the comb in which the queen deposits the eggs that are to become males are different from the worker cells, and this fact is generally interpreted to mean that the queen is capable of determining the sex of her offspring by allowing or preventing the fertilization of the egg. The sperm which was received by the young queen at the time when she left the hive with a swarm is stored up in a special sac or receptacle with muscular walls and an outlet that opens near the oviducts. It is generally assumed that the queen squeezes out the sperm when an egg that is to be fertilized is laid, but does not do so when a male is to be produced. Some writers have marveled at this wonderful power, that seems almost akin to intelligence, by which the queen determines 'at will' the sex of her offspring, but this may give an entirely exaggerated idea of what takes place, for the act may be a very simple reflex. It has been shown by Drory that if the queen is supplied with an artificial comb containing only drone cells she may be forced to lay in them fertilized eggs that become workers. Conversely, if supplied with worker cells only she will sometimes lay unfertilized eggs in them. This has been interpreted to mean that there are really two kinds of eggs that are laid by the queen, male and female, and that only the latter are capable, as a rule, of being fertilized. On this assumption we should be forced to conclude either that the queen can determine which kind of egg is to be laid and places it in its proper cell, or that she has a knowledge

* The small eggs appear to be laid by the smaller winged individuals and the larger eggs by the larger individuals.

of which kind of egg she is about to lay next, and seeks the proper cell to deposit it in. There are, however, some further facts that show that the conditions may be more complicated than has been generally supposed.

It has been possible to introduce a virgin queen of an Italian stock into a hive containing workers and males of a German stock. These two kinds of bees are sufficiently different to be readily distinguished from each other. The Italian queen becomes fertilized by the German males. In consequence all the queens and workers that come from her eggs are hybrids, since they come from fertilized eggs, but the males or drones are nearly all of the same kind as the queen, which indicates that they have come from unfertilized eggs. Occasionally, however —and this is the point of special interest in the present connection— a few males appear that are hybrids, as Dzierzon long ago observed. Hence we must suppose that an egg has been fertilized, and despite this fact it has developed into a male. This conclusion may indicate, as Beard has recently claimed, that the sex of the egg must have been already determined, and was not altered by the accidental entrance of a spermatozoon.

In this connection it should be pointed out that Weismann and Petrunkewitsch found that out of 272 drone eggs that they studied there was one that had been fertilized. Whether it would have become a male or not, could not be determined; for it is said that the queen sometimes makes a mistake and deposits a worker egg in a drone cell. Indeed 'whole combs of drone cells may produce workers instead of drones.'

These are some of the principal facts that seem to show that the sex of the individual is predetermined in the egg. From the evidence Cuénot arrives at the following general conclusions: He thinks that in the great majority of animals the sex is determined in the egg and at latest when the egg is fertilized. In no instance, he claims, has it been shown that the sex of the individual can be determined later than fertilization. The classic examples, insects and frogs, in which it was supposed that external conditions acting on the later embryo determined the sex, have been shown to be capable of a different interpretation. It has been especially made clear, Cuénot claims, that a meager or an abundant supply of food has no influence on the determination of the sex of the embryo. He believes moreover that it is the egg and not the spermatozoon that determines the sex of the individual. In several insects, in *Dinophilus,* in pigeons, and in the winter eggs of aphids and of daphnids, this has been clearly shown to be the case. In other animals, as in the rotifers and in the social hymenoptera, the spermatozoon appears to have a determining influence. In the mammals the entrance of the spermatozoon may have only the same influence as that of the egg itself. It will be observed that there is a certain catholicity in these conclusions at which Cuénot arrives, and in the present uncertain state of our knowledge on many important points it is probably wiser not to take too narrow a point of view in regard to what factors determine the sex of the individual.

Strasburger* has recently arrived at a somewhat similar conclusion in regard to sex, basing his evidence mainly on certain observations and experiments in higher plants. He, too, concludes that the sex of the individual is determined in the egg, but he does not attempt to push the question further than this general statement.

Lenhossek† has also discussed in a more popular form the question of the determination of sex, and he likewise urges that the sex of the individual is determined in the egg. His discussion of the relative number of males and females born in the human race is particularly instructive, but it would carry us too far here to discuss the conclusions at which he arrives.

Born‡ has carried out a series of experiments with mice, and finds that the amount of food given to the parents produces no effect on the relative numbers of males and females born. He also finds that the age of the parents has no effect, nor has close interbreeding. He arrives at the conclusion that the sex of the higher animals and plants is determined in the egg.§

In striking contrast to the general conclusions of Cuénot, Strasburger, Lenhossék, and of Born there are two more recent theories in which an attempt has been made to describe in detail how the sex of the individual may be determined in the egg. Beard's paper,‖ published in 1902, may be said, in a sense, to take up the problem where it was left by Cuénot. He attempts to bring the problem of the differentiation of the sexes into connection with the recent work relating to the origin of the reproductive cells or gametes. Beard tries to show that there are not only two kinds of eggs, but also two kinds of spermatozoa that correspond to the two kinds of eggs. It is supposed by him, however, that the determination of sex rests entirely with the egg, and that the spermatozoa do not have any influence on sex-determination. It is assumed, moreover, that one of the two

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* *Biologisches Centralblatt*, XX., 1900.

† 'Das Problem der geschlechtsbestimmenden Ursachen,' Jena, 1903.

‡ *Sitz. phys. med. Gesell. Würzburg*, 1902.

§ Born points out that while it has been shown experimentally that in hermaphroditic animals and plants, especially in the lower groups, it is possible to cause one or the other kind of sexual organs to develop or to be suppressed, that in the higher forms, at least in those in which the sexes are separated, it has been found that the sex can not be changed by external factors.

‖ *Zoologische Jahrbücher*, XVI., October, 1902.

kinds of spermatozoa has lost its power of fertilizing the egg and in most cases has become degenerate.

In respect to the occurrence of the two kinds of spermatozoa, Beard brings together rather a heterogeneous collection of facts. It has been known for some time that in a few cases two kinds of spermatozoa are found. The oldest and now the most thoroughly studied example is that of the snail, *Physa vivipera.* In this animal there are hair-like spermatozoa that resemble the ordinary forms of spermatozoa, and also worm-like forms which are as numerous as the other kind. A remarkable fact has recently been discovered by Meves in regard to these spermatozoa. An unusual and probably degenerate process occurs in the formation of the worm-like spermatozoon, so that instead of containing the reduced number (seven) of chromosomes it contains but a single one. In another form, *Pygæra,* this second form of spermatozoon contains no chromatin material whatsoever, *i. e.,* it is headless and presumably functionless as well.

In the long list of cases given by Beard in which two forms of spermatozoa have been described, there are several cases in which the two distinct forms appear to be always present and characteristic, as in the cases cited above; but he has also included some other cases in which giant spermatozoa occur, and some of these at least have been shown to be the result of a failure of the spermatocytes to divide. Until it can be shown that this failure to divide is usual and characteristic of one set of these spermatocyte cells the result may really have no bearing at all on Beard's contention.

Much more striking are the cases in which there is an accessory chromosome present in two of each of the four cells that develop from a single spermatogonial cell. The discoveries of McClung, Montgomery and Sutton in this connection indicate that there are two kinds of spermatozoa, and McClung has urged that this difference is connected with the determination of sex; but there is nothing more than the supposition that this may be so to go upon at present. In these cases, although the form of the spermatozoa is the same for the two kinds, there appears to be a difference in the amount of the chromatin material. It has not been shown that a difference of this kind would have any value in the determination of sex, and even if this were the case the results do not conform to the requirements of Beard's theory, as we shall see presently.

Beard calls attention to the fact that in nearly all the cases in which two kinds of spermatozoa have been described there is evidence of the degeneration of one of the two kinds. From this he draws the rather sweeping conclusion that throughout the animal kingdom one of the two forms of spermatozoa has become suppressed. He arrives at this conclusion in the face of an overwhelming body of evidence to the contrary, for in the great majority of forms all the spermatozoa that are formed develop in the same way and are, so far as we can see, capable of fertilizing the eggs.*

Beard's conclusions in regard to the determination of sex may be summarized as follows:

1. The sex of the individual is determined in the egg before fertilization.

2. The determination of sex probably takes place at the time of the reduction in the number of chromosomes.

3. Each egg and its two polar bodies are potentially of the same sex, either male or female.

4. A corresponding differentiation of the primary germ-cells takes place in the male. An early separation of the spermatogonial cells into male and female occurs. After this each cell may continue to divide, but remains of the sex that it has acquired in the differentiating division. Finally each of these cells produces four spermatozoa. This division is comparable to the one in the egg-series when the polar bodies are given off, so that each group of four spermatozoa corresponds to a female egg and its three female polar bodies, or to a male egg and its three male polar bodies; but in the cases of the spermatozoa the individuals are supposed to be without sexual qualities. It is the egg alone that determines the sex.

5. One set of these fourfold groups of spermatozoa Beard supposes to have become functionless, in the sense that even if it develops the spermatozoa have lost the power to fertilize the eggs. The other spermatozoa are functional so far as fertilizing the egg is involved, but, as stated above, take no part in the determination of sex.

Beard also advances certain views in regard to parthenogenesis. The sex of the individual that develops from a non-fertilized; *i. e.*, from a parthenogenetic egg, is not in any sense a consequence of the non-fertilization of the egg. Whether the individual is a male or a female depends entirely upon whether a male or a female egg has been produced. Whenever we find long series of parthenogenetic females, as in the aphids, developing from and also producing parthenogenetic eggs, Beard supposes that only female eggs have been produced in the ovary, and that the male eggs, which have appeared in one at least of the first generations of the germ-cells 'must be either delayed in their ripening or suppressed.' Here we meet with a paradox that is so

* Meves has recently found in a male bee that two kinds of spermatids are formed by an unequal division of the spermatocyte. The smaller of the two, although it begins to undergo changes similar to those which in the larger one produce a spermatid, appears to be arrested in its development before the change is completed. *Mittheilungen Verein Schlesw.-Holst. Aerzte*, XI., Mai, 1903.

patent and touches such a fundamental point of Beard's theory that it is more than surprising that he has said nothing about it. If the female aphid develops from a female egg (the polar bodies of which are on Beard's theory also female), we can understand why in the next generation she must give rise to female eggs, but why should males ever be again produced? Since it has been established beyond question that these parthenogenetic females do produce both males and females at the end of the summer, the question is where have the male eggs come from?* Beard appears to take for granted that a female egg can give rise to cells that become male eggs. If so his theory can have very little if any value, since the entire conception on which it rests, namely, the separation of the male and the female eggs at one division, is rendered valueless, I think, by the assumption that after such a thing has once taken place a female cell may in the next generation give rise to male eggs. Furthermore Beard's assumption, that the separation of the male and the female eggs occurs at the time when the reduction in the number of the chromosomes takes place in the egg, is pure guess-work, and not very good guessing either, for certain recent work indicates that the reduction in the number of the chromosomes involves a process that can have no conceivable connection with the separation of the male from the female elements of the egg. On the whole it does not appear that Beard has offered a very convincing theory as to how the determination of the sex of the individual is accomplished.

Castle† also has recently advanced certain hypotheses in regard to the determination of sex. In certain superficial respects his view appears similar to that of Beard, but closer scrutiny shows that the two views are essentially different in many important points.

Castle assumes that there are two kinds of eggs, male and female, and two kinds of spermatozoa, male and female. He supposes that both kinds of spermatozoa are functional in the sense that each carries with it the possibility of determining the sex of the individual, and each spermatozoon is also capable of fertilizing an egg, but a male spermatozoon can fertilize only a female egg and a female spermatozoon a male egg. It is evident, therefore, that Castle's idea in regard to the spermatozoa is fundamentally different from that of Beard. Furthermore, Castle supposes that the separation of the male from the female qualities of each egg takes place at the time when the second polar body is extruded, and, in consequence, the egg and one of the polar bodies will be female and the other two polar bodies male, or if the egg remains female, one polar body will be female and the

* The same paradox appears wherever a female contains male eggs.

† *Bulletin Museum Compt. Zoology at Harvard College*, January, 1903.

other two male. Similarly for the spermatozoa; two of each four (formed from the first spermatocyte) are female, and two are male.

The evidence on which Castle rests his assumption that there are two kinds of spermatozoa, as well as two kinds of eggs, is contained in the following statement: "That sex is borne by the egg is shown clearly by the case of parthenogenetic animals, which without the intervention of a male produce young of both sexes. That the spermatozoon also bears sex is manifest in the case of animals like the honey bee, for the egg of the bee, if unfertilized, invariably develops into a male, but if fertilized into a female." The finality of the conclusions drawn from these facts is by no means above question.

Perhaps the most distinctive part of Castle's paper is his attempt to apply the much-discussed Mendel's law to problems of sex-determination; an idea that had suggested itself to Bateson and Saunders, but had been rejected, because the 'distribution of sex among first crosses shows great disparity from the normal proportions.' Castle does not admit however the force of this objection.

A specific example may be the simplest way of illustrating Mendel's law and its application to sex as maintained by Castle. If a white mouse is crossed with a wild gray mouse all the offspring of this first cross will be gray like the wild mouse. The gray color of the gray mouse is said to be *dominant* and the white color (inherited from the other parent) does not appear, but is supposed to be present in a sort of latent condition. It is said to be *recessive*. If now these primary hybrid mice are interbred some of their young will be white and the rest gray in the proportion of one to three. If these white mice, when they become grown, are interbred their offspring will always be white as well as all their subsequent descendants. Some of the gray mice will also breed true, but the rest that are gray hybrids will, if interbred, give rise to some white and some gray in the proportion again of one to three. This is only a partial statement of Mendel's law, but will suffice for our present purposes.

The explanation that Mendel offered to account for the proportionate number of individuals that inherit the dominant and the recessive characters is very simple and is probably correct. As applied to our illustration of the mice it would be as follows: When the egg of the white mouse is fertilized by the spermatozoon of the gray mouse the fertilized egg and all the cells into which it divides contain chromatin material in the nucleus half from the white and half from the gray parent. The dark element dominates whenever the two are together, hence the first generation of hybrids are all dark. The cells of this primary hybrid that have gone into the reproductive organs (in the female into the ovary and in the male into the testis) are supposed to be at first like all the other cells of the body, and contain both white and dark elements.* But at some time in their later history, and presumably at the time when the egg sends off its polar bodies and at the time when the four spermatozoa are formed, a separation of the dark from the white elements occurs, so that two cells of the one kind and two of the other are formed. Thus the germ-cells are, as it were, purified, and consist of those that contain only white and of those that contain only dark elements. This is supposed to be the condition of the germ-cells in the ovary and in the testis of the primary hybrids.

Suppose now that these hybrids breed together, the white and the black spermatozoa will meet the white and the black eggs, and since it is a question of chance alone how they will come together, all possible combinations will be made. When a white germ-cell meets with a white one, a white individual results, and since it contains only white elements all its descendants will be white (if it is bred, of course, to white individuals). If a gray germ-cell meets a gray germ-cell, a gray individual will result, and all its purely bred descendants will be gray. If, however, a white and a gray germ-cell unite, the individual that develops will contain both elements in all its body-cells and, since the gray always dominates in such combinations, the individual will be gray, but will have the white as a recessive character that may crop out in subsequent generations. On the theory of chance combinations there will be twice as many of these gray-white individuals as of the white or of the pure gray. The series stands 2:1:1. Since in outward appearance all the gray-white mice are like the pure gray, we get three grays to every one white.

Let us now return to Castle's theory and see how he tries to make an application of Mendel's principle to sex. Just as there are two kinds of mice in our illustration, white and black, there are two kinds of sexual individuals, males and females. It is now assumed that the germ-cells, when they reach their final divisions, separate their male from their female elements, giving pure male and pure female eggs, and pure male and pure female spermatozoa. If, as in the mice, all chance combinations of the germ-cells are possible, there will result three kinds of individuals in the proportion of 2:1:1. The first of these, that are twice as common as either of the other two, would be *sex-hybrids*. If we assume, as in the mice, that one character always dominates in such a combination, the male let us say, there would be twice as many males of this hybrid kind as there are individuals of either of the other two pure kinds, and since there are as many pure males as there are pure females, there would be in all three times as many males born as females. Since we know that there is no such disproportion of one sex to the other, it appears absurd to attempt to

* More accurately, elements corresponding to the white and black colors.

apply Mendel's law to the problem of sex. Castle is therefore obliged to make a further assumption to avoid this difficulty. He assumes that a male spermatozoon can fertilize only female eggs, and a female spermatozoon only male eggs. There is no evidence known at present supporting this assumption, but it must be admitted that it can not be disproved, however improbable it may appear. On this view every fertilized egg is a sex-hybrid, and may give rise to a male or to a female according to which element dominates. Thus we return once more to our original question as to what determines the sex of the individual. We shall see presently that Castle fails to meet this fundamental question.

There is one result that Castle cites, which he claims indicates that his assumption that the eggs may show a selective power towards certain of the spermatozoa is not unwarranted. He found some years ago in the ascidian, *Ciona intestinalis,* that the eggs of one individual can not be fertilized by the sperm from the same individual, except very rarely. This case is cited as indicating that successful fertilization depends upon unlikeness between the gametes that unite. I have repeated this experiment on *Ciona* and have confirmed in large part this result, but, unfortunately for the point of view, I found in other ascidians that this relation does not hold. In *Molgula,* for example, the eggs are perfectly fertile with sperm from the same individual. Furthermore, by making the sperm of *Ciona* more active by adding ether to the water, I have been able to make them, under certain conditions, fertilize all the eggs of the same individual. In the light of these facts I do not think the conditions in *Ciona* can be given the interpretation that Castle has applied to them.

There is another side of Castle's hypothesis that must be briefly referred to, since he suggests a way of meeting a difficulty that is fatal to Beard's theory. I refer to parthenogenetic development and to the production at the end of a parthenogenetic series of male and female individuals. Castle supposes that in parthenogenetic reproduction the female character dominates over the male, when the two are present together, and that when a separation of the sex-characters takes place it does so at the time of the formation of the second polar body in the egg, and probably at the corresponding state of development in the spermatozoon. There is a fact in this connection, the bearing of which Weismann was the first to fully appreciate, namely, that the parthenogenetic eggs of daphnids and of some rotifers give off only one polar body, while eggs that are to be fertilized give off two polar bodies. Castle suggests that the second polar body is the female gamete, hence when it is given off the egg must become a pure male if it develops. If this polar body should be retained in the egg the conditions are exactly the same as when a female spermatozoon enters a male egg. Hence, since the female element dominates in these animals when the two sexes meet, the individual must become a female. Since therefore such an egg carries the male element in a recessive form, this element may, if it becomes separated from its female associate, give rise to a male. In this way the theoretical difficulty referred to above is met.

Let us follow out a little further the applications of this view. It is probable in the honey-bee that all the eggs give off two polar bodies. Consequently unfertilized eggs must produce pure males. If they are fertilized by female spermatozoa they will give rise to females, and, on the hypothesis, only female spermatozoa can enter male eggs.

In rotifers and certain crustaceans only one polar body is given off, but since this is the first polar body it does not involve the question of sex. Consequently the parthenogenetic eggs in these forms are sex hybrids. If at any time the conditions change so that one or the other sex element dominates, males and females may arise. But why the female element should dominate in some eggs and the male in others is not explained, and thus we are in exactly the same predicament as we were before Castle's hypothesis was proposed.

One case of special difficulty should not pass unnoticed since Castle has made an interesting suggestion that appears to clear up a difficulty, provided the facts on which the conclusion rests are confirmed. The eggs of the honey-bee extrude two polar bodies, as we have said, and hence are purely male. It is assumed that these males must produce spermatozoa that are female. This is a necessary assumption, because the eggs of the bee having extruded their two polar bodies are purely male, but become female after they are fertilized. Therefore the spermatozoon must bring the female element into the egg. Castle tries to meet this difficulty of the formation of female spermatozoa in a purely male individual by reference to a recent observation of Petrunkewitsch, namely, that the reproductive organ of the male bee develops not from the egg itself, but from the second polar body which fusing with one of the first pair reenters the egg. This second polar body is, on Castle's theory, purely female, hence the spermatozoa must be female. The ingenuity of the explanation is admirable, and rescues the theory from a fatal objection, but of course even if Petrunkewitsch's results are accurate (and they are not above suspicion) it by no means follows that the spermatozoa that come from the second polar body are female, as Castle assumes. The facts in regard to the parthenogenesis, and in regard to the special case of the bee, may possibly be given a much simpler explanation than that which Castle applies to them. For instance, if in certain insects the addition of the chromatin material of a spermatozoon (or what amounts to the same thing the chromatin contained in a polar body) determines that the egg shall become a female, we can explain the results without complicating the problem by the assumption of male and female spermatozoa, and male and female eggs. Castle's theory appears needlessly complex, and the whole attempt to apply the Mendelian principle to the question of sex does not appear to have been very successful. The weakest side of the theory has already been spoken of, namely, that it fails to account for the very problem that a theory of sex should explain, namely, the problem of what it is that determines whether an egg that contains both potentialities becomes a male or a female.

The reaction that has set in against the old view, that the sex of the embryo could be determined at a relatively late stage in development, is no doubt in the right direction. It has been shown in several cases by recent discoveries that the sex of the embryo is already determined in the fertilized egg, and in other cases it appears to be determined even before fertilization, but this need not mean that there are male and female eggs, and male and female spermatozoa. We have just examined two recent theories that rest on assumptions of this kind and have found, in my opinion, that they are both unsatisfactory. Let us see whether it may not be possible to bring under one point of view the old and the new discoveries in regard to the determination of sex, and construct a hypothesis that does not involve the idea that there is separation of the primoidia of sex in the germ-cells.

1. It has been shown in a few cases that two kinds of eggs are produced which become male and female individuals, in some cases with, in others without, fertilization. It may be erroneous to conclude from these facts that the eggs themselves are male and female in the sense that the elements (primoidia) that determine the sex of the embryo have become separated and confined to male or to female eggs. In a case like that of the silk-worm, where a graded series exists, the size of the egg appears to be the determining factor in respect to which sex develops, not that the female sex-elements are found only in the large eggs, and the male elements in the small eggs. It seems more reasonable to assume on the contrary that both elements are present in all kinds of eggs. In other cases other factors than that of size determine which sex develops.

In regard to the two forms of spermatozoa that have been found in a few species, there is no evidence that one sort contains only the primoidia of a male individual and the other kind those of the female. In those arthropods in which an accessory chromosome has been found we have no evidence to show that this chromosome is the male or the female element, and so long as we know nothing at all in respect to the conditions in the egg it is useless to speculate further on these cases.

2. There is experimental evidence pointing to the conclusion that factors, external to the egg itself, may determine in some species what kind of eggs will be produced, as in *Hydatina,* and in the aphids where a change in the food causes the appearance of males and females. In bees the addition of the chromatin of the spermatozoon appears as a rule to determine that the egg gives rise to a female.

In other cases it appears that the addition of the chromatin in one of the polar bodies may accomplish the same result. Here the relation may be purely a quantitative one. In other animals the addition of the spermatozoon to the egg is not, it appears, the factor that determines the sex.

3. It is known in bees and in butterflies that individuals sometimes appear that are male on one side of the body and female on the other side. The explanation of this peculiarity may be found in the unusual way in which the nucleus of the *fertilized egg* is divided. If, for instance, all or most of the chromatin brought in by the spermatozoon should be carried into one of the first formed cells along with half of the chromatin of the egg-nucleus, then all the cells that descend from this cell may develop female characters, and all those from the other, male characters. This need not mean that the spermatozoon has brought into the egg female characters that dominate in all the cells in which it is contained, but only that those cells that contain more of the chromatin differentiate their female characters, and all those cells that contain less chromatin differentiate their male characters only.

4. Having discovered that the sex is already determined in the unfertilized egg in some cases, and in others that it is connected with the process of fertilization, the question at once suggests itself whether the determining influence comes from the nucleus or from the cytoplasm. At present we have no conclusive evidence pointing in either direction. That the quantity of the nuclear material may be important seems probable in the case of the bee. That the size of the egg, which is due to a greater amount of cytoplasm, may be a factor in the result seems in other cases to be important, but so long as we do not know what relation the nucleus bears to the cytoplasm in these forms we can not decide as to the meaning of greater volume as a sex determinant. If, as seems highly probable, identical twins come from halves of the same egg, then since the pairs may be of either sex it seems to follow that the absolute size of the egg is not a factor. Whether in these cases the relative amount of chromatin in the nucleus enters into the problem remains to be shown.

It should be pointed out that while we must suppose that the influences in the embryo that control the *development* of one or of the other sex reside, or have resided, in the nucleus of the egg, this is a different question from that as to whether the nucleus or the cytoplasm of the egg determines which of the two possibilities that are potentially present in the nucleus shall be awakened.

5. Our general conclusion is that while recent theories have done good service in directing attention to the early determination of sex in the egg, those of them which have attempted to connect this conclusion with the assumption of the separation of male from female primoidia in the germ-cells have failed to establish their point of view. The egg, as far as sex is concerned, appears to be in a sort of balanced state, and the conditions to which it is exposed, even when it is not fully formed, may determine which sex it will produce. It may be a futile attempt to try to discover any one influence that has a deciding influence for all kinds of eggs. Here, as elsewhere in organic nature, different stimuli may determine in different species which of the possibilities that exist shall become realized.

THE ACADEMY OF SCIENCE OF ST. LOUIS.

A BIOGRAPHY.

BY PROFESSOR WILLIAM TRELEASE,
MISSOURI BOTANICAL GARDEN.

WHEN the Henry Shaw School of Botany was inaugurated as a department of Washington University in 1885 the venerable Dr. Eliot, then president of the board of directors and chancellor of the university, said that more than forty years earlier, five or six young men, of whom he was one, met together on Main Street, near Chestnut, in the office of Judge Mary P. Leduc, their object being to found an academy of science: "But," he said, "not one of our number knew enough of science to found a primary school, except Dr. George Engelmann, who was an enthusiastic student, especially in botanical research, and who inspired us all with something of his zeal. We organized a society and proceeded to purchase five or six acres of ground, far out of the city, I think near Eighth Street and Chouteau Avenue. There Dr. Engelmann began a botanical garden and arboretum on a small scale. It was kept up, after a fashion, for some years, but the society faded out and the land was sold, and apparently there was an end of the academy; but under the law of the survival of the fittest, Dr. Engelmann 'survived' and became an Academy of Science in himself."

Engelmann, however, was not the kind of man to work indefinitely without closer association with the few other St. Louis men interested in science than was afforded by chance, and on March 10, 1856, after several preliminary meetings, the existing Academy of Science of St. Louis was organized. It is recorded that the men in attendance at the meeting for organization were, in addition to Dr. Engelmann, who acted as chairman, Charles P. Chouteau, James B. Eads, Nathaniel Holmes, Moses L. Linton, William M. McPheeters, Moses M. Pallen, Simon Pollak, Charles A. Pope, Hiram A. Prout, Benjamin F. Shumard, Charles W. Stevens, William H. Tingley, John H. Watters and Adolphus Wislizenus.

A previously appointed committee, consisting of Tingley, Prout, Shumard and Holmes, reported a constitution and by-laws, which were adopted. The original constitution, which was amended somewhat in the course of the first year, consists of six articles, referring respectively to style, objects, members, officers, meetings and amendments. The second article is so important that it is here quoted in full:

Section 1. It shall have for its object the promotion of science: it shall embrace zoology, botany, geology, mineralogy, paleontology, ethnology (especially that of the aboriginal tribes of North America), chemistry, physics, mathematics, meteorology and comparative anatomy and physiology.

Section 2. It shall furthermore be the object of this academy to collect and treasure specimens illustrative of the various departments of science above enumerated; to procure a library of works relating to the same, with the instruments necessary to facilitate their study, and to procure original papers on them.

Section 3. It shall also be the object of this academy to establish correspondence with scientific men, both in America and other parts of the world.

Membership was divided into associate and corresponding classes, the former, constituting the main body of the academy and exclusively entrusted with the conduct of its affairs, to include 'men desirous of cultivating one or more branches of science above enumerated,' while corresponding membership, as is usual in such cases, was intended for eminent men of science and other persons not residing in or near the city, but disposed to further the objects of the academy by original researches, contributions of specimens or otherwise. The customary provisions were made for election, lapsing of membership and expulsion for cause, no person expelled being under any circumstances admissible to reelection. The provisions referring to officers, meetings and constitutional amendments are such as are usually adopted.

The original by-laws likewise contained six articles, referring respectively to committees, library, museum, communications, meetings, and authority. Apparently provision for amendments was not thought of, or was considered unnecessary.

The scope of live interest of the original members may be inferred from the section providing for standing committees, which were to represent ethnology, comparative anatomy, mammalogy, ornithology, herpetology and ichthyology, malacology and chemical geology, entomology, botany, paleontology and geology, mineralogy, chemistry, physics, embryology and monstrosities—in addition to library and publication committees. These standing appointive committees, in conjunction with a board of curators provided for in the constitution as elective officers, were charged with the care of their respective departments and expected to make exchanges of duplicates, to arrange, label, catalogue and keep in order all donations and deposits, and to report in writing at a specified meeting each year. The somewhat quaint by-laws referring to the library and museum contain such provisions as were thought desirable to ensure the greatest good to the greatest number in their use. The article on communications provides for the reference of those designed for publication to special committees, for the preservation in the archives of all, whether published or not, and for discussion of original papers on the subjects before enumerated. Fortnightly meetings were arranged for, with an adequate order of business, and current rules of order under the heading 'authority.'

Steps appear to have been taken promptly for securing a charter or act of incorporation from the legislature, and such an act was passed the next winter, approved on the 17th of January, 1857, and presented and adopted at the academy meeting of February 9 following.

The charter provides that under the name of The Academy of Science of St. Louis the incorporators and their associates and successors shall have perpetual succession, may sue and be sued, implead and be impleaded in the courts, may acquire and dispose of real, personal or mixed property for the advancement of science and the establishment in St. Louis of a museum and library for the study of its various branches; that they may have a common seal and break or alter the same at pleasure, and may make and alter such constitution, regulations and by-laws, not contrary to the laws of the land, as may be requisite for their government. Exemption from taxation is provided for all property owned or held by the academy so long as it is held and used in good faith for the designated objects, except that leasehold interests which may be granted to other persons are made taxable. It is distinctly stated that members acquire no individual ownership in the property and effects of the academy, their interest in the same being declared to be usufructuary merely, and not to be transferred, assigned, hypothecated or otherwise disposed of except by corporate act of the academy: and whenever the corporation shall have failed to answer the purposes for which it was created, or shall suffer its charter to be forfeited by the law of the land, its cabinet, collections and library are to revert to and become vested in the City of St. Louis, to be deposited with some public institution in the city, for general use and inspection, under such regulations as the city may prescribe.

One or two of the gentlemen present at the first meeting appear to have taken little active part in the affairs of the academy, but most of them were evidently much in earnest, and these, as well as some of those whom they proceeded to elect to associate membership, attended the fortnightly meetings with regularity. Arranged in the order of the frequency with which their names are recorded in the roster of members at the meetings of 1856, these more active charter members stand thus: Pope, Holmes, Pallen, Pollak, Stevens, McPheeters, Prout, Shumard, Engelmann, Wislizenus, Eads, Tingley and Chouteau. It is not difficult to analyze the constitutional provisions and the early activity of the academy in connection with the interests and attainments of these original members.

Charles A. Pope was one of the most brilliant surgeons of the West, and dean of the St. Louis Medical College. He is said to have possessed personally a very valuable museum collection, representative of morphology and comparative anatomy. The records for 1856 show that at the meetings of that year he presented to the academy or deposited with it 'A specimen of eyeless fish (*Amblyopsis astacus*) from Mammoth Cave, Ky., petroleum from Arkansas, and an insect, also specimens of rock salt and other minerals from Hallam near

Salzburg'; 'Specimens of *Productus* from the Carboniferous limestone of St. Louis Co.'; 'A weasel'; 'Specimen of a grizzly bear'; 'An interesting suite of Cretaceous and Tertiary fossils, specimens in zoology, and Indian curiosities'; 'Two specimens of horned frogs from South-West Missouri'; 'Indian curiosities . . . also a fine specimen of fossil turtle (*Testudo Oweni*) from Nebraska'; 'Specimen of *Heliophyllum Halli*, a *Chaetetes*, and a *Spirifer*'; 'A specimen of tarantula, found . . . seventy miles below St. Louis' and 'A tarantula and a centipede from Texas, also shells from North Alabama.' He was better able than any other member to afford material assistance to the academy in its early days, through his connection with the medical school, and promptly offered to the new body a meeting room in the building of the O'Fallon Dispensary, connected with the Medical School, and the use of the collections in his hands. He was made chairman of the committee on comparative anatomy.

Nathaniel Holmes* was a lawyer of wide interests and versatile talents who later removed to Cambridge as Royal Professor of Law in Harvard University. He was promptly elected corresponding secretary, and held that office for many years, making a practice of intelligently reading the more important of the academy's exchanges—for the reception of his analyses of which a special order of business was established. It was mainly through his efforts that the academy was placed on the mailing lists of foreign bodies at a time when it had nothing to offer in exchange, and in this way he contributed more, perhaps, than any other member to perpetuating it when its life flagged.

Moses M. Pallen † was one of the active physicians of the city, and a professor in the St. Louis Medical College. He was made chairman of the committee on herpetology and ichthyology.

Simon Pollak, who died in St. Louis a few weeks ago, at a very advanced age, was an active physician.

Charles W. Stevens was a physician, an excellent anatomist and a professor in the St. Louis Medical College. He was made chairman of the committee on mammalogy, and, before the end of the year, recording secretary.

William M. McPheeters, still living in St. Louis, and the sole survivor of the founders of the academy, was a physician of broad interests and a professor in the St. Louis Medical College. He was made chairman of the committee on entomology.

Hiram A. Prout ‡ was a physician. He was made chairman of the curiously devised committee on chemical geology and malacology. He appears to have taken an active part in most of the meetings that he attended.

Benjamin F. Shumard § was a physician and also a professional geologist well known as an authority on paleontology. He was at this time occupied with the geological survey of the State, and soon after the organization of the academy was made state geologist of Texas. He was naturally chosen as chairman of the committee on paleontology and geology.

George Engelmann ‖ was likewise a practising physician, who found much time for scientific research. He was a recognized authority on botany, and, among other interests, cultivated meteorology, and he was justly regarded as the leading scientist of the west. He was the first president of the academy, was frequently reelected to that office, and stimulated many of its activities.

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* Trans. Acad. Sci. of St. Louis. **11**: xxvii.

† Trans. Acad. Sci. of St. Louis. **3**: ccxxii.

‡ Trans. Acad. Sci. of St. Louis. **2**: 178.

§ Trans. Acad. Sci. of St. Louis. **3**: xvii.

‖ Trans. Acad. Sci. of St. Louis. **4**: xc, and Supplement.

Adolphus Wislizenus * was a physician, intensely interested in meteorology, electrical phenomena, etc. He was made chairman of the committee on ethnology.

James B. Eads † was a civil engineer, broadly trained and interested in the scientific aspects of his profession. His name will long be remembered in connection with the first St. Louis bridge and the jetties at the mouth of the Mississippi River—his creations. He was made chairman of the committee on physics.

William H. Tingley was a physician, and actively served the academy as secretary until his removal from the city, which occurred before the end of the first year.

Charles P. Chouteau ‡ was the St. Louis representative of Mr. Astor's great fur house, an extensive traveler in the Northwest, and in close touch with the work being done by Hayden in the then new and still wonderful 'Bad-Lands.' At the meeting of April 21, 1856, he offered to deposit with the academy (and to present his personal interest of about one fourth in them) the collections already made by Hayden, as soon as a place was fitted to receive them. This gift was but one of many, and he soon put the academy in the way of utilizing the great resources at his command in the many trading posts of the upper Missouri and its tributaries.

It is not by chance or without significance that 'M.D.' is affixed to the names of all the founders of the academy except Chouteau, Eads and Holmes, or that before the end of the year 1856, when the original associate membership of 15 had been increased to 104, no less than 35 of the first additions to the roll were also physicians, for it was in the courses preparatory to and immediately concerned with medicine that the chief opportunity for scientific study lay half a century ago.

At the first meeting of the academy Dr. Engelmann called attention clearly to the fact that its firm establishment demanded the provision of an endowment fund; and it was also noted that the valuable collections of fossil remains and other natural objects then in the city ought to be secured for permanent preservation. Little success appears to have rewarded the efforts to raise money; but by making almost every one of the original members the head of a committee charged with some branch of museum activity, the acquisition of specimens was greatly stimulated. The record of Dr. Pope's gifts during the first year might be paralleled, if not equaled, by entries concerning the gifts of other members.

After one or two abortive efforts to affiliate with the new academy a private museum which then existed in St. Louis, Dr. Pope's offer of a home with the medical school was accepted, and the property of the earlier Western Academy of Science, referred to above, was given to swell the rapidly growing collections. The museum was evidently the first love and mainspring of the new academy. Though money was not available for extensive purchases, and the records show that even a

* Trans. Acad. Sci. of St. Louis. **5**: xxxvii, 464.

† Trans. Acad. Sci. of St. Louis. **5**: xiii.

‡ Trans. Acad. Sci. of St. Louis. **11**: xxi.

taxidermist was kept for a time to care for the material which was presented only through the advance of his salary by members month by month, one of the first principles in museum administration was practically recognized before the end of April in the authorization of a collecting trip in search of some important fossils that were then being talked of; and Mr. Chouteau several times allowed a representative of the academy to accompany his parties into the northwest.

In gathering the nucleus of a library, which went hand in hand with the formation of a museum, letters were sent to learned bodies which published scientific matter. In the course of this correspondence it was learned that the valuable Smithsonian 'Contributions to Knowledge' could be sent only to societies able to offer an equivalent in published matter, which clearly brought before the new academy the exchange value of such publications; and even before this point was so emphasized, a committee had been appointed to consider the question of undertaking some publication on the part of the new academy. At the meeting of August 25, 1856, preliminary steps were taken toward launching this venture, though the members present seem to have been in doubt not only regarding its financial possibility, but as to the productive activity of the small working membership. At the next meeting, however, the practicability of undertaking the publication of papers was shown, and doubt as to the immediate power of the academy to furnish creditable matter for publication was removed by Dr. Shumard's offer of a paper by himself and Dr. John Evans, on new species of fossil shells from the Cretaceous formation of Nebraska. Other papers were soon handed in, and the initial number of the new 'Transactions' was issued early in 1857. It contained, in addition to the charter, constitution and by-laws, journal of proceedings, etc., this paper by Evans and Shumard, a description of a new *Productus* by Prout, an account of glycerine by Schiel, a paper on phyllotaxis by Hilgard, an account of certain *Mastodon* remains by Koch, a study of the inscriptions on a brick from Nineveh by Seyffarth, an account of Indian stone graves in Illinois by Wislizenus, descriptions of new crinoids by Shumard, an account of the geological formations underlying St. Louis, as shown by the Belcher artesian well borings, by Litton* and the first of a long and important series of local meteorological records by Engelmann and Wislizenus.

There does not appear to have been much change in the academy during the first few years of its life. Before the end of the first year, Engelmann, to whom the elaboration of the Cactaceae collected on the United States and Mexican boundary survey had been entrusted, so

* Dr. Abram Litton (Trans. Acad. Sci. of St. Louis. **12**: xxiv) was elected at one of the first meetings after the organization of the academy and was the first thoroughly trained chemist west of the Mississippi. He was made chairman of the committee on chemistry.

arranged his medical practise as to permit his absence for about two years, spent with Gray and in Europe—and a new president was of necessity elected; but the office was well filled by Shumard, who during this period was the leading investigator among the members. Meetings were held regularly. The museum continued to grow, and accessions to it to be reported. Occasional and for the most part good papers were contributed to the transactions, thus furnishing means for the increase of the library through exchanges, and Holmes presented abstracts of the most important or interesting of the accessions. But the raising of money for other than current purposes seems to have been given up, and with the hard and trying times of the civil war the border city of St. Louis could have been expected to concern itself but little with science. And yet in the gloomy year of 1863 twenty-two meetings were held, with an average attendance—ignoring two meetings for which the number is not recorded—of eight members. At these meetings letters were read from corresponding members, of whom a goodly number of the distinguished men of the day had by this time been elected, and from institutions with which relations had been established; and exchange publications were laid on the table and discussed. For some meetings nothing more is recorded, but a knowledge of the men who were constant in their attendance makes it certain that much unrecorded comment on the scientific work and spirit of the times should be read between the lines of the journal. On other occasions scientific communications or informal accounts of work in hand were presented. In his report on that year's activity of the academy, Engelmann justly takes pride in the collections and library already acquired, the inauguration of the second volume of transactions, and the fact that two hundred exchanging institutions of science, in all civilized countries, were bidding God-speed to the struggling St. Louis body. Only sixty active members, however, were reported at this time, and the publication of transactions had placed a *per capita* debt of about ten dollars on each of these. The testimony of surviving members of this period is not needed to show that the life of the academy then hung in the balance; but the men who were interested in its existence were not the sort of men who let their efforts come to naught, and it would have been more surprising if it had died than that it lived. The war came to an end, the country, freed from the great strain it had been subjected to, prospered, new members came to replace those who had died or removed, and the academy continued to exist.

In retrospect, we are often tempted to wonder what would have come about if some particular thing had or had not happened; and the temptation is present here. The thing that did happen at this point in the history of the academy was a disastrous fire which destroyed that part of the medical building in which the academy met, early in 1869, and wiped out the collections of Dr. Pope, and with them nearly all of the academy's museum. The library, then numbering not far from 3,000 volumes, fortunately was saved, through the activity of a few members, and most of the reserve copies of the academy's transactions, which had been covered by a falling floor, were included in this salvage.

Even before the fire, the academy had outgrown the accommodations that had been given it by Dr. Pope, as is shown by the appointment, some time before, of a committee to try to secure new and more ample quarters. Without the check of this fire, cramped surroundings might perhaps have caused stagnation in the material growth of the academy: but the loss of the museum effected lasting and at the time all but complete paralysis of this side of its activity. Still, out of the fire came sympathy, encouragement and some help. New quarters were offered in the public school board's building, and the public school library shelved its books; but the academy was a tenant-at-will, restricted in its powers, without funds for amplifying its collections or properly caring for them, and the need of putting it on a safer basis was so unmistakable that in 1872 a serious effort was again made to secure endowment funds. As a result of this effort, which was shared by the Missouri Historical Society, the academy was made the recipient, through the generosity of Mr. James H. Lucas, of a building site on which a home for the two societies was to be erected. Only $50,000 was considered necessary for the construction and maintenance of an adequate building; but even this sum was not forthcoming, so that ultimately the academy sold its share in the building site and put the money out at interest, and still has it, with some additions, safely invested.

For another dozen years the academy continued to meet in the quarters to which it moved after the fire. Another effort to secure a home was made and failed. Then for a like period it enjoyed the hospitality of Washington University. When the rooms that it occupied there were needed for university purposes, more than a decade since, it became a tenant of the Missouri Historical Society, which, unlike the academy, had at last secured a home of its own. There was thus secured a meeting room and limited shelving for the library, but such museum material as the academy possessed has been stored, for the most part, in basements and out-of-the-way places, where it has been of little use to members or to the public.

The interest felt by the early members in scientific effort at the great centers of such activity, as has been said, led to early association with prominent workers abroad, from whom publications and communications were received. The prompt establishment of such relations, fortified by the commencement of the academy's own activity as a publishing body, quickly resulted in the formation of a valuable scientific library, especially rich, naturally, in the publications of organizations having objects similar to its own. Most of these exchanges have been received without interruption, and prove invaluable to investigators who desire to go into the earlier literature of their subjects. At the end of 1902, 569 exchanging institutions were reported by the librarian, and the library contained 14,491 books and 11,017 pamphlets. Unfortunately, lack of room has caused these to be rather difficult of access for some years past, and the index, started many years ago by Dr. Baumgarten, has fallen into arrears. The latter fault, however, is in process of correction, and it is believed that the library will be more usable and more used in the future than has been the case heretofore.

In the homeless state in which the academy has passed the last third of a century, little inducement has been found for the accumulation of museum material that could not be displayed and could scarcely be housed. Some things, however, there are, which will form a nucleus for the museum of the future, for while the activity of the academy has been concentrated of late on holding meetings and publishing its transactions, the original inclusion of a museum among its prominent objects has been neither forgotten nor discarded. Among the present collections are a dozen or so of good fossiliferous slabs from various formations, some of them of unique value; a few remnants of the Hayden collection saved from the fire, containing among other things the type of *Tetanotherium Prouti;* a good specimen of *Bos cavifrons;* some ten thousand paleontological specimens brought together by Yandell, containing his own types and those of many of the species described by Shumard, whose own poorly preserved collection, of about the same size, is owned by Washington University; several hundred specimens of pottery from the mounds of southern Missouri, on which is based a quarto publication by Evers, issued by the academy some years since; two or three dozen human crania from the same district, the measurements of which have proved so divergent from those of skulls of comparable periods that those to whom their study was entrusted have never ventured on a description of them; several dozen meteorite specimens, of which the most important is one originally weighing about 35 pounds, which is described and figured in the first volume of the academy's transactions; and a collection of over 600 butterflies, beautifully mounted on Denton tablets, was presented to the academy a few years ago by subscription, through the efforts of Mrs. W. L. Bouton.

It may seem to have been by chance, but I think it appears from what has already been said that it was not, that the early existence of the academy was closely associated with the St. Louis Medical College, and that leading members of the faculty of that institution have always been among its active members. Too much credit can not be given to these men when the history of St. Louis comes to be written. Busy physicians, they gave their services free of cost to the school they established, letting its earnings go to form a permanent medical fund, the ultimate wise use of which they did not question, though they provided against its alienation. Step by step they raised the grade of their school until it compared favorably with the best of the Eastern medical schools, though in doing so they sacrificed financial success; and at length, that it might enjoy the broadest affiliation, they merged it with Washington University, in which St. Louis always has had confidence and in the development of which it feels justifiable pride to-day. And yet, though professional men, they did not go into the academy for 'shop talk.' The meetings have never been closed to discussions of interest to the medical profession, but of their own volition these men presented only subjects of scientific interest. Even while they were the principal active members, geology, meteorology, botany and ethnology were the chief subjects of discussion, and the papers presented for publication show a keen discrimination between the art of medicine and the sciences, on some of which it rests.

Up to the time of its removal from Washington University, the academy met in a rather informal manner. My own connection with it dates from the autumn of 1885, when I came to the city to live. The notices that I received were more commonly to the effect that the next meeting would be held at a certain time and place than with any indication of what would be done at the meeting. On a long table were to be found the recent additions to the library. At the head of the table sat the president and recording secretary. Around it were half a dozen or a dozen members who looked over the papers between attending to the items provided for on the order of business. When 'written communications' were called for, a paper for publication might be handed in, sometimes accompanied by an oral abstract, sometimes not. The order 'oral communications' was pretty sure to lead some member to produce a specimen, piece of apparatus, or recent publication, on which he spoke, usually in a way to interest everybody present. Not infrequently nearly the entire body, like a German scientific gathering, gravitated after adjournment to a summer garden or winter 'Lokal,' where the discussion was apt to be continued over a glass of beer until the younger men felt that it was time for them to set their faces homeward.

Ladies were occasionally interested in the rumor or announcement that some particular paper was to be presented, but they appeared awed by the informality of the seating about the board, and could rarely be made to feel welcome after a tortuous wandering through the long halls and museum at the top of the University had led them to it. In the meantime the membership had greatly changed. Shumard, Prout, Pope, Swallow, Eads, Holmes, Wislizenus and Engelmann had dropped from the active workers. Even the places of their successors had been taken by a younger generation, and the number of non-professional members had been very greatly increased.

These are some of the causes which led to a serious consideration, in 1893, of means for further widening the academy's influence and usefulness, a first step toward which was the appointment of a committee to report on the desirability of a revision of the constitution. On the report of this committee, the constitution was considerably changed, not in essentials, but radically by the adoption of a letter ballot for elections, amendments and the like, in place of the vote formerly taken at a regular meeting after due notice of the business to be done; and by provision for the election of a non-office-holding committee each winter to nominate officers for the ensuing year, with the privilege of additional nominations from the floor when the committee reported.

Direct effects of these provisions were to check a perfunctory re-nomination of officers to which informal nomination on the spur of the moment may lead along the line of least resistance and to place the franchise in the hands of the entire membership instead of leaving it through non-attendance to the few members who might be at the meeting when a vote was taken. Current matters of administrative business were also taken out of the hands of the membership and directly vested in a council, consisting of the principal officers. No doubt the general result of the innovations was good.

Some notable changes in the life of the academy showed themselves very soon after the revision of the constitution and the removal of the meeting-place from Washington University to the building of the Missouri Historical Society. For instance, the provision of a nominating committee having time for reflection and compelled to hold a meeting for the preparation of a list of nominees has led to a more frequent nomination of men of affairs for the offices of president and vice-presidents, as a means of identifying the non-professional majority of the members with the life of the academy, in place of the customary election to those offices of the most distinguished scientific men on the roll, or of those whose attendance was most constant; and the removal of business details from the meetings has cut out many spicy discussions on the financial standing and intentions of members in arrears and other non-technical matters, leaving the sessions free for the strictly scientific purposes of the academy.

Perhaps the most noticeable change of this period has been in the character of the program. In its new quarters, the academy met in a formal lecture room, with a platform for the presiding officers and regularly placed seats for the audience, the exchanges being displayed in a separate room, for inspection before the meeting. Attendance was made easier and the presence of ladies was more frequently noted; but almost in the turn of a hand, the charming impromptu character of the meetings gave place to formality. Current publications were not brought in by those who, if they had had them in hand, would have commented on them. Specimens not announced were not brought to be shown if opportunity offered. Apparatus, chiefly from the laboratories of the university staff, which had been easily exhibited when the meetings were held under the university roof, was rarely taken down, transported and rearranged where facilities were few, with the certainty that the reverse process must be gone through in the busy hours of the following day. So it quickly came about that if nothing was announced for a given meeting little or nothing was offered, and the council was thus compelled to provide a stated program for each meeting, which contributed to cut out the last remnant of spontaneity in offering the many small things which go to make up the daily life of the teacher, investigator or reader, and which, fresh from his own life, are of greatest interest to his associates. To counteract this regrettable loss, the council, for the greater part of the past decade, has striven to make the program of evident interest to the non-professional members by providing, at least for alternate meetings, lectures divested of technicalities on matters of current scientific progress. Do what they may, however, though they have succeeded in winning the approbation of the non-scientific contingent, they have not much more than doubled the average attendance, while the membership has correspondingly grown; and they have not secured the attendance of any considerable number of members or other persons not themselves closely identified with pure or applied science.

It has been evident for several years past that the accommodations at the historical society's building were inadequate to the needs of the academy, and access to the building had become less convenient because of great changes in the location of the residence section of the city. This led to another effort being made, a year or two ago, to secure the much needed building; and again little reason was found for hope. But during the present year, as a gift from Mrs. William McMillan and her son Mr. William Northrop McMillan, the academy has been put in possession of a building, conveniently located with reference to intersecting car lines traversing the now widely separated residence districts. It was originally built for a private school, and has therefore been found directly adapted to many uses of the academy; such changes as were needed and practicable have been made, and the building has been renovated and equipped with modern heating and lighting appliances.

With the opening of the fall, therefore, the academy, for the first time in its existence, meets in its own home, and this, fortunately, not only without any encumbrance of debt, but with a small invested fund which its friends now hope to see rapidly swelled to an adequate endowment. It may safely be said, therefore, that the hitherto always present question whether or not the academy might some day find itself without a meeting-place or the means of securing one is finally answered in a very satisfactory manner; and official and personal expressions without number testify to the warm gratitude with which those who have so long struggled with little more than hope to support them have witnessed the laying of this solid foundation of security for the future. That their struggles are at an end, however, they can not flatter themselves. Ample as the new building is for the present life of the academy, it is but temporarily suited to the housing of valuable collections, since it is not fire-proof; and one of the first things for future activity to accomplish is the provision of a suitable fire-proofed library and museum at the rear of the present building—for which ample space exists. Very unfortunately, too, while the academy is nominally able for the first time in many years to arrange its library and more important collections for convenient public use, it is actually confronted by the necessity, which has heretofore been felt by its late host, the historical society, of utilizing no inconsiderable part of its new home for purposes of revenue, by housing other homeless bodies, so that, as heretofore, its publication resources may be maintained. It is probable that many a vision of a reading room in constant use by investigators and science teachers, and of synoptical rooms thronged with nature and science classes from all grades of the schools of the city, will still be dreamed for some years by the council before giving place to the realities. That the academy will ultimately be enabled to perform this part of its functions, however, should now be certain; and the arousing of public interest in such matters which the world's fair and its congresses and the national scientific meetings of this winter are sure to lead to, makes it reasonable to hope that the time when this may be accomplished lies not very far in the future.

In its inner life, as well as in its outer semblance, the academy is not unlikely soon to experience marked changes. Its activity as a center of publication will doubtless remain unchanged. With the growth of the city, of the medical schools and of Washington University, with which many of its most active members have always been connected, scientific results of merit are certain to be offered for publication in increasing number; and there is little reason to question that in the future, as in the past, no paper of real value will lie long in manuscript awaiting the funds essential to its publication. As is necessarily true of most learned bodies, the world over, the academy's transactions are of an undesirable heterogeneity in their subject-matter, but their publication in brochures, each devoted to a single paper, ensures the availability of each paper when the entire volume is not desired; and if a national agreement were ever to be reached by which the functions of publication were delegated by the principal scientific bodies to a central bureau, in such manner as to secure a subject division of volumes, it is not probable that the Academy of Science of St. Louis would be found to oppose such a step, though its isolation may prevent it from taking the initiative.

Perhaps the most probable immediate change in the inner working of the academy lies in the direction of its meetings. It is hardly to be expected or even hoped that these as a whole will ever revert to the character of those held when Holmes presented critical and spicy analyses of the contents of such publications as came to hand, or Engelmann or Riley chatted from the master's seat on investigations being carried on. Publications to-day are too complex for most amateurs of science to care to follow them in detail, and the minutiae of current research promise but small audiences for their advance presentation.

In these changed conditions lies the mainspring of probable changes in the organization and meetings of the academy. No doubt, as heretofore, the results of research offered for publication will be presented at the general meetings, the manuscript, with data for discussion by experts, if these are present, lying on the table, and the processes and conclusions being briefly and clearly presented in abstract from the floor. No doubt, too, at such intervals as may prove best, specialists will continue to present in untechnical language, comprehensible to laymen and teachers, analyses of progress achieved in the scientific world. But it is more than probable that these general meetings will be supplemented by others held by small sections of restricted aims, within each of which will be found the enthusiasm for current literature and the warm interest in special detail that characterized the earlier meetings of the academy as a whole.

Under the constitution, such sectional organization is provided for. If I do not mistake the drift of the times, the growing number of engineers and chemists, whose professions rest upon and demand a continued touch with the current progress of science; of physicians and pharmacists, whose professional life is full of opportunities for the observation and record of scientific detail and generalization and of teachers with university training, but so fully occupied with the daily routine that they can not for the moment do research work although they can not afford, if they would, to lose touch with what others are doing in biology, chemistry and physics—are going to find in the organization of sections in the academy the most logical and economical way of meeting their own needs, while through community of interest they will reach a unity of purpose which will inevitably react on the entire community, to the common good.

THE TETRAHEDRAL KITES OF DR. ALEXANDER GRAHAM BELL.*

By GILBERT H. GROSVENOR,

EDITOR OF THE NATIONAL GEOGRAPHIC MAGAZINE.

I HAVE been asked by the editor of The Popular Science Monthly to write an article for that journal describing the tetrahedral kites of Dr. Alexander Graham Bell. I am glad to comply with his request, especially as I have had the good fortune for several summers past to watch the marvelous kites which Dr. Bell has been building in his laboratory at beautiful Baddeck, Nova Scotia. In this brief article there is not space to describe all the experiments that have been made, and I shall endeavor to explain, therefore, only the more important principles that I have seen evolved.

Dr. Bell began building kites in 1899. He was led to experiment with them because of his interest in the flying machine problem and his belief that a successful kite will also make a successful flying machine. A kite that will support a man and an engine in a ten-mile breeze will probably also support the man and engine when driven by a motor at the rate of ten miles an hour. This proposition has not been actually proved, but there can be little doubt that it makes no difference whether the kite is supported by the motion of the air against it or by its own motion against the air.

In a calm a kite rises when it is pulled by a man or horse, because of its motion through the air; there is no reason to believe that it would not also rise when urged through the air by propellers. A kite then can be changed to a flying machine by hanging a motor and propellers to it and dropping the string which attaches the kite to the ground.

The first kites that Dr. Bell built for his experiments were of the Hargrave box type, which had been the standard kite since its invention by Mr. Laurence Hargrave, of Australia, in 1892. Small Hargrave box kites flew very well, but their flying ability became poorer as their size was increased; a gigantic Hargrave with two cells as big as a small room would not sustain itself in the air, and experiments showed that only a hurricane could make it fly. To obtain much lifting power with box kites it was necessary to send up a number of them hitched on one line. But Dr. Bell's object was great lifting power in one kite and not in a team of kites. He realized that he was thwarted at the very outset by an old law, which was recently formulated by Dr. Simon Newcomb and which has made many believe that the flying machine is impossible without the discovery of a new metal or a new force.

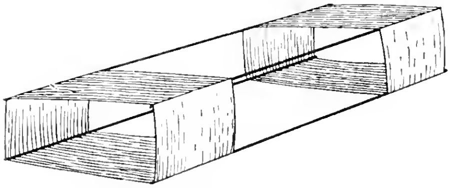


DIAGRAM 1. HARGRAVE BOX KITE.

This law is that the weight of kites or machines built on exactly the same model increases as the cube, when all the dimensions are increased alike, while the supporting or wing surface increases as the square.

A Hargrave box kite two meters on a side weighs eight times as much as one that is one meter on a side, but it has only four times as much sustaining or wing surface; the weight is tripled, while the wing surface is doubled; hence as the size of a box kite is increased a point soon comes when the weight is so great that the wing or supporting surface will not lift the weight.

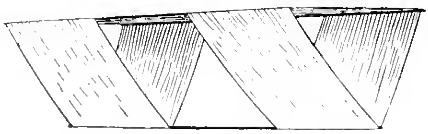


DIAGRAM 2. TRIANGULAR CELLS.

Dr. Bell then set to work to see if he could not outwit this law by devising a new form of kite which he could enlarge indefinitely without the weight increasing faster than the wing surface. He saw that if he could get a large kite by combining many small kites instead of by increasing the dimensions of his model the weight would not increase faster than the wing surface. He decided, therefore, to combine many small cells into one large kite instead of using two large cells each as big as a barn door. The Hargrave box cell however did not lend itself to combination. Two box cells fly well, but when a number of them are tied together they do not act with the same harmony. A box cell is structurally weak in all directions and requires a great deal of bracing to keep it from being twisted in a strong breeze; this bracing adds to the weight and makes head resistance to the wind; the more cells combined together, the more bracing required proportionally. Furthermore, the cells must be grouped in two sets at a distance from each other, and as the sets tend to pull apart, the framework connecting the two sets has to be very strong and heavy. As a result the experiments showed that neither

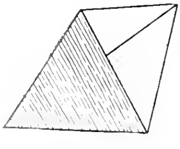


DIAGRAM 3 REGULAR TETRAHEDRAL WINGED CELL.

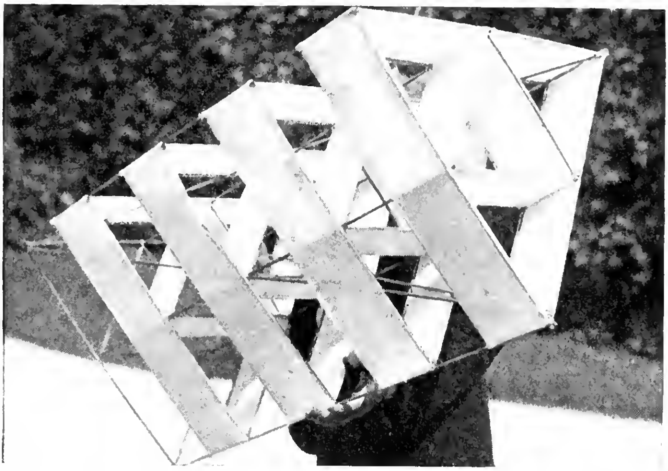


FIG. 1. KITE BUILT OF TWELVE TRIANGULAR CELLS. It is formed of two triangular kites, one inside the other.

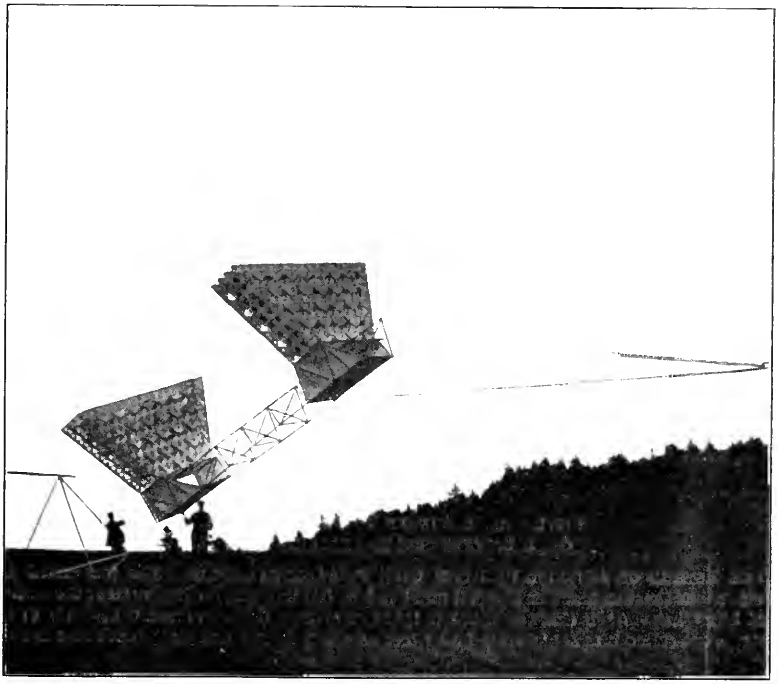


FIG. 2. GIANT KITE BUILT OF TRIANGULAR CELLS. The superstructure consists of seventy kites, like the one in Fig. 1, tied together at the corners and arranged in two sets of thirty-five kites each. Each of these kites was tested individually before being combined and found to fly well by itself. There are a total of 840 triangular cells in the giant kite. The total length of the kite is 29.5 feet. The picture shows the kite rising into the air.

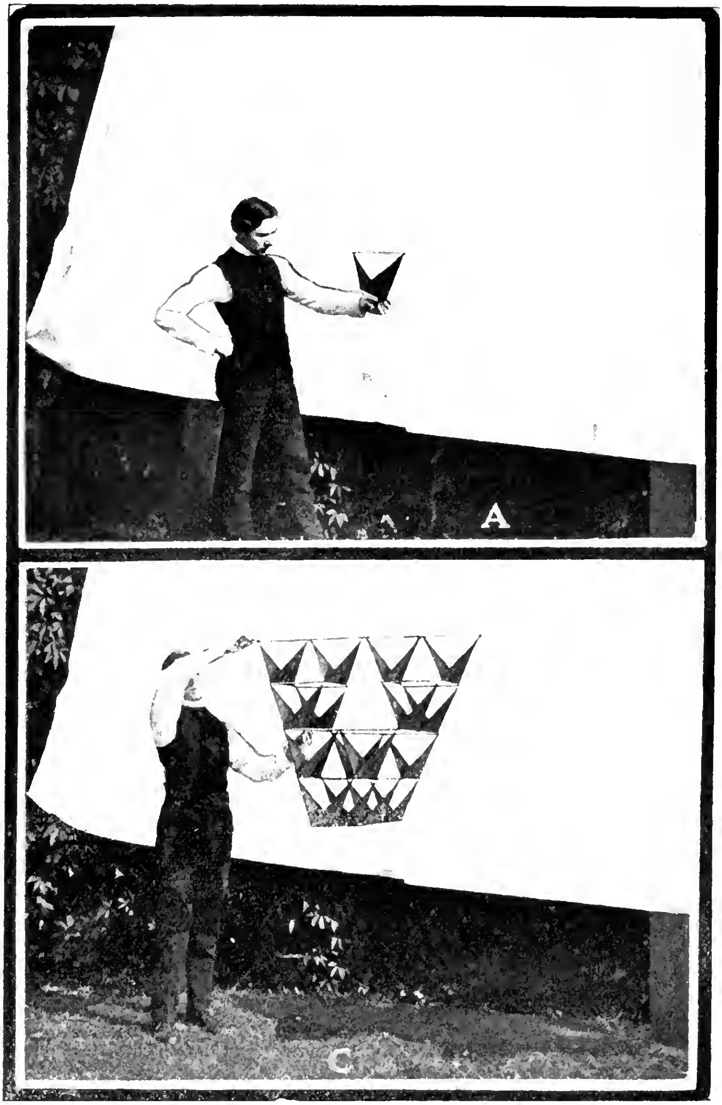
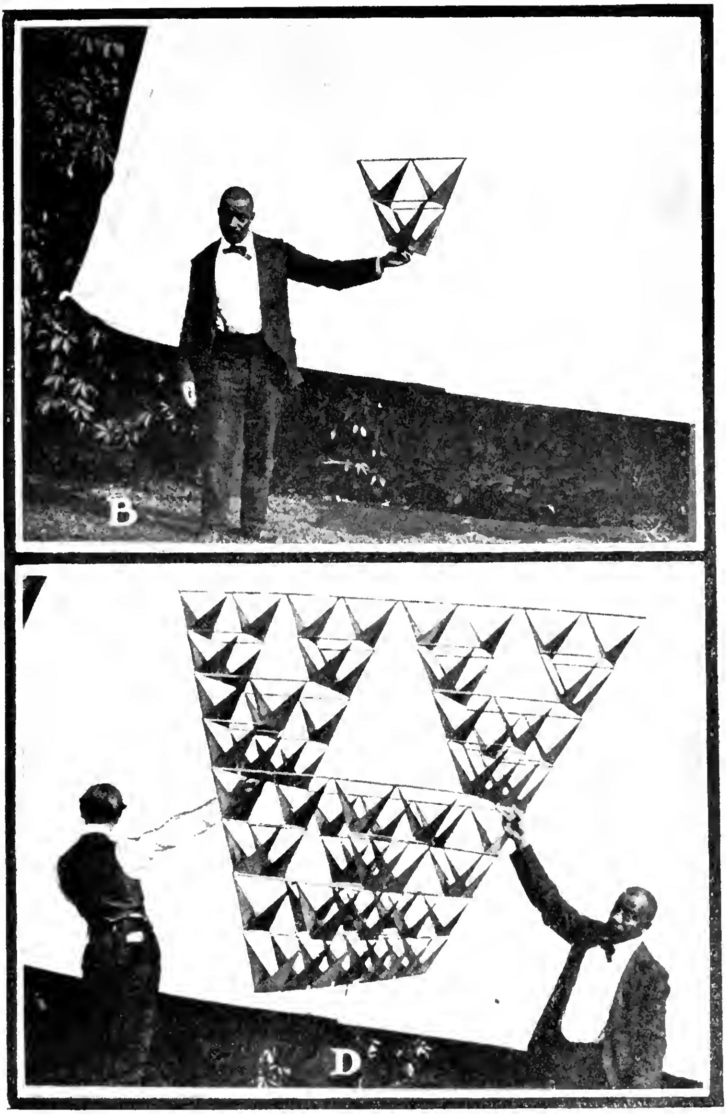


FIG. 3. *A*. A WINGED TETRAHEDRAL CELL.
C. A SIXTEEN-CELLED TETRAHEDRAL KITE.

THE METHOD OF BUILDING UP KITES WITH TETRAHEDRAL CELLS. The four-celled kite *B* weighs four times as much as one cell and has four times as much wing-surface; the sixteen-celled kite *C* has sixteen times as much weight and sixteen times as much wing-surface; and the sixty-four celled kite *D* has sixty-four times as much weight and sixty-four times as much

the efficiency nor the size of a kite could be increased by using many small Hargrave box cells instead of two large box cells.

The problem was then to invent a new cell, one that could be used in combination. Circular cells, polygonal cells of six, eight and



B. A Four-celled Tetrahedral Kite.
D. A Sixty-four-celled Tetrahedral Kite.

wing-surface. The ratio of weight to surface, therefore, is the same for the larger kites as for the smaller. In the middle of the kites there is an empty space, octahedral in form, which seems to have the same function as the space between the two cells of the Hargrave box kite. The tetrahedral kites that have the largest central spaces preserve their equilibrium best in the air.

twelve sides, and cells of various other shapes were devised, tried and thrown away.

Finally the triangular cell was hit upon. It immediately proved an immense advance over the rectangular Hargrave, being stronger in construction, lighter in weight and offering less head resistance to the wind.

Diagram 2 shows a drawing of a kite built of two triangular cells. The triangular cell needs bracing in one direction only, on its flat surfaces; in a transverse direction it is self-braced, so that internal bracing, which causes head resistance, is unnecessary.

By tying a number of kites built of triangular cells corner to corner, as shown in Fig. 1, Dr. Bell was able to construct a giant kite, Fig. 2, in which the ratio of weight to wing surface is not much more than that of the smaller kites of which it is composed. Combinations of

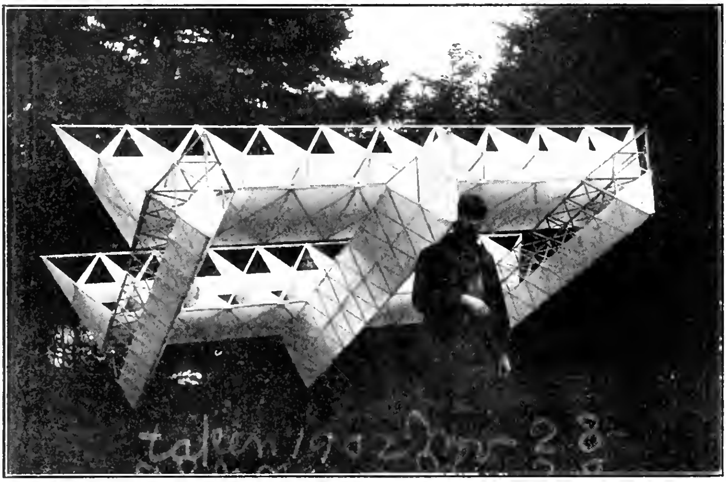


FIG. 4. FLOATING KITE BUILT OF TETRAHEDRAL CELLS.

triangular kites, however, must be arranged in two sets with a powerful connecting framework as shown in Fig. 2. The larger the two sets, the farther apart must they be, and, therefore, the connecting frame becomes exceedingly stout and heavy. This connecting framework is of course dead weight; it is a very serious handicap and soon limits the size of kites that can be built of triangular cells.

By his invention of the triangular cell Dr. Bell was able to build larger kites than he had been able to build before. The old limit of size was stretched considerably, but a limit remained none the less.

The principal improvements of the triangular cell, greater lightness and strength, are due to the cell being self-braced in a transverse direction, from side to side. Longitudinally, fore and aft, it is, however, very weak, like the box cell. Dr. Bell reasoned that a cell could be made self-bracing in every direction by making it triangular in all directions or tetrahedral in form.

Accordingly a number of regular tetrahedral cells, Diagram 3, were built in the laboratory. The experiments made with these cells have given startling results:

First.—A tetrahedral cell has astonishing strength even when composed of very light wooden sticks. As Dr. Bell has expressed it: "It is not simply braced in two directions in space like a triangle, but in three directions like a solid. If I may coin a word, it possesses 'three-dimensional' strength: not 'two-dimensional' strength like a triangle, or 'one-dimensional' strength like a rod. It is the skeleton of a solid, not of a surface or a line."*

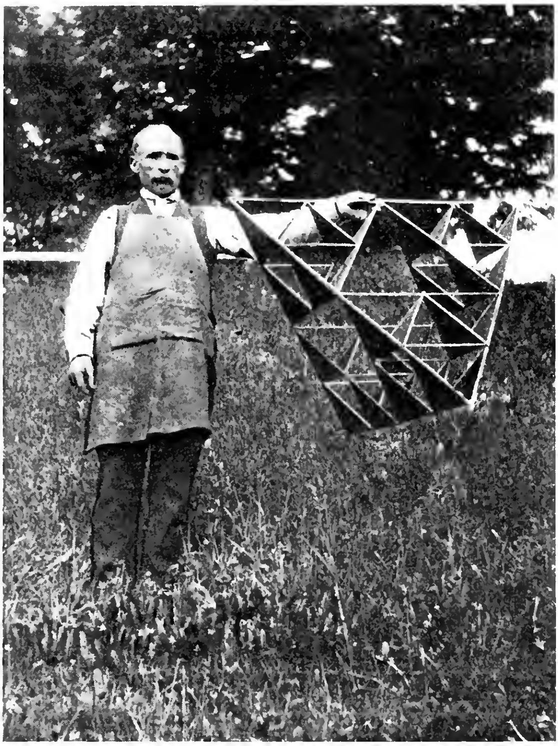


FIG. 5. SIXTEEN-CELLED TETRAHEDRAL KITE.

Second.—A large kite constructed of tetrahedral cells is as solid as a small one, for it is likewise self-braced in all directions.

Third.—A kite built of tetrahedral cells is an almost perfect flier; it is steady in squalls, a good 'lifter' and flys almost directly overhead. Tetrahedral cells when combined do not interfere with each other in the least or hurt each other's flying ability as box or triangular cells do when combined.

* 'The Tetrahedral Principle in Kite Structure.' By Dr. Alexander Graham Bell. *National Geographic Magazine*, June, 1903.

Fourth.—By the use of the tetrahedral cell it is possible to build kites unlimited in size and in which, however gigantic the kite, the ratio of supporting surface to weight remains the same as in a small kite.

The successive doubling in size of the kite shown in Fig. 3 may be carried on indefinitely without the weight increasing faster than the wing surface. The cells all act in harmony; no part of a kite built of tetrahedral cells has to be strengthened to counterbalance an opposing force or a weakness in some other part of the kite; no weight is thrown away.

By his invention of the regular tetrahedral winged cell, Dr. Bell thus got around the old law which said you can build kites up to a

FIG. 6. SIXTY-FOUR CELLED KITE COMPOSED OF FOUR OF PRECEDING. 'RED FLIER.'

certain size, but no greater. The adherents of that law have always admitted that the law might be circumvented if a kite could be combined of many small models, but they have denied or at least doubted that a working combination of small models effective enough to carry a man, and to be called a flying machine, could be made. With his tetrahedral cell Dr. Bell has, however, been able to build kites of tremendous power, strong enough to carry up several men. One of his first kites lifted two men off their feet in a squall, and they only saved themselves from an undesirable ascent by instantly dropping the rope. Later this same kite (Fig. 4) snapped its rope, a three-eighth-inch new manila rope, as quickly as a thread. Kites much more powerful than this one have since been built and prove beyond a question that a practical, efficient and powerful method of combination of small forces has been discovered.

Dr. Bell has been building during the past summer thousands of tetrahedral cells varying in size from 25 cm. to 1 meter. Some of them are covered with light red silk weighing about 40 grams to the square meter and others with nainsook, very fine cotton, about as light as the silk. Some of the earlier cells were covered with cheesecloth, but the cheesecloth weighed so much—over 100 grams to the square meter—that Dr. Bell has discarded it. The framework of the cells is usually of black spruce, which is light and strong.

To make a tetrahedral cell, take six sticks of equal length and place three of them on a table so as to make an equilateral triangle. Erect one of the three remaining sticks at each corner of the triangle and bring the tops together. It is the old-fashioned puzzle of making four triangles with six matches. Then cover any two sides and you have a tetrahedral winged cell.

A number of cells outlined against the sky look like a flock of birds; for instance look at Fig. 18; the wings of a cell are also like a bird's wings in that they are not rigid like a board; the silk covering yields somewhat to the pressure of the wind as the feathers of a bird's wing.

Hundreds of tetrahedral cells are now being made in which the frame consists of hollow aluminum tubing. The aluminum weighs very little more than the spruce wood hitherto employed and gives much greater strength to the frame.

Fig. 7. 'Red Flier' in the Air.

Using these cells just as a mason uses bricks to build houses of many forms, he has been constructing kites of every shape that a fertile brain could devise. Steadiness in the air and lifting power have been the main object in all. Some of his combinations are gigantic, exceeding twenty-five feet in length and twelve and fifteen feet in height and width, but in spite of their strength all are so light that his trained assistants send the giant kites up into the air as easily as the little fellows.

The kite shown in Fig. 5 is tetrahedral in form and built of sixteen tetrahedral cells. This was the first tetrahedral kite constructed by Dr. Bell. It is a wonderful flier, darting up from the ground with a shrill whistle and climbing to extraordinary heights. It is a pretty sight to see the operator bring the kite in after the experiment is over.

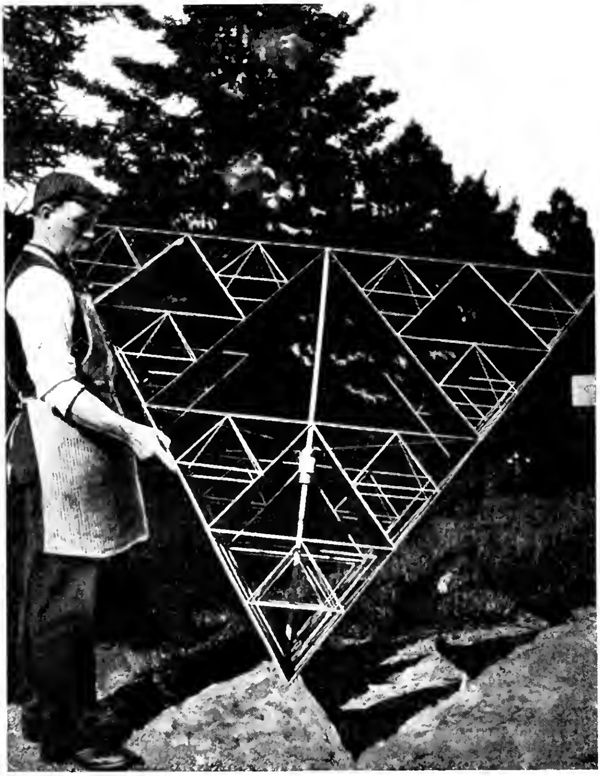


FIG. 8. SIXTEEN LARGE-CELLED KITE CARRYING FIVE POUNDS OF LEAD.

The kite flies steadily without a turn or quiver as the line is reeled in and finally alights on his hand as gently as a bird. Figs. 6 and 7 show a sixty-four-celled kite made of four kites like the preceding. The kite is two meters on a side. The most remarkable feature of this kite, aside from its perfect equilibrium and steadiness in squalls, is its ability to fly almost directly overhead. Even in the lightest breeze I have rarely seen it flying at an angle of less than eighty degrees. The kite is admirably adapted for meteorological observations at great heights, as it can carry considerable weight with the greatest ease. Fig. 8 shows a kite of the same size but with sixteen cells instead of

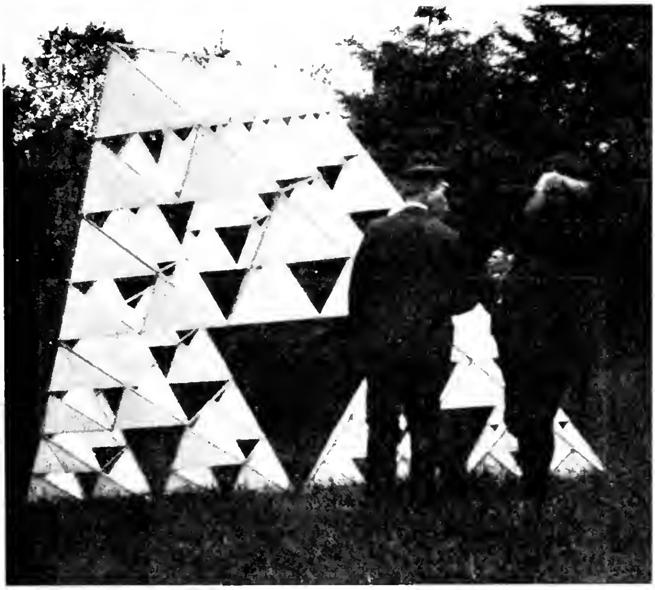


FIG. 9. SIXTY-FOUR CELLED WHITE FLIER RESTING ON ITS KEEL.

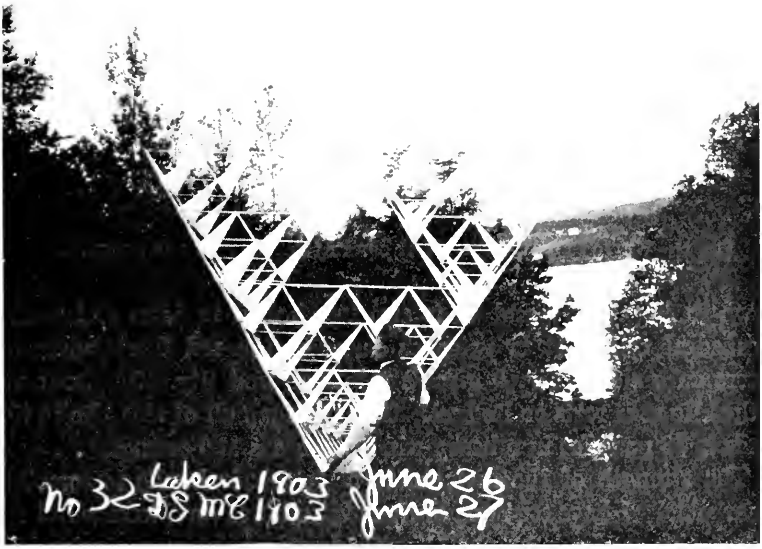


FIG. 10. WHITE FLIER. (FRONT VIEW.)

sixty-four, the cells being four times as large. The kite is not as successful as the preceding one. Dr. Bell's experiments have convinced him that the small cells are better; when the wind varies in strength as in a squall, the shifting of pressure on a small cell is less than the shifting on a large cell; hence the resultant shifting of pressure on a kite built of small cells is considerably less than on a kite built of large cells. Fig. 8 shows the method of attaching five pounds, a piece of lead in this case; the kite is not disturbed by the weight. The kite

FIG. 11. WHITE FLIER. CARRYING IT OFF THE FIELD AFTER THE EXPERIMENT.

shown in Figs. 9, 10 and 11 is also tetrahedral in form and built of tetrahedral cells. It is twice as large as the red flier, being four meters on a side. Fig. 9 gives a side view and Fig. 10 a front view of the kite as it rests on its keel. The average pull of this kite in light winds is 80 pounds; in a heavy wind it exceeds 150 pounds.

The strength of the kites made of tetrahedral cells is something remarkable. I have seen one of these kites towed on a tetrahedral float for more than a mile on the bay at a speed of eleven or twelve knots without breaking, though one end was dragging one foot under water all the time. As I saw the kite pulled along I expected to see it shattered to pieces, but beyond a few broken sticks it was as well and strong at the end of the journey as when it started.

The big tetrahedral kites, twelve feet and more on a side, look like awkward things to travel with or to store away, but they may be packed as handily and in as small compass as blankets or rugs. Each kite is made in collapsible sections, which open and then fold up, as shown in Fig. 12. Half a dozen large kites can in this way be carried in a trunk from place to place and put together in a few minutes.

The more recent experiments made have been to obtain a giant manlifting kite, or flying machine, that will rise from the surface of a lake. Any one who has ever watched a heavy bird rise from the ground has doubtless noticed that it runs along the ground for a few feet before it rises—the bird must acquire some momentum before its wings can lift its heavy body into the air. The natives of certain parts of the Andes understand this fact very well and by means of it catch the great Andean vultures. A small space is shut in with a high fence and left open at the top. Then a lamb or piece of carrion is placed on the ground inside. Presently a vulture sees the bait and swoops down upon it: but when once he has lighted on the ground inside he can not get out for he has no running space in which to acquire the momentum that is necessary before his wings can lift him. In the same way the first difficulty of all flying machines is to acquire the first momentum that will lift the machine into the air. To overcome this difficulty the flying machine inventor usually shoots his machine from a high platform which makes it necessary for the machine to rise immediately. But if the flying machine can not start in a natural way the chances are its method of working is not right and it is doomed to failure. And even if a machine could fly perfectly after it had been started how could it get up again if it came down for food or fuel at some point where there was no platform and starting

FIG. 12. A SECTION OF A KITE FOLDED UP FOR PACKING.

apparatus? In a word the solution to the whole flying machine problem is to get a machine that will start of itself without being shot off as if from the mouth of a cannon. The successful machine in rising will probably have to imitate the start of a large and heavy bird—that is glide along the ground or surface of a lake for some distance with constantly increasing speed until it rises of its own momentum.

A little kite, such as that shown in Fig. 5, darts up from the hand if there is the least breath stirring. The larger kite, shown in Figs. 6 and 7, is equally nimble, but in a faint breeze, to raise the large White Flier, shown in Figs. 9 and 10 and which is more than twelve feet on a side, the operator has to run a few yards towing the kite behind him.

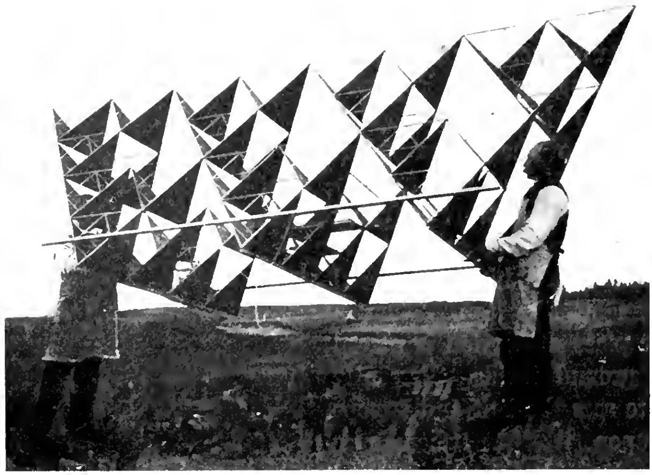


Fig. 13. Model of Mabel II.

Kites larger than the White Flier Dr. Bell sends skyward by tying the rope to the collar of a fast horse and then sending the steed galloping down the field. Of course, when a good wind blows all these kites soar upward as easily as the little fellow.

But to raise the giant kite Mabel II., shown in Fig. 15, Dr. Bell found a more serious problem. It would be difficult for a man or horse to pull the great frame so steadily as to keep her from being dashed against the ground and smashed before she could rise.

The kite has power enough to lift several men, but how was Dr. Bell to get her up into the air? If he could raise Mabel II. naturally, like one of the smaller kites, he could be pretty sure that she would go up when a motor, with propellers, was suspended to her. A pull or a push would be identical in its effect. In a word, if Dr. Bell could get this great man-lifting kite into the air by towing, as he did the smaller kites, he would succeed in obtaining a successful form for a flying machine.

There are two ways in which Mabel II. might be towed—on wheels along a track or on floats on the surface of a lake. Dr. Bell preferred to try the second method first, as it is simpler and easier.

With tetrahedral frames he built three long boats and covered them with oilcloth to make them watertight. The boats possess great strength, and yet, because of their tetrahedral structure, are so light as not to overweight the kite. The three boats were then ranged parallel to one another and the whole structure placed upon and securely fastened to them.

Fig. 15 shows Mabel II., just before she was launched. This figure and Figs. 16 and 17 give an excellent idea of the construction of the kite. Across the floats extend two bridges, built of tetrahedral cells. Resting on the bridges are four large kites, like the one shown in Fig. 8. The spaces between the four kites are filled with smaller tetrahedral cells. In all there are 272 cells in the structure.

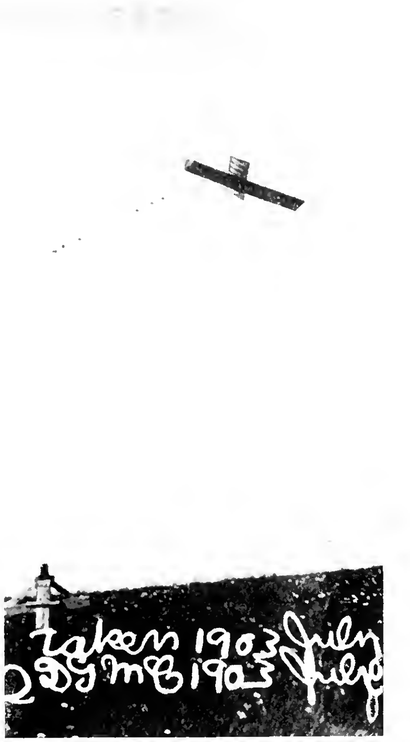


FIG. 14. TESTING ONE OF THE BOATS OF MABEL II.

Fig. 18 shows the kite floating merrily on the water waiting to be put to the test. With her tiers of red wings above and white wings below she was a beautiful sight. But would she fly? A small model of Mabel II., shown in Fig. 13 had flown beautifully on land. The flying weight of this model was greater than the flying weight of Mabel II., and Dr. Bell had therefore every reason to believe that Mabel II. would also fly if he could raise her.

When everything was ready Mabel II. was towed out to the center of the bay and her flying line cast aboard the steamer which Dr. Bell had engaged for the experiment. The flying line was made fast to a cleat on deck and the steamer started ahead at full speed, twelve or thirteen knots an hour.

But Mabel II. was working under two bad handicaps—first, a

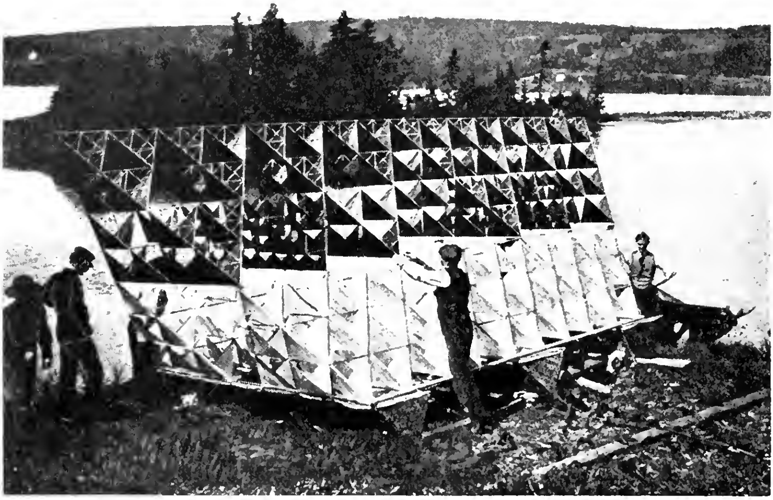


Fig. 15. Mabel II. before Launching.

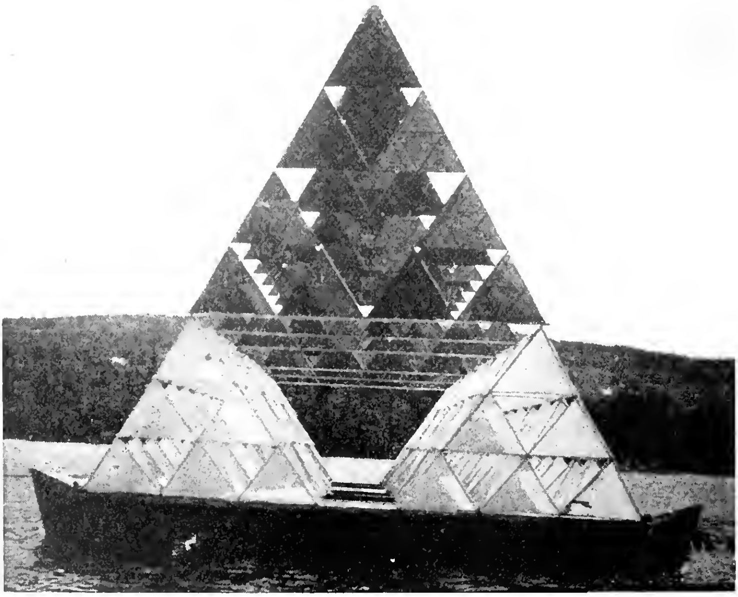


Fig. 16. End View of Mabel II.

heavy downpour had begun some minutes before the start and had thoroughly drenched the kite, making her so heavy that every one but Dr. Bell urged that the experiment be postponed (when Mabel II. was

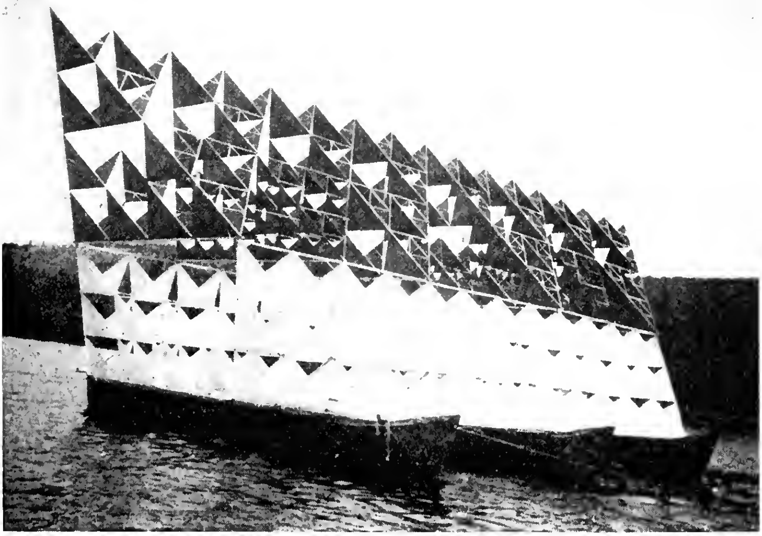


FIG. 17. FRONT VIEW OF MABEL II.

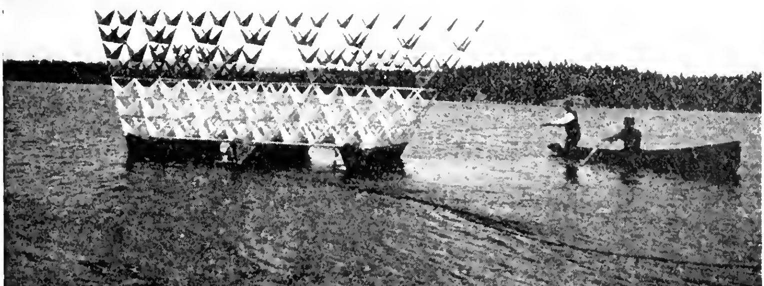


FIG. 18. MABEL II. OUTLINED AGAINST SKY SHOWING BIRD-WING EFFECT.

weighed after the experiment it was found that the rain water and leakage in the boats had increased her weight by sixty-four pounds); second, the operator on the deck of the steamer had given Mabel II.

too short a line, so that she was blanketed by the big hull of the steamer and therefore received but a small fraction of the wind of motion.

In spite of these two serious disadvantages, however, as the steamer gathered headway, the great kite first trembled for a few moments, and then rose gracefully from the water and flew steadily the full length of her line.

Fig. 19 shows the kite as she rose from the water after being towed a short distance. The rain was pouring down in such torrents at the time that my other pictures were not successful.

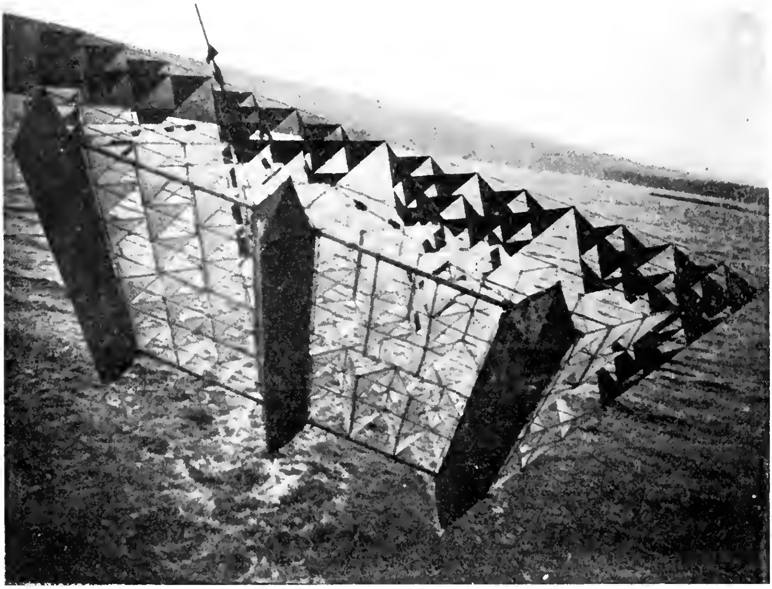


Fig. 19. Mabel II. rising into the Air.

The experiment was thus a success, and showed conclusively that Dr. Bell has obtained a man-lifting kite, or flying machine, that will rise of itself. If a pull will make the kite rise, there is no reason to doubt that an equally powerful push, such as propellers would give, would be equally successful in causing the kite to ascend.

Though the tests have proved that Mabel II. can easily carry a man and engine, no actual ascents have been made this summer. When ascensions are made the man will sit in the center of the open space between the two bridges (see Fig. 16).

One of the beauties of Dr. Bell's models is that in every one there is a large roomy space in the center where the operator and his passengers can sit. This position is much safer and more comfortable than sitting in a chair suspended some yards below the machine. As the ultimate machine will probably be of tougher material than wood and silk, in time of war the operator and the motor would be protected as well as hidden, instead of being a splendid target for every shot from below.

Kites that are tetrahedral in form, as the red and white fliers shown in Figs. 6 and 9 and those used to form the superstructure of Mabel II., have perfect equilibrium, but because of their small resultant area of horizontal or sustaining surface, their lifting power, though considerable, is not as great as Dr. Bell is satisfied to obtain. His latest combinations have, therefore, been made in the hope of obtaining greater horizontal surface, and thus greater lifting power. In Figs. 21 and 22 is shown a new form of kite, Victor I., which is undoubtedly the most wonderful kite ever devised and put together.

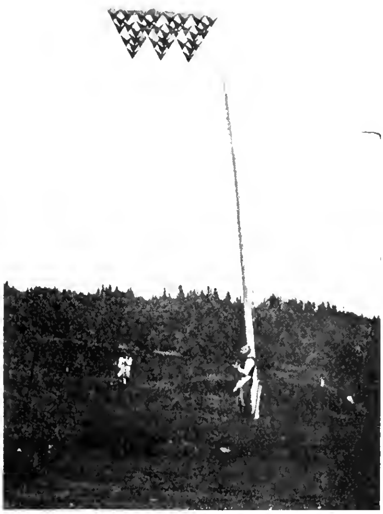


FIG. 20. MODEL OF MABEL II. IN AIR.

This great H-shaped kite rose from the hand, without running, in a breeze so light that a flag on a pole fifty yards away hung limp and motionless. It glided up and up until it was flying six or seven hundred yards high, steady as a table top. The breeze at that elevation was perhaps five or six miles, though on the ground the movement of the air was so light as to be imperceptible even on the grass or trees. In a breeze of fifteen miles it flew as steadily as before, but nearer the perpendicular and with a tremendous pull.

A glance at the photographs will readily explain what makes the kite such a remarkable flier. The cells of the two wings are reversed, the keels of the cells pointing up instead of down, and the tips pointing down instead of up, while above each tier of cells stretches a wide aeroplane. This wide expanse of sustaining surface helps the winged cells tremendously and at the same time does not interfere with their working. Victor I. is three meters long, three meters wide and one meter deep and weighs only twelve pounds. The flying weight is only three hundred and fifty grams to the square meter of horizontal surface. A smaller kite of similar model has been constructed whose flying weight is about two hundred grams.

The wonderful lightness of this model will be better understood when we realize that it carries twenty-five square feet of supporting or horizontal wing surface to one pound of weight, while a wild duck

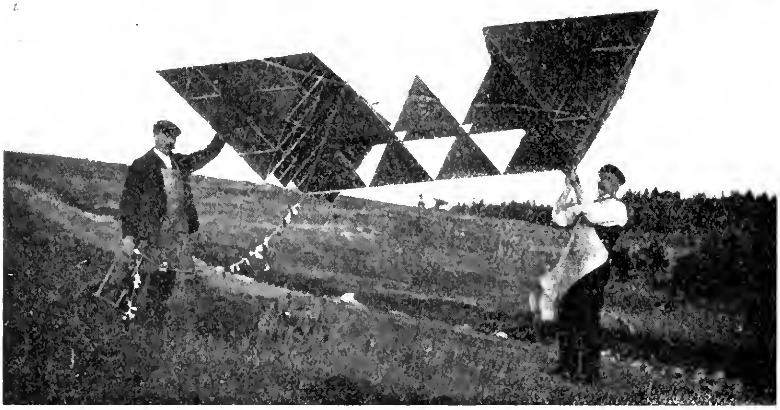


Fig. 21. Victor I.

has only one half of one square foot of wing surface to one pound of weight. The model almost rivals a mosquito in lightness—one pound of mosquitoes represents an area of wing surface of forty-nine square feet.

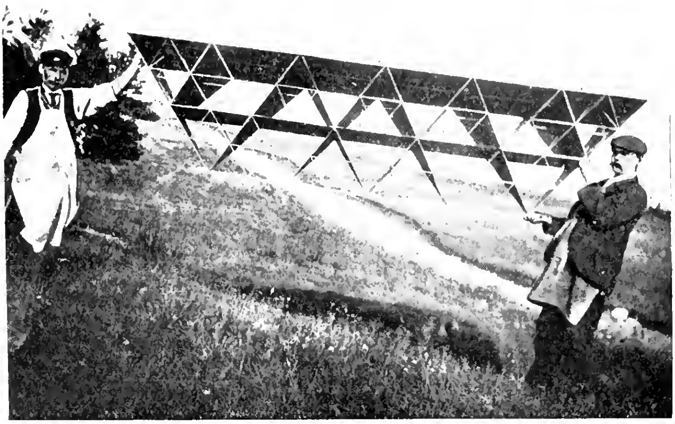


Fig. 22. End View of one of the Cells of Victor I.

Dr. Bell is now making a wind boat on this model, and it would not be surprising if this new wind boat should eclipse even the redoubtable Mabel II.

The framework of this latest model is also strong enough to support a man, and yet its flying weight is, as I have said, only 200 grams to the square meter of supporting surface. When we consider that the flying weight of other machines in which the greatest lightness has been striven for is nearly one hundred times as great as in this kite, we realize the tremendous advance made by Dr. Bell in at least one direction—a marvelous combination of lightness and strength.

In not one of the successful kites of Dr. Bell has the flying weight exceeded 500 grams to the square meter of supporting surface, whereas in various other machines the ratio exceeds 10,000 grams to the square meter.

Dr. Bell has thus constructed one form of successful flying machine, Mabel II. Another form, which may be even more successful and of which Victor I. is a model, is nearly completed. To obtain the form of a flying machine has been the principal problem to solve; the matter of a motor is comparatively simple.

The next step is to place a motor on Mabel II., or an enlarged Victor I., with a propeller extending from each side of the kite like an aerial paddle wheel. Strong and light motors are in the market and to be had easily. Then, as the operator sits inside with spinning propellers he can drive the kite up and down the surface of the bay testing how to control and steer her. Later, with the propellers going faster, he can send the kite skimming along a few yards above the surface and continue the experiments at this small height above the water without danger to life.

Finally, by still further increasing the speed of his propellers he can shoot upward and leisurely proceed wherever he may desire. Great speed is not Dr. Bell's object. Ten or fifteen miles an hour is enough to start with.

Dr. Bell has now reached the point where the flying machine is no longer problematical. It is simply a question of time necessary to put things together. Whether the first flying machine carrying a man is built by him at his laboratory in Beinn Bhreagh is probably immaterial to him, but the chances are that if some one else does not build a successful machine within the next year or two he will have a flying machine of his own by that time.*

* Figures 1–8, 10, 12, 13, 14, 15 and 20 are from photographs by Mr. David George McCurdy, the photographer of Dr. Bell's laboratory; the photographs shown in Figures 9 and 11 and those of Mabel II. and Victor I. were taken by the author.

HERTZIAN WAVE WIRELESS TELEGRAPHY, VII.

By Dr. J. A. FLEMING,
PROFESSOR OF ELECTRICAL ENGINEERING, UNIVERSITY COLLEGE, LONDON.

A NUMBER of more or less imperfect arrangements, having the isolation of communications for their object, have been devised or patented, which are dependent upon the use of several aerials, each supposed to be responsive only to a particular frequency; and attempts have been made to solve the problem of isolation by MM. Tommasi, Tesla, Jegon, Tissot, Ducretet and others.

We may then pass on to notice the attempts that have been made to secure isolation by a plan which is not dependent on electrical syntony. One of these, which has the appearance of developing into a practical solution of the problem, is that due to Anders Bull.* In the first arrangements proposed by this inventor, a receiver is constructed which is not capable of being acted upon merely by a single wave or train of waves or even a regularly spaced train of electric waves, but only by a group of wave trains which are separated from one another by certain unequal, predetermined intervals of time. Thus, for instance, to take a simple instance, the transmitting arrangements are so devised as to send out groups of electric waves, these wave trains following one another at time intervals which may be represented by the numbers 1, 3 and 5; that is to say, the interval which elapses between the second and third is three times that between the first two, and the interval between the fourth and fifth is five times that between the first two. This is achieved by making five electric oscillatory sparks with a transmitter of the ordinary kind, the intervals between which are settled by the intervals between holes punched upon strips of paper, like that used in a Wheatstone automatic telegraphic instrument. It will easily be understood that by a device of this kind, groups of sparks can be made, say five sparks rapidly succeeding each other, but not at equal intervals of time. One such group constitutes the Morse dot, and two or three such groups succeeding one another very quickly constitute the Morse dash. These waves, on arriving at the receiving station, are caused to actuate a punching arrangement by the intermediation of a coherer or other kumascope, and to punch upon a uniformly moving strip of paper holes, which are at intervals of time corresponding to the intervals between the sparks at the transmitting station. This strip of paper then passes through another telegraphic instrument, which is so constructed that it prints upon another strip

* See *The Electrician*, Vol. XLVI., p. 573, February 8, 1901.

a dot or a dash, according to the disposition of the holes on the first strip. Accordingly, taken as a whole, the receiving arrangement is not capable of being influenced so as to print a telegraphic sign except by the operation of a series of wave trains succeeding one another at certain assigned intervals of time.

An improvement has been lately described by the same inventor* in which the apparatus used, although more complicated, performs the same functions. At each station two instruments have to be employed; at the transmitting station one to effect the conversion of Morse signals into the properly arranged series of wave trains, and at the receiving station an instrument to effect the reconversion of the series of wave trains into the Morse signals. These are called respectively the dispenser and the collector. The details of the arrangements are somewhat complicated and can only be described by the aid of numerous detailed drawings, but the inventor states that he has been able to carry on Hertzian wave telegraphy by means of these arrangements for short distances. Moreover, the method lends itself to an arrangement of multiplex telegraphy, by sending out from different transmitters signals which are based upon different arrangements of time intervals between the electric wave trains. Although this method may succeed in preventing a receiving arrangement from being influenced by vagrant waves or waves not intended for it, yet an objection which arises is that there is nothing to prevent any one from intercepting these wave trains, and with a little skill interpreting their meaning. Thus, if the record were received in the ordinary way on a simple receiver, corresponding to a Morse dot would be printed five dots at unequal intervals, and corresponding to a Morse dash would be printed two such sets of five dots. A little skill would then enable an operator to interpret these arbitrary signals. On the other hand, the inventor asserts that he can overcome this difficulty by making intervals of time between the impulses in the series so long that the latter become longer than the intervals between each of the series of waves which are dispatched in continuous succession when the key is pressed for a dash. In this case, when telegraphing, the series of dots would overlap and intermingle with each other in a way which would make the record unintelligible if received in the usual manner, but would be perfectly legible if received and interpreted by a receiver adapted for the purpose.

Another way of obliterating the record, as far as outsiders are concerned, is to interpolate between the groups of signals an irregular series of dots, *i. e.,* of wave trains, which would affect an ordinary coherer, and so make an unintelligible record on an ordinary receiver,

* See *Electrician,* Vol. L., p. 418, January 2, 1903.

but these dots are not received or picked up by the appropriate selecting instrument used in the Anders Bull system.

The matter most interesting to the public at the present time is the long distance telegraphy by Hertzian waves to the accomplishment of which Mr. Marconi has devoted himself with so much energy of late years. Every one, except perhaps those whose interests may be threatened by his achievements, must accord their hearty admiration of the indomitable perseverance and courage which he has shown in overcoming the immense difficulties which have presented themselves. Five years ago he was engaged in sending signals from Alum Bay, in the Isle of Wight, to Bournemouth, a distance of twelve or fourteen miles; and to-day he has conquered twice that number of hundred miles and succeeded in sending, not merely signals, but long messages of all descriptions over three thousand miles across the Atlantic. Critics there are in abundance, who declare that the process can never become a commercial one, that it will destroy short distance Hertzian telegraphy, or that the multiplication of long distance stations will end in the annihilation of all Hertzian wave telegraphy. No one, however, can contemplate the history of any development of applied science without seriously taking to heart the lesson that the obstacles which arise and which prove serious in any engineering undertaking are never those which occur to armchair critics. Sometimes the seemingly impossible proves the most easy to accomplish, whilst difficulties of a formidable nature often spring up where least expected.

The long distance transmission is a matter of peculiar interest to the author of these articles, because he was at an early stage in connection with it invited to render Mr. Marconi assistance in the matter.* The particular work entrusted to him was that of planning the electrical engineering arrangements of the first power station erected for the production of electric waves for long distance Hertzian wave telegraphy at Poldhu, in Cornwall. When Mr. Marconi returned from the United States in the early part of 1900, he had arrived at the conclusion that the time had come for a serious attempt to accomplish wireless telegraphy across the Atlantic. Up to that date the project had been an inventor's dream, much discussed, long predicted, but never before practically taken in hand. The only appliances, moreover, which had been used for creating Hertzian waves were induction coils or small transformers, and the greatest distance covered, even by Mr. Marconi himself, had been something like 150 miles over sea. Accordingly, to grapple with the difficulty of creating an electric wave capable of making itself felt at a distance of 3,000 miles, even with the delicate receiving appliances invented by Mr. Marconi, seemed to require the

* See Mr. Marconi's Friday evening discourse at the Royal Institution, June 13, 1902; also *The Electrician*, Vol. XLIX., p. 390.

means of producing at least four hundred times the wave-energy that had been previously employed. The author was therefore requested to prepare plans and specifications for an electric generating plant for this purpose, which would enable electrical oscillations to be set up in an aerial on a scale never before accomplished.

This work involved, not merely the ordinary experience of an electrical engineer, but also the careful consideration of many new problems and the construction of devices not before used. Every step had to be made secure by laboratory experiments before the responsibility could be incurred of advising on the nature of the machinery and appliances to be ordered. Many months in the year 1901 were thus occupied by the author in making small scale experiments in London and in superintendence of large scale experiments at the site of the first power station at Poldhu, near Mullion, in Cornwall, before the plant was erected and any attempt was made by Mr. Marconi to commence actual telegraphic experiments. As this work was of a highly confidential nature, it is obviously impossible to enter into the details of the arrangements, either as made by the writer in the first instance, or as they have been subsequently modified by Mr. Marconi. The design of the aerial and of the oscillation transformers and many of the details in the working appliances are entirely due to Mr. Marconi, but as a final result, a power plant was erected for the production of Hertzian waves on a scale never before attempted. The utilization of 50 or 100 H.P. for electric wave production has involved dealing with many difficult problems in electrical engineering, not so much in novelty of general arrangement as in details. It will easily be understood that Leyden jars, spark balls and oscillators, which are quite suitable for use with an induction coil, would be destroyed immediately if employed with a large alternating current plant and immensely powerful transformers.

In the initial experiments with this machinery and in its first working there was very considerable risk, owing to its novel and dangerous nature; but throughout the whole of the work from the very beginning, no accident of any kind has taken place, so great have been the precautions taken. The only thing in the nature of a mishap was the collapse of a ring of tall masts, erected in the first place to sustain the aerial wires, but which have now been replaced by four substantial timber towers, 215 feet in height, placed at the corners of a square 200 feet in length. These four towers sustain a conical arrangement of insulated wires (see Fig. 26) which can be used in sections and which constitute the transmitting radiator or receiver, as the case may be. Each of these wires is 200 feet in length and formed of bare stranded wire.

At the outset, there was much uncertainty as to the effect of the curvature of the earth on the propagation of a Hertzian wave over a distance of many hundreds of miles. In the case of the Atlantic transmission between the station at Poldhu in Cornwall and that at Cape Cod in Massachusetts, U. S. A., we have two stations separated by about

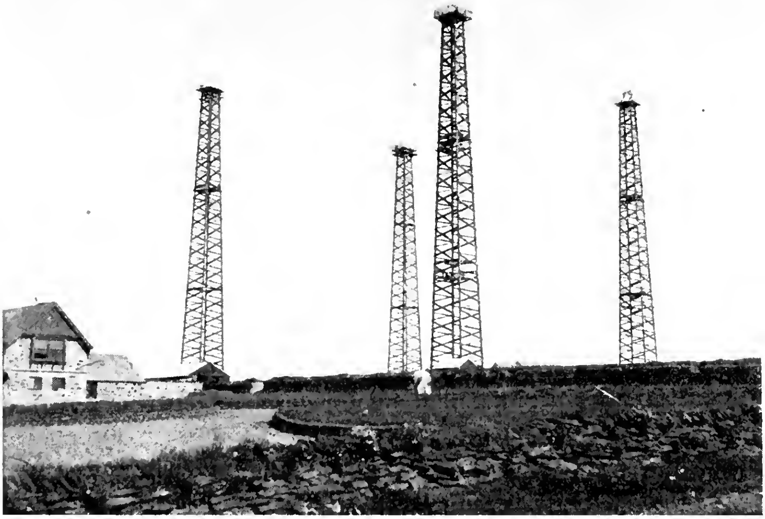


FIG. 26. WOODEN TOWERS SUPPORTING THE MARCONI AERIAL AT POLDHU POWER STATION, CORNWALL, ENGLAND.

45 degrees of longitude on a great circle, or one eighth part of the circumference of the world. In this case, the versine of the arc or height of the sea at the halfway point above the straight line or chord joining the two places is 300 miles.

This question has recently attracted the attention of several eminent mathematical physicists. The extent to which a free wave propagated in a medium bends round any object or is diffracted depends on the relation between the length of the wave and the size of the object. Thus, for instance, an object the size of an orange held just in front of the mouth does not perceptibly interfere with the propagation of the waves produced by the speaking or singing voice, because these are from two to six feet in length; but if arrangements are made by means of a Galton whistle to produce air waves half an inch in length, then an obstacle the size of an orange causes a very distinct acoustic shadow. The same thing is true of waves in the ether. The amount of bending of light waves round material objects is exceedingly small, because the average length of light waves is about one fifty-thousandth part of an inch. In the case of Hertzian wave telegraphy, we are, however, dealing with ether waves many hundreds of feet in length, and the waves sent out from Poldhu have a wave-length of a thousand feet or more, say one fifth to one quarter of a mile. The distance therefore between Poldhu and Cape Cod is only at most about twelve thousand wave-lengths, and stands in the same relation to the length of the Hertzian wave used as does a body the diameter of a pea to the wave-length of yellow light. There is unquestionably a large amount of diffraction or bending of the electric wave round the earth, and proportionately speaking it is larger than in the case of light waves incident on objects of the same relative size.

Quite recently Mr. H. M. Macdonald (see *Proc. Roy. Soc. Lond.*, Vol. LXXI., p. 251) has submitted the problem to calculation, and has shown that the power required to send given electric waves 3,000 miles along a meridian of the earth is greater than would be required to send them over the same distance if the sea surface were flat in the ratio of 10 to 3. Hence the rotundity of the earth does introduce a very important reduction factor, although it does not inhibit the transmission. Mr. Macdonald's mathematical argument has, however, been criticized by Lord Rayleigh and by M. H. Poincaré (see *Proc. Roy. Soc.*, Vol. 72, p. 40, 1903).

The accomplishment of very long distances by Hertzian wave telegraphy is, however, not merely a question of power, it is also a question of wave-length. Having regard, however, to the possibility that the propagation which takes place in Hertzian wave telegraphy is not that simply of a free wave in space, but the transmission of a semi-loop of electric strain with its feet tethered to the earth, it is quite possible that if it were worth while to make the attempt, an ether disturbance could be made in England sufficiently powerful to be felt in New Zealand.

Leaving, however, these hypothetical questions and matters of pure conjecture, we may consider some of the facts which have resulted from Mr. Marconi's long distance experiments. One of the most interesting of these is the effect of daylight upon the wave propagation. In one of his voyages across the Atlantic, when receiving signals from Poldhu on board the S. S. *Philadelphia*, he noticed that the signals were received by night when they could not be detected by day.* In these experiments Mr. Marconi instructed his assistants at Poldhu to send signals at a certain rate from 12 to 1 A. M., from 6 to 7 A. M., from 12 to 1 P. M. and from 6 to 7 P. M., Greenwich mean time, every day for a week. He has stated that on board the *Philadelphia* he did not

* See *Proc. Roy. Soc.*, June 12, 1902. 'A note on the Effect of Daylight upon the Propagation of Electromagnetic Impulses Over Long Distances,' by G. Marconi.

notice any apparent difference between the signals received in the day and those received at night until after the vessel had reached a distance of 500 statute miles from Poldhu. At distances of over 700 miles, the signals transmitted during the day failed entirely, while those sent at night remained quite strong up to 1,551 miles, and were clearly decipherable up to a distance of 2,099 miles from Poldhu. Mr. Marconi also noted that at distances of over 700 miles, the signals at 6 A. M., in the week between February 23 and March 1, were quite clear and distinct, whereas by 7 A. M. they had become weak almost to total disappearance. This fact led him at first to conclude that the cause of the weakening was due to the action of the daylight upon the transmitting aerial, and that as the sun rose over Poldhu, so the wave energy radiated, diminished, and he suggested as an explanation the known fact of the dissipating action of light upon a negative charge.

Although the facts seem to support this view, another explanation may be suggested. It has been shown by Professor J. J. Thomson that gaseous ions or electrons can absorb the energy of an electric wave, if present in a space through which waves are being transmitted.* If it be a fact, as suggested by Professor J. J. Thomson, that the sun is projecting into space streams of electrons, and if these are continually falling in a shower upon the earth, in accordance with the fascinating hypothesis of Professor Arrhenius, then that portion of the earth's atmosphere which is facing the sun will have present in it more electrons or gaseous ions than that portion which is turned towards the dark space, and it will therefore be less transparent to long Hertzian waves.† In other words, clear sunlit air, though extremely transparent to light waves, acts as if it were a slightly turbid medium for long Hertzian waves. The dividing line between that portion of the earth's atmosphere which is impregnated with gaseous ions or electrons is not sharply delimited from the part not so illuminated, and there may be therefore a considerable penetration of these ions into the regions which I may call the twilight areas. Accordingly, as the earth rotates, a district in which Hertzian waves are being propagated is brought, towards the time of sunrise, into a position in which the atmosphere begins to be ionized, although far from as freely as is the case during the hours of bright sunshine.

Mr. Marconi states that he has found a similar effect between inland

* See *Phil. Mag.*, Vol. IV., p. 253. Series 6, August, 1902. J. J. Thomson, 'On Some Consequences of the Emission of Negatively Electrified Corpuscles by Hot Bodies.'

† The opinion that ionization of the air by sunlight is a cause of obstruction to Hertzian waves propagated over long distances has also been expressed by Mr. J. E. Taylor. See *Proc. Roy. Soc.*, Vol. LXXI., p. 225, 1903. 'Characteristics of Earth Current Disturbances and their Origin.'

stations, signals having been received by him during the night between Poldhu and Poole with an aerial the height of which was not sufficient to receive them by day. It has been found, however, that the effect simply amounts to this, that rather more power is required by day than by night to send signals by Hertzian waves over long distances.

Some interesting observations have also been made by Captain H. B. Jackson, R.N.,* on the influence of various states of the atmosphere upon Hertzian wave telegraphy. These experiments were all made between ships of the British Royal Navy, furnished with Hertzian wave telegraphy apparatus on the Marconi system. Some of his observations concerned the effect of the interposition of land between two ships. He found that the interposition of land containing iron ores reduced the signaling distances, compared with the maximum distance at open sea, to about 30 per cent. of the latter; whilst hard limestone reduced it to nearly 60 per cent. and soft sandstone or shale to 70 per cent. These results show that there is a considerable absorption effect when waves of certain wave-length pass through or over hard rocks containing iron ores. It would be interesting to know, however, whether this reduction was in any degree proportional to the dryness or moisture of the soil. Earth conductivity is far more dependent upon the presence or absence of moisture than upon the particular nature of the material which composes it other than water.

The observations of Captain Jackson, however, only confirm the already well-known fact that Hertzian waves, as employed in the Marconi system of wireless telegraphy, within a certain range of wave-length, are considerably weakened by their passage through land, over land or round land. In some cases he noticed that quite sharp electric shadows were produced by rocky promontories projecting into the line of transmission. His attention was also directed (*loc. cit.*) to the more important matter of the effect of atmospheric electrical conditions upon the transmission. The effect of all lightning discharges, whether visible or invisible, is to make a record on the telegraphic receiver. On the approach of an atmospheric electrical disturbance towards the receiving station on a ship, the first visible indications generally are the recording of dots at intervals from a few minutes to a few seconds on the telegraphic tape. Captain Jackson states that the most frequent record is that of three dots, the first being separated from the other two by a slight interval like the letters E I on the Morse code, and this is the sign most frequently recorded by distant lightning. But in addition to this, dashes are recorded and

* See *Proc. Roy. Soc.*, May 15, 1902. 'On Some Phenomena affecting the Transmission of Electric Waves over the Surface of the Sea and Earth,' by Capt. H. B. Jackson, R.N., F.R.S.

irregular signs, which, however, sometimes spell out words in the Morse code. He noted that these disturbances are more frequent in summer and autumn than in winter and spring, and in the neighborhood of high mountains more than in the open sea. In settled weather, if present, they reach their maximum between 8 and 10 P. M., and frequently last during the whole of the night, with a minimum of disturbance between 9 A. M. and 1 P. M. Another important matter noted by Captain Jackson is the shorter distance at which signals can usually be received when any electrical disturbances are present in the atmosphere, compared with the distance at which they can be received when none are present. This reduction in signaling distance may vary from 20 to 70 per cent. of that obtainable in fine weather. It does not in any way decrease with the number of lightning flashes, but rather the reverse, the loss in signaling distance generally preceding the first indications on the instrument of the approaching electrical disturbance. It is clear that these observations fit in very well with the theory outlined above, viz., that the atmosphere when impregnated with free electrons or negatively charged gaseous ions is more opaque to Hertzian waves than when they are absent. Captain Jackson gives an instance of ships whose normal signaling distance was 65 miles, failing to communicate at 22 miles when in the neighborhood of a region of electrical disturbance. These effects in the case of wireless telegraphy have their parallel in the disturbances caused to telegraphy with wires by earth currents and magnetic storms.

Another effect which he states reduces the usual maximum signaling distance is the presence of material particles held in suspension by the water spherules in moist atmosphere. The effect has been noticed in the Mediterranean Sea when the sirocco wind is blowing. This is a moist wind conveying dust and salt particles from the African coast. A considerable reduction in signaling distance is produced by its advent.

Another interesting observation due to Captain Jackson is the existence of certain zones of weak signals. Thus, for instance, two ships at a certain distance may be communicating well: if their distance increases, the signaling falls off, but is improved again at a still greater distance. He advances an ingenious theory to show that this fact may be due to the interference between two sets of waves sent out by the transmitter having different wave lengths.

Finally, in the paper referred to, he emphasizes the well-known fact that long distance signaling can only be accomplished by the aid of an aerial wire and a 'good earth.' Summing up his results, he concludes: (1) That intervening land of any kind reduces the practical signaling distance between two ships or stations, compared with that which would be obtainable over the open sea, and that this loss in distance varies with the height, thickness, contour and nature of the land; (2) material particles, such as dust and salt, held in suspension in a moist atmosphere also reduce the signaling distance, probably by dissipating and absorbing the waves; (3) that electrical disturbances in the atmosphere also act most adversely in addition to affecting the receiving instrument and making false signals or *strays,* as they are called; (4) that with certain forms of transmitting arrangement, interference effects may take place which have the result of creating certain areas of silence very similar to those which are observed in connection with sound signals from a siren.

It is clear, therefore, from all the above observations, that Hertzian wave telegraphy taking place through the terrestrial atmosphere is not by any means equivalent to the propagation of a wave in free or empty space; and that just as the atmosphere varies in its opacity to rays of light, sometimes being clear and sometimes clouded, so it varies from time to time in transparency to Hertzian waves. The cause of this variation in transparency probably being the presence in the atmosphere of negatively charged corpuscles or electrons. If there are present in the atmosphere at certain times 'clouds of electrons' or 'electronic fogs,' these may have the effect of producing a certain opacity, or rather diminution in transparency to Hertzian waves, just as water particles do in the case of sunlight.

We may therefore in conclusion review a few of the outstanding problems awaiting solution in connection with Hertzian wave wireless telegraphy. In spite of the fact that this new telegraphy has not been accorded a very hearty welcome by the representatives of official or established telegraphy in Great Britain, it has reached a point, unquestionably owing to Mr. Marconi's energy and inventive power, at which it is bound to continue its progress. But that progress will not be assisted by shutting our eyes to facts. Many problems of great importance remain to be solved. We have not yet reached a complete solution of all the difficulties connected with isolation of stations. In the next place, the question of localizing the source of the signals and waves is most important. Our kumascopes and receiving appliances at present are like the rudimentary eyes of the lower organisms, which are probably sensitive to mere differences in light and darkness, but which are not able to *see* or *visualize,* in the sense of locating the direction and distance of a radiating or luminous body. Just as we have, as little children, to learn to see, so a similar process has to be accomplished in connection with Hertzian telegraphy, and the accomplishment of this does not seem by any means impossible or even distant. We are dealing with hemispherical waves of electric and magnetic force, which are sent out from a certain radiating center, and in order to localize that center we have to determine the position of the plane of the wave and also the curvature of the surface at the receiving point. Something therefore equivalent to a range-finder in connection with light is necessary to enable us to locate the distance and the direction of the radiant point.

Lastly, there are important improvements possible in connection with the generation of the waves themselves. At the present moment, our mode of generating Hertzian waves involves a dissipation of energy in the form of the light and heat of the spark. Just as in the case of ordinary artificial illuminants, such as lamps of various kinds, we have to manufacture a large amount of ether radiation of long wave length, which is of no use to us for visual purposes; in fact, creating ninety-five per cent. of dark and useless waves for every five per cent. of luminous or useful waves, so in connection with present methods of generating Hertzian waves, we are bound to manufacture by the discharge spark a large amount of light and heat rays which are not wanted, in order to create the Hertzian waves we desire. It is impossible yet to state precisely what is the efficiency, in the ordinary sense of the word, of a Hertzian wave radiator. How much of the energy imparted to the aerial falls back upon it and contributes to the production of the spark, and how much is discharged into the ether in the form of a wave.

Nothing is more remarkable, however, than the small amount of energy which, if properly utilized in electric wave making, will suffice to influence a sensitive receiver at a distance of even one or two hundred miles. Suppose, for instance, that we charge a condenser consisting of a battery of Leyden jars, having a capacity of one seventy-fifth of a microfarad, to a potential of 15,000 volts; the energy stored up in this condenser is then equal to 1.5 joules, or a little more than one foot-pound. If this energy is discharged in the form of a spark five millimeters in length through the primary coil of an oscillation transformer, associated with an aerial 150 feet in height, the circuits being properly tuned by Mr. Marconi's method, then such an aerial will affect, as he has shown, one of Mr. Marconi's receivers, including a nickel silver filings coherer tube, at a distance of over two hundred miles over sea. Consider what this means. The energy stored up in the Leyden jars cannot all be radiated as wave energy by the aerial, probably only half of it is thus radiated. Hence the impartation to the ether at any one locality of about half a foot-pound of energy in the form of a long Hertzian wave is sufficient to affect sensitive receivers situated at any point on the circumference of a circle of 200 miles radius described on the open sea. Hertzian wave telegraphy is sometimes described as being extravagant in power, but, as a matter of fact, the most remarkable thing about it is the small amount of power really involved in conducting it. On the other hand, Hertzian wave manufacture is not altogether a matter of power. It is much more dependent upon the manner in which the ether is struck. Just as half an ounce of dynamite in exploding may make more noise than a ton of gunpowder, because it hits the air more suddenly, so the formation of an effective wave in the ether is better achieved by the right application of a small energy than by the wrong mode of application of a much larger amount. If we translate this fact into the language of electronic theory, it amounts simply to this. It is the electron alone which has a grip of the ether. To create an ether wave, we have to start or stop crowds of electrons very suddenly. If in motion, their motion implies energy, but it is not only their energy which is concerned in the wave-making, but the acceleration, positive or negative, *i. e.,* the quickness with which they are started or stopped. It is possible we may discover in time a way of manufacturing long ether waves without the use of an electric spark, but at present we know only one way of doing this, viz., by the discharge of a condenser, and in the discharge of large condensers of very high potentials it is difficult to secure that extreme suddenness of starting the discharge which we can do in the case of smaller capacities and voltages.

How strange it is that the discharge of a Leyden jar studied so profoundly by Franklin, Henry, Faraday, Maxwell, Kelvin and Lodge should have become an electrical engineering appliance of great importance!

Whilst there are many matters connected with the commercial aspect of Hertzian wave telegraphy with which we are not here concerned, there is one on which a word may properly be said. The ability to communicate over long distances by Hertzian waves is now demonstrated beyond question, and even if all difficulties are not overcome at once, it has a field of very practical utility, and may even become of national importance. Under these circumstances, we may consider whether it is absolutely necessary to place the signaling stations so near the coast. The greater facility of transmission over sea has already been discussed and explained, but in time of war, the masts and towers which are essential at present in connection with transmitting stations could be wrecked by shot or shell from an enemy's battleship at a distance of five or six miles out at sea, and would certainly be done within territorial waters. Should not this question receive attention in choosing the location of important signaling stations? For if they can, without prejudice to their use, be placed inland by a distance sufficient to conceal them from sight, their value as a national asset in time of war might be greatly increased.

It has been often contended that whilst cables could be cut in time of war no one can cut the ether; but wireless telegraph stations in exposed situations on high promontories, where they are visible for ten to fifteen miles out at sea and undefended by any forts, could easily be destroyed. The great towers which are essential to carry large aerials are a conspicuous object for ten miles out at sea; and a single well-placed shell from a six-inch gun would wreck the place and put the station completely out of use for many months. Hence if oceanic telegraphy is ever to be conducted in a manner in which the communication will be inviolable or, at any rate, not be capable of interruption by acts of war, the careful selection of the sites for stations is a matter of importance. A small station consisting of a single 150-foot mast and a wooden hut can easily be removed or replaced, but an expensive power station, the mere aerial of which may cost several thousand pounds, is not to be put up in a short time.*

Meanwhile, whatever may be the future achievements of this new *supermarine* wireless telegraphy conducted over long distances, there can be no question as to its enormous utility and present value for intercommunication between ships on the ocean and ships and the shore. At the present time, there are some forty or more of the transatlantic ocean liners and many other ships equipped with this Hertzian wave wireless telegraph apparatus on the Marconi system. Provided with this latest weapon of applied science, they are able to chat with one another, though a hundred miles apart on the ocean, with the ease of guests round a dinner table, to exchange news or make demands for assistance.

> Ships that pass in the night, and speak each other in passing—
> Only a signal shown, and a distant voice in the darkness;
> So, on the ocean of life, we pass and speak one another,
> Only a look and a voice, then darkness again, and a silence.

Abundant experience has been gathered to show the inexpressible value of this means of communication in case of accident, and it can hardly be doubted that before long the possession of this apparatus on board every passenger vessel will be demanded by the public, even if not made compulsory. Although the privacy of an ocean voyage may have been somewhat diminished by this utilization of ether waves, there is a vast compensation in the security that is thereby gained to human life and property by this latest application of the great energies of nature for the use and benefit of mankind.

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* Mr. Marconi has informed the writer that these strategic questions have received attention in selecting the sites for large Marconi power stations in Italy.

THE SALMON AND SALMON STREAMS OF ALASKA.

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The Salmon of the Pacific.

THE salmon of the Pacific differ notably as a whole from the single species called salmon (*Salmo salar*) in the Atlantic. Anatomically the Pacific salmon (*Oncorhynchus*) differ from the salmon of the Atlantic (*Salmo*) in the greater number (14 to 20) of developed anal rays (the Atlantic salmon having 10 to 12), in the greater number of branchiostegal rays, 13 to 16, the Atlantic salmon having about 11, and in the usually larger number of pyloric cæca, 65 to 180, the Atlantic salmon having 65. In habits, the distinctions are still more marked. The Atlantic salmon spawns in the small streams and runs in the rivers in the fall for a long distance. In the run, the males become hook-jawed and somewhat distorted and many are attacked by fungus, dying before reaching the sea. But they attempt to reach the sea, and a large percentage of them revive, to spawn again.

The Pacific salmon, *Oncorhynchus,* have more definite runs. In the process of running, they take no food of any kind. The oil in the body is consumed, the flesh becomes pale, the jaws in the males become much elongated, the front teeth are enlarged, the color is changed and the whole body is greatly distorted. After spawning the fishes drift tail foremost in the stream, and all die within about a week. There is no reason to believe that any individuals of any species of Pacific salmon survive the reproductive act.

All the salmon spawn in cold or cooling water. The eggs are hatched when the water cools to 54°. Freezing kills them but any temperature between 32° and 54° is favorable to their development. Any temperature above 54° causes the egg to develop precociously and the young salmon dies. The temperature of the streams of the north fall earliest to 54°. For this reason, the run is earlier in northern waters than in southern ones in Alaska. All the species spawn in flowing water, the male with its tail scooping out the gravel in which the female deposits the eggs and over which the male casts out the milt.

The Species of Pacific Salmon.

There are five species of salmon in Alaska and neighboring regions. These differ widely in habit and in value, a matter of vital importance to an understanding of the salmon question.

The Quinnat Salmon.

1. The Quinnat salmon (*Oncorhynchus tschawytscha* Walbaum). This species is called king salmon in Alaska, Chinook salmon on the Columbia, spring salmon on Fraser River, Tyee salmon where the Chinook jargon is spoken and Tchaviche among the Russians. This is the salmon of the Columbia and Sacramento, the only species having value south of Puget Sound. It reaches a larger size than any of the others, the average at four years being 22 pounds and occasionally running to 60, 80 or even 100 pounds. In quality of flesh it is also superior to any of the others, at its best no wise inferior to the Atlantic salmon. Its flesh is red, rich and tender, becoming however progressively paler in color and less rich in flavor, as the spawning season approaches, although the flesh of spawning fish is sometimes dull red. The Quinnat is readily known by its large size and the presence of round black spots on back and tail. As the breeding season approaches it becomes blackish, the sides blotched with dull red.

The Quinnat runs in the large rivers, especially those having glacial or snow-fed tributaries. Its chief run is in May in the north, in June and sometimes in early July in the Columbia and even later in the Sacramento. In the Columbia, there is a more or less distinct full run in September. In Alaska, the principal run is in May.

The Quinnat salmon runs to the very headwaters of the streams it inhabits. In the Columbia, it goes to the Sawtooth Mountains of Idaho, as well as to the headwaters of the Clackamas, Cowlitz, Des Chûtes and other streams furnishing suitable spawning beds. In the Yukon some individuals each year ascend to Caribou Crossing on Lake Bennett, a distance of 2,250 miles from the sea. In Alaska the king salmon runs in appreciable numbers in the following rivers: Stikine, Taku, Unuk, Chilkat, Alsek, Kussilof, Copper, Knik, Shushitna, Nushigak and Kvichak. Schools of king salmon are occasionally seen among the islands of southeast Alaska, in pursuit of schools of herring. It is not likely that the species goes far out to sea, or for any great distance from the stream in which it was spawned. It is commonly asserted that each salmon returns to the particular stream in which it was spawned. There is no evidence that this is true. A discussion of this point will be found in a previous article in this journal.

The Red Salmon.

The red salmon (*Oncorhynchus nerka* Walbaum). This fish is known throughout Alaska as red salmon. In the Columbia, it is called blue-back salmon, while in Fraser River it is known as Sockeye, a Chinook word, originally spelled Sukkegh, then Sawkwi. To the

Russians it is Krasnaya Ryba, which means red-fish. This species is the neatest and most symmetrical of the salmon. Its usual weight at four years is about seven pounds, varying from six to ten pounds. The flesh is deep-red, firmer, drier and less palatable than that of the Quinnat. The flesh is more compact than that of any other salmon, hence in canning it is boiled longer. In the sea the red salmon is clear sky-blue above, silvery below, without spots. After entering the river, for the purpose of spawning, the color soon changes to crimson, at first bright, but soon blotched with darker and blood-red, the head becoming bright olive green in sharp contrast with the red. The jaws in the male become extravagantly produced and hooked.

This species runs chiefly in July, and often goes for a very long distance. In the Yukon, it ascends to 'Forty Mile,' a distance of over 1,800 miles from the sea. In the Columbia, it ranges as far as the lakes of the Sawtooth range in Idaho. It always spawns in small streams which run into the head of a lake. It never runs in any stream which does not have as a tributary a lake with available spawning grounds in the streams at its head. The red salmon often enters small streams, even those a few feet across, and sometimes in great numbers. The determining factor is always the presence of a suitable lake with spawning beds above it. The lake may be a few rods from the sea as at Boca de Quadra, or it may be many hundreds of miles as in the case of the Columbia, but the lake is always present in every stream in which red salmon run.

In certain large lakes at a distance from the sea, in Idaho, there is a dwarf form of the red salmon, exactly similar to the sea form, but rarely exceeding half a pound in weight. These are probably land-locked in these lakes as both sexes are freely represented among them. At the sea, the dwarf fish running are almost all males. In the spawning season of the Quinnat salmon, many young males but one or two years of age enter the river with the larger fish, spawning precociously, and all dying. Perhaps these dwarf red salmon are simply precocious individuals spawning and dying before their time. No females were seen among these by us at Astoria. In streams of Cook Inlet, there is a late run of very small red salmon, locally known as 'Arctic salmon.' These are doubtless young fish running prematurely. They are not confined to Cook Inlet, but many were seen by us at Karluk. Of a large number examined, all but two were found to be males. The small red-fish running in Necker Bay on Baranof Island are of the same nature. With them are some full grown red salmon. Why this particular stream is attractive to precociously spawning fish is a matter for investigation.

The Silver Salmon.

The silver salmon (*Oncorhynchus milktschitsch*) is called Coho about Puget Sound, Kisutch or Bielaya Ryba (white-fish) by the Russians. This species is very similar in size and color to the red salmon. It is distinguished at once by the much smaller number of gill-rakers (23 instead of 37). Its dorsal fin is always black at tip. The flesh is less firm than that of the red salmon, and the scales fall off when the fish is handled, leaving only those along the lateral line. The fine texture and loose attachment of the scales is the most convenient mark to distinguish the silver salmon. In the spawning season it becomes hook-nosed and the color changes to blotchy red. The flesh of the silver salmon is rather pale, without the deep red hue of the red salmon. In flavor it is rather better than the latter, and only the pale color keeps it from ranking with the best of salmon.

The silver salmon runs in the fall and ascends the streams for a short distance only. It remains close in shore. The young can be taken with a seine at almost any time along the shores in Alaska, and these seem to remain in the rivers longer than the young of the other species. The species is taken in small numbers at all the fishing grounds in Alaska. When enough are taken, it is canned as 'Coho' or as 'medium red,' but no dependence can be placed on it. It runs in Alaska from August 15 to September 15. When it begins to run in the streams it is not far from its spawning time, and its flesh is deteriorated. For these reasons, although a fine food-fish, it will never have much economic importance.

The silver salmon is common in the rivers of Japan. The king salmon is unknown in Japan, there being no ice-fed rivers suitable for it. The red salmon runs in a few lakes (as Lake Akan) in the extreme north (Nemuro) of the northern island of Hokkaido or Yeso.

The Humpback Salmon.

The humpback salmon (*Oncorhynchus gorbuscha*) is known to the Russians as Gorbuscha and to the trade as pink salmon. This is a small fish, seldom weighing over six pounds and often not over three. It differs from the other salmon in its very small scales. The presence of oblong black spots on the tail is also characteristic. Its flesh is soft, very much less firm than in the preceding species. It is pale in color, and without much of the characteristic salmon flavor. When fresh it is fairly palatable and quite wholesome, and the bellies when salted are of good quality. The flesh becomes soft in a short time after death, becoming tainted in 48 hours or less in the cool climate of Alaska. When the species begins to run in the river, its flesh loses the little oil it has and is almost worthless as food. The humpback salmon carries the changes due to the spawning period to an extravagant degree, being hook-jawed, hump-shouldered and distorted more excessively than any other species.

The humpback is the most abundant of the salmon among the Alaskan Islands. It exists in millions, it swarms everywhere in waters near the sea, breeding in brooks, lakes, swamps and brackish estuaries—anywhere where a little fresh water can be found. It runs for a slight distance, and does not go far from the shore. From its great abundance and the ease by which it is taken in nets, this species is exceedingly cheap in Alaska, the individuals costing about a cent apiece. In the large rivers, the humpback rarely runs. It is therefore almost unknown in the Sacramento, the Columbia and even the Fraser River. Small rivers which do not rise in lakes are often crowded with humpbacks. Such streams are known as humpback streams.

The humpback is not found in Japan, where it is replaced by a closely allied species, with unspotted tail, the Masu (*Oncorhynchus masou*).

The Dog Salmon.

The dog salmon (*Oncorhynchus keta*) is known also as calico salmon and as chum, to the Russians as Hayko, and in Japan where it is especially abundant as Saké. It is rather larger than the silver salmon, averaging about ten pounds. It is plump and silvery, when taken in the sea, and may then be best distinguished from the red salmon by the tendency of the dark color of the back to form vertical bars on the side. In the breeding season, it becomes largely black, still obscurely barred, and the jaws are greatly elongated and distorted.

The flesh of the dog salmon is very pale, with little of the salmon flavor and none oi its color. When fresh from the sea it is however well-flavored and wholesome. When canned it is dirty white, soft and mushy, and with a strong taste of mud. It is then practically worthless as food. It runs in the rivers in the fall and for very short distances. Its flesh is then still more pale and mushy. It is in fact unfit for canning, and the few firms who have packed it have been unable to dispose of the goods. The 'Rainbow Brand' was established for dog salmon.

The dog salmon takes salt well. It is the large salmon or saki of Japan, of which great quantities are salted in Japan, and Japan has also furnished a market for the same species salted in Alaska. The dog salmon—taken fresh in spring—is frozen and sent in cold storage to the East and to Germany, where it sells readily. The species is attractive in appearance, and when taken in the sea is good food, although unsuited for canning purposes.

The dog salmon enters all sorts of rivers in the fall, spawning at no great distance from the sea. It is less abundant than any of the other species, although it can be taken in almost any stream from the Columbia River to the rivers of northern Japan.

The relative food value of the five different species of salmon may be well expressed by the five digits, Quinnat five, red salmon four, silver salmon three, humpback salmon two, dog salmon one. The canned product has at the present time approximately the same relation of values, except that the aggregate value of the red salmon now considerably exceeds that of the Quinnat.

The Trout of Alaska.

Besides the five species of salmon, four species of trout are found in Alaska. These may be briefly noticed. The steel head trout (*Salmo gairdneri*) is frequently taken in the mouths of the large streams, which it enters for the purpose of spawning. It reaches a weight of 10 to 16 pounds. The large examples are valued for purposes of cold storage. The species is sometimes salted, but rarely canned. It is a handsome fish, black spotted, and may be known by the very short head, which it one fifth the whole length to the base of the tail.

The cut-throat trout (*Salmo clarki*) is found in streams about Sitka and southward to Vancouver Island. It has no economic value in Alaska. Although sometimes weighing 15 to 25 pounds in favorable lakes, it does not ordinarily exceed three pounds. The species may always be known by a concealed dash of scarlet on each side of the throat. This is wanting in the steel-head, which is likewise spotted with black.

The rainbow trout (*Salmo irideus*) occurs also in Alaska. It has been taken in Naha River at Loring and in some other places. It lacks the red dash of the cut-throat trout and has larger scales. From the steel-head it is separated by its larger head, larger scales and smaller size.

The Dolly Varden (*Salvelinus malma*), miscalled 'salmon trout' in Alaska, is one of the most abundant fishes in Alaska. It swarms in every stream and enters the sea, where it occasionally reaches the weight of eleven pounds. The young trout are the most persistent enemies of the salmon fry, destroying them by millions, although in turn the salmon feed on the fry of the trout. The Dolly Varden is one of the finest game fish—a fact little appreciated in Alaska. In the rivers, its color is rich dark blue or olive with crimson spots. In the sea, this color changes to steel gray with spots of paler gray.

The trout is an excellent food fish, but of no economic value except about the towns where it may be consumed fresh. It can not be taken in such numbers as the interests of canning require, and it is too small for advantageous sale in cold storage. The Dolly Varden is wholly wanting in the Upper Yukon region.

The Great Lake trout or Mackinaw trout (*Cristivomer namaycush*) is common in the Yukon region, which has a fauna very much like that of Lake Superior. It abounds in the lakes, takes a hook readily and reaches a weight of 50 pounds or more. A certain number of these are shipped fresh to mining centers, as White Horse and Dawson.

The Streams of Alaska.

The rivers of Alaska, considered in relation to the salmon industry, may be divided into three classes. King salmon streams, red salmon streams and humpback salmon streams. The streams of the first class from a quarter of a mile to a hundred miles wide at the mouth, have a long course and are fed by melting ice or snow, and the course for the most part is not through glacial lakes. In these rivers the king salmon or Quinnat salmon run in the spring, as in the Sacramento or Columbia. With them run also a certain number of red salmon, and in the river mouths humpback, dog and silver salmon. The run of the king salmon is however the chief characteristic. The species in Alaska is less valuable than in the Columbia, because owing to the shorter run the fishes are nearer the spawning season and a large percentage have white meat even in June, a larger percentage than the Columbia shows even in August. For various reasons, rough bottom, swift current, high tides, etc., most of these streams are not easily fished. In the Stikine River, for example, traps are swept away by the currents, seines are tangled up, a deep gill net will meet an under current of salt water under the fresh water, and is thus upset. The only effective fishing gear is therefore a very shallow gill net floating in the fresh water at the surface. Rivers of the first class are the following: Yukon, Kuskoquim, Shushitna, Copper, Alsek, Taku, Speel, Whiting, Stikine and Unuk Rivers. The streams about Bristol Bay should not be placed in this class, as they flow through lakes and are essentially red salmon streams, in spite of their large size.

The streams of the second class or red salmon streams are those of large or small size which flow through lakes or have lakes tributary to them. In all these the red salmon runs freely, spawning always in the gravelly bed of the stream at the head of some lake. The four greatest of red salmon streams are the Fraser River, Karluk River, Nushegak River and Kvichak River, all large streams flowing through lakes. In proportion to the amount of water, probably no stream in the world normally carries more salmon than the Karluk River.

The streams of the third class, or humpback salmon streams, comprise the remaining streams of Alaska. These may be large swift rivers as the Skaguay River, or they may be little brooks, in any case not frequented by the king salmon, and having no lake in the course, hence not fit for the red salmon. Their runs are confined to the ignoble species, which ascend for a short distance only. In the larger streams to the northward as Skaguay River and Dyea River, the dog salmon predominates. Southward as in Fish Creek, at Ketchikan and Anan Creek, the humpback salmon predominates, although the humpback is equally common in the red salmon streams. Some of these streams of the third class as Fish Creek flow through lakes. Presumably these lack fit spawning grounds.

The question as to what constitutes the mouth of the river is one of some importance in Alaska. The tides run very high, often twenty-five feet or more, the high tide extending far up the estuaries, which at low tide may be occupied by fresh water. The Naha Stream at Loring flows through a series of lakes, the lowermost of which (Roosevelt Lagoon) lies close to the estuary of the stream, the water flowing from the lake over a considerable waterfall at low water. At high tide this cascade is reversed, the salt water passes by an overfall into the lake, which is thus converted into a brackish lagoon. It is a well separated lake at low water, part of the sea at high water.

THE STORM CENTER IN THE BALKANS.

By Dr. ALLAN McLAUGHLIN,

U. S. PUBLIC HEALTH AND MARINE HOSPITAL SERVICE.

MANY students of European political conditions believe that the end of Turkey as a European power is in sight and that in the near future important events will occur in the Balkan Peninsula which will change the map of that part of Europe.

The solution of the Balkan question has been confidently expected at various times during the past fifty years, but never have the signs of the times so consistently pointed toward this result as they do at the present time. The condition of anarchy and guerilla warfare in the so-called province of Macedonia and the accounts of wholesale murder of old men, women and children, even after due allowance for possible exaggeration, must excite a feeling of horror in the most indifferent observer. The position of the christian inhabitants in the unhappy country is such as to cause an outburst of popular feeling even in England against the Turk. The significance of the tone of hostility evinced by the English press lies in the fact that hitherto England has been the chief supporter of the Turk's political position in Europe.

The polyglot population of these Turkish provinces, differing from the Turk no less than from one another in race and speech, makes a favorable soil for the sowing of seeds of political discord, the value of which outside influences are not slow to recognize.

The Turk has availed himself of the racial differences of his subjects and encouraged the hostility of Greek for Slav, and the hatred of the Albanian for both. To understand the complicated conditions of the present insurrection it is necessary to consider the racial factors which go to form the population of the disaffected provinces and to review briefly the outside influences which tend to keep the Balkan question alive, and the reasons why the question has not sooner been settled.

There is no official division of the Turkish empire known as Macedonia; but the name has a wide popular usage in designating the territory occupied by these warring racial elements of European Turkey. The name is popularly applied to the Turkish vilayets of Salonika and Monastir. The resident factors in the racial problem of Macedonia consist of Slavs (Bulgars and Serbs), Albanians, Greeks, Roumans and Turks.

The Slavs came into Macedonia in the seventh century. They came in irresistible numbers, forced the Albanians to the mountains of the west, the Greeks to the south and the Roumans to the north. Two distinct elements were concerned in the Slavic invasion, the Bulgars and Serbs. The Bulgar and Serb alternated in the supremacy of the country for nearly eight centuries, until the Turk finally conquered both. For the past four hundred years the sultan has ruled the country and his rule has been frequently marked by barbaric cruelty and fanatical race hatred. The Slavic race (Servian or Bulgarian) predominates numerically in Macedonia. The race types that have survived the Slavic invasion and the Turkish conquest (Rouman, Greek and Albanian) are all modified by the infusion of Slavic blood.

Greeks are scattered throughout Macedonia in considerable numbers. They are mostly in the cities and towns engaged in trade and commerce, and are like the Rouman—inclined to let the Slav till the soil. The feeling between Greek and Turk is what might be expected after the race conflict of centuries. The Greek can never consider the Turk as anything but an intruder, and he will never relinquish his cherished dream of a great Greek empire with Constantinople for its capital. Yet many Greeks see their way clear to accept Turkish pay and assist in defeating the revolutionary schemes of their Slavic neighbors, the Bulgars.

The Wallachs, Vlachs or Roumans are a distinct division of the Latin family of peoples and to-day number about 5,000,000, most of them in Roumania; but Roumans are found in Bessarabia, Transylvania, Hungary, Albania and Macedonia. In Macedonia are numerous colonies of Roumans; and the Zintzars, as these Macedo-Roumans are called, are a factor of considerable importance in the question of the future of Macedonia. They are descended from a blended stock made up of Roman colonists and disbanded soldiers, and the Illyrian and Thracian inhabitants of Macedonia at the time of the Roman conquest (146 B. C.). The whole of Macedonia was, up to the seventh century and the coming of the Slav, occupied by a Latin-speaking race. The Slavic conquest forced the Roumans in great numbers to their brothers north of the Danube and many were carried farther by the wave of invasion—as far west as the Tyrol. The supremacy of the Slav did not wipe out the Rouman race, although the races probably blended to some extent. The Rouman exists to-day as a distinct type, speaking a Romance language and possessing in a marked degree the pride of race common to all peoples of Roman blood. In physical appearance the Vlachs are short and dark. They are very industrious and are usually engaged in trade and manufacturing. They are skilled in the building trades and metal working.

The Albanians are probably the chief disturbing element in Macedonia to-day, if we except outside influences. They constitute an important factor in the question, not only because thousands of them live in western Macedonia, but because many thousands more are enrolled in the Turkish army as irregular troops, or bashi-bazouks. The cradle of their race lies along the shores of the Adriatic from Montenegro on the north to Greece on the south. The country corresponds to ancient Epirus and in physical character resembles the highlands of Scotland. They are descended from the old Illyrians, who were never recognized as Hellenes by the ancient Greeks, but were probably allied to the Greeks racially.

The Roman occupation left many traces, especially in the valleys and more accessible parts of the country, and the great number of Latin derivatives in the Albanian language makes it semi-Romance in character as spoken to-day. The Albanians have blended to some extent also with Slavic elements in the north and Greeks in the south. Their religion is a form of Mohammedanism, but they take their religion less seriously than the moslem Turk and probably embraced it more for political reasons than for feelings of religious conviction. They made a magnificent fight against the conquering Turks in the fifteenth century. For twenty years under their heroic leader, George Castriot, they repelled army after army sent against them. After the death of Castriot, or Scanderbeg, as the Turks called him, the Albanians lost heart and with the fall of Scutari in 1478 they passed under Turkish dominion. They were governed by pashas appointed by the Porte, and under one of these, Ali Pasha, in the early part of the last century they became practically independent. They at first sympathized with Greece in the Grecian war for independence, but the Greeks refused their offers of friendship, and in a certain town besieged and captured by Greeks, there were massacred along with the Turkish garrison a body of 3,000 Albanians who had signified their willingness to desert the Turks and deliver the town to the Greek besiegers. Their treatment at the hands of the Greeks forced the Albanians into the arms of the Turk, and they have since fought valiantly to maintain the supremacy of the Porte. Their native dress is not unlike that of the Scotch highlander, and their skill and bravery in war, their constant interclan strife and their fierce untamable character make the analogy almost complete between the Scotch highlander and this other highlander of the Albanian mountains. The Albanian is a born plunderer. War is his business, and pillage his pastime; and he is held in great dread by the Slav, Rouman and Greek inhabitants of Macedonia.

The Macedonian question is kept alive by several distinct forces. The warring racial elements—Slav, Greek, Rouman and Albanian—and common hatred of the christian inhabitants for the Turk cause constant turmoil and riot. The desire of Servia, Bulgaria and Greece to annex Macedonia no doubt also contributes to the local unrest. The influence of Russia must not be overlooked. Russia has been accused, and history supports the accusation, of fomenting insurrection in

Macedonia through the agency of the Macedonian Revolutionary Committee.

Thus in this small territory of Macedonia we have five distinct elements, each discontented with Turkish domination, and yet each suspicious of his neighbor and fellow sufferer of alien race. The Albanian is at present on the side of the Turk. The Greek hates the Albanian, fears the Slav and detests the Rouman; yet hopes to dominate all three in some miraculous way from Constantinople after the Turk is forced out of Europe.

The Rouman hopes for the restoration of Rouman supremacy in the Balkan states through the agency of Roumania. The Serb and Bulgar are suspicious of the Greek and yet do not trust each other. All these races have one thing in common—the desire to free themselves from Turkey. The sultan is clever enough to take advantage of these race quarrels in Macedonia. In this game he has played Greek against Slav, and the Albanian against both, and thus made his own supremacy secure.

Russia has continually stirred up trouble in the Balkans, hoping to profit thereby. Each state separated from the Turkish empire brought Russia one step nearer the Bosphorus. In fact, Russia if left to herself would have settled the Macedonian question long ago. But this would necessitate driving the Turk across the Bosphorus and Russian occupation of Constantinople.

With Russia in Constantinople, the control of the eastern end of the Mediterranean sea and the entrance to the Suez canal would be lost to England. The weak Slavic Balkan states would become Russian, and the Slovenes and Croats, and all Austria's Slavic dominion south of the Danube would probably be lost to Russia.

England can never permit Russia to occupy Constantinople and control the great waterway to India, no matter what sentimental reasons might be advanced for ending Turkish barbarity. Austria must consider each Russian advance toward Constantinople as a step toward her own impending disintegration.

Germany, with the kindly feeling engendered by liberal railway concessions in Asia Minor and Mesopotamia, will endeavor to strengthen the sultan's failing grasp on the last European province left him. Time alone can tell what action the great powers will take. Turkey and Bulgaria are on the verge of war and in the event of such a war European intervention would surely follow.

It is almost certain that the powers will intervene anyway and give to the disaffected provinces some form of civilized government. It is very unlikely that Russia will soon occupy Constantinople. All the great powers, with the possible exception of France, would be against such a step. Nor is it likely that the petty ambition of Servia, Bulgaria, Roumania or Greece will be gratified by territorial acquisitions in Macedonia.

THE GROWTH OF RURAL POPULATION.

BY FRANK T. CARLTON,

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IN the last decade numerous articles were written and many warnings sounded regarding the depopulation of the rural districts in the eastern and north central portions of the United States. To a person believing that the country, not the city, furnishes the ' bone and sinew ' of the nation, a study of the census returns for 1890 provided sufficient foundation for such articles. Now another ten years have passed into history; new and, in many cases, quite different industrial conditions obtain; a new census has been taken and its results are now available. It is the purpose of this article to discuss the tendencies which are found at the present time in regard to the changes in rural population and to show that an improvement in rural conditions seems to be indicated by statistical study as well as by a survey of the social and industrial situation.

Taking the township as a basis of comparison, we find that during the decade, 1880–1890, the population decreased in 57 per cent. of the townships of the state of Ohio, in 48 per cent. of those of Indiana and in 56 per cent. of the townships of Illinois; during the decade, 1890–1900, the percentages are, respectively, 52, 43½ and 34. In these three north central states a total of 2,037 townships, or 54½ per cent., decreased in population during 1880–1890; but only 1,631, or 43 per

State.	Number of cities having a population of 25,000 or more.	Total increase in population of these cities, 1880-1890.	Same, 1890-1900.	Total increase in population of state, 1880-1890.	Same, 1890-1900.	Total increase in population of state outside large cities, 1880-1890.	Same, 1890-1900.
New York......	12	848.481	1,052,155	914,982	1,265,251	66,501	213,096
Ohio...........	9	287,188	298,958	474,254	485,229	187,066	186,271
Indiana........	5	72,683	103,337	214,103	324,058	141,420	220.721
Illinois.........	7	646,122	655,797	748,480	995,199	102,358	339,402
Massachusetts..	19	305,409	366,160	455,858	566,403	150,449	200,243
Vermont.......	none			136	11,219	136	11,219
New Hampshire.	1	11,496	12,861	29,539	35,058	18,043	22,197
New Jersey.....	10	205,053	238,268	313,817	438,736	108,764	200,468
Delaware.......	1	18,953	16,077	21,885	16,242	2,932	1,165
Total......	64	2,395,385	2,743,613			777,669	1,394,782

cent., decreased during the last decade. New York shows little change, the figures for the two decades being nearly identical. In Massachusetts, only 34 per cent. of the townships show a decrease in population during the last decade.

The above table presents several important and interesting facts regarding distribution of the increase in population of the nine states studied. All except Delaware show a greater increase in the population of the large cities during the period 1890–1900 than during the preceding decade. Delaware and Ohio, outside of the large cities, increased less during 1890–1900 than during 1880–1890. In Delaware alone the entire population of the state increased less during 1890–1900 than during the decade preceding. In these nine representative states, the population of the large cities increased 347,227 more during 1890–1900 than during 1880–1890; while the remaining portion of the states, the rural districts, increased 517,313 more during 1890–1900 than during 1880–1890.

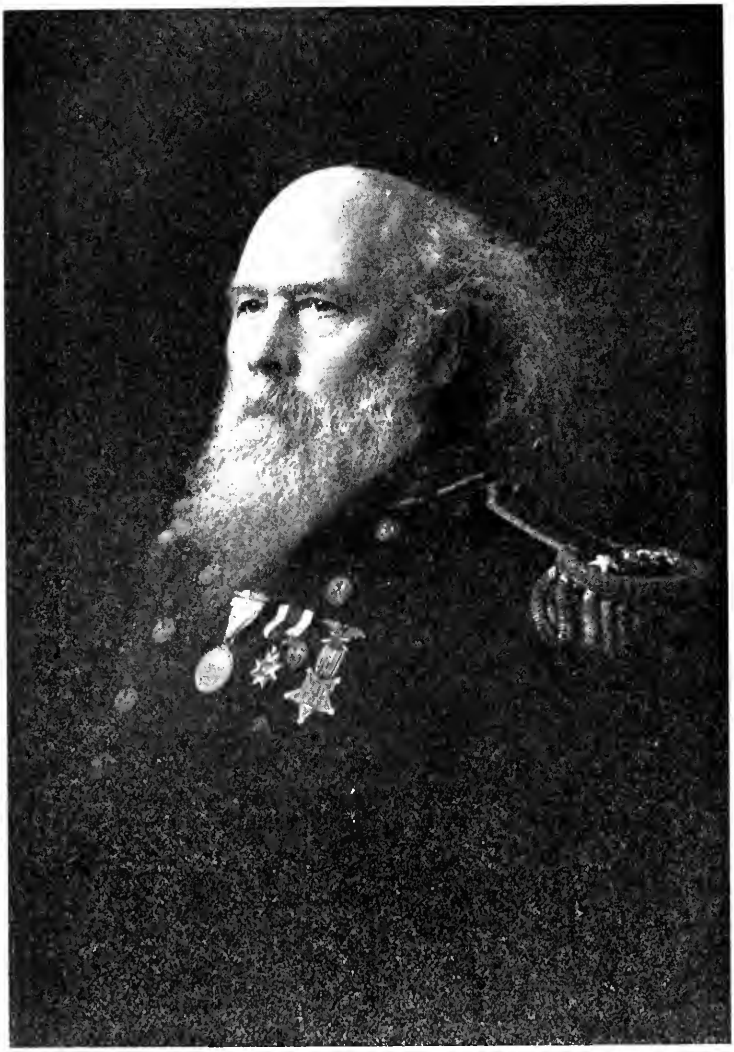
These figures indicate that, although the growth of our large cities is still more rapid than that of the remaining parts of the country, the rural districts are not being depopulated; but, on the contrary, are rapidly increasing in population. The growth is by no means uniform. The counties near the rapidly growing cities of Chicago, Cleveland and Toledo are increasing in population; while many in central and southern Ohio are decreasing. The contrast between New Jersey and Delaware, as shown in the table, is undoubtedly to be attributed to the influence of New York City and Philadelphia in the case of New Jersey, and the lack of such influence in the case of Delaware. The writer attributes much of this growth in the vicinity of these cities to the development of an extensive suburban electric railroad system. This may be objected to on the ground that the electric roads were not in operation long enough before 1900 to produce an appreciable effect. In order to prove or disprove definitely the census of 1910 will be required.

In the state of New Jersey only one county, Huntingdon, decreased in population during the last decade. Of the 104 cities, towns and boroughs in this state separately returned in both 1890 and 1900, 86 increased during that period. Only two counties, Barnstable, in the Cape Cod district, and Nantucket, an island, in the state of Massachusetts, show a decrease in population during the last decade. The three New England states, Maine, New Hampshire and Vermont, report only two cities having a population of more than 25,000 people; they may, therefore, be called 'rural' states. An examination of the population of these three states reveals one significant common tendency—the percentage of increase was greater in each state during 1870–1880 than during 1880–1890; but the percentage for 1890–1900 was greater than for 1870–1880. There is a distinct recovery in the rate of increase in population.

The statistics given of the north central and New England states show that, taken as a whole, the rural sections are not being depopulated, but are increasing in population at a gradually accelerated rate; townships and villages located near large cities, as a rule, show the greatest gain in population; better methods of transportation and communication and improved social conditions actually do tend to stop the depopulation of the rural districts. The reasons which may be given for this increased rate of growth in the population of the rural and suburban districts are many. They may be conveniently classified as follows: First, recent changes and improvements in industrial methods and conditions; second, the improvement in the home and social life of rural communities, due to better methods of transportation and communication.

At present there is a marked tendency for manufacturing plants to locate in the suburbs or the outskirts of a city. It seems probable that this tendency is to continue and that our manufacturing establishments are in the future to be located farther from the crowded portions of a large city or in a small city or town. The value of land is lower and rents are lower than in the densely populated portions of the city. Better shipping facilities can usually be obtained; switches can be built into the plant itself with little expense. The old two-, three-, or more story shop is being supplanted by the one-story steel structure; methods of construction have undergone a radical change in recent years. The new style building is better lighted, heated and ventilated than the old; it also requires more floor space and provides for traveling cranes to carry heavy parts of machinery. Coincident with this change in shop construction has come a change in the methods of transmitting power. Shafting and belting are being replaced in many new shops by compressed air and electricity. The use of compressed air and electricity allows the machines to be spaced much farther apart, as power can be economically transmitted over a much greater distance than in the case where shafts and belts are used. Long distance transmission of electrical power and the utilization of water power will aid in scattering manufacturing establishments in localities outside the large cities—witness the rapid growth of industrial settlements near Niagara Falls and the Sault Sainte Marìe. Water power is destined to play a continually increasing part in industrial operations; but if we are able to transmit power economically to considerable distances, there will be no necessity for a close concentration of manufacturing plants in the vicinity of any water-fall. No claim is made that such a change involves a return to smaller units or to a greater number of small proprietors. It, taken in connection with the preceding, does, however, point to a scattering of manufacturing plants; to a spreading out over more ground space in the case of each individual establishment and to more healthful, natural and inviting home and shop surroundings for the working men. One company may own many plants located on one large site or in many different parts of the United States, as circumstances may dictate. The great economies which consolidation permit are in the expense of management, in buying, selling, advertising and the like. These are as readily obtained when the business is carried on in several moderately large establishments as in one mammoth one. Increased facilities for rapid transportation also allow workmen to live many miles from their work. In this connection one more point must be discussed. Employers as well as students of social conditions are beginning to understand that the efficiency and value of workingmen to their employer depends, in a large measure, upon the home and shop conditions and environment. Poorly fed, poorly housed and poorly clothed workmen are not efficient laborers; also, dark, dingy, unsightly, poorly ventilated and badly heated factories are distinctly detrimental to the amount and quality of the work done in them. Looking at the matter from the standpoint of profits, as purely a business proposition, employers are beginning to realize this fact and to attempt to remedy it. The following quotation, taken from a magazine devoted to shop management and economy, illustrates the trend of thought: "The duty of a corporation, like that of an individual, is of a dual nature, viz., toward itself and toward its neighbors. Its duty to itself comprises the necessity of turning out its product cheaply and at the same time excellent in quality. To fulfill these requirements the management must see that the component factors of production are kept in prime condition. The more intelligent the employees and the more efficient their facilities for production, other things being equal, the cheaper and better will be the resultant output. . . . The manager who lives in luxury, without seeming to care for the condition or welfare of his employees, rouses antagonisms, which are not conducive to collaboration with his interests either in the works or in the community." A better grade of workingmen is, as a rule, attracted to a shop located in the suburbs owing to its superior advantages in regard to shop and home environment. The theory of demand and supply is not the sum and substance of economic thought and reasoning. The human element must be considered. Humanitarian principles are beginning to be recognized in the business world and must be reckoned with in the future.

The improvement of the rural school, the increased rural circulation of the daily paper and the magazine, the electric suburban and interurban railroads, improved roads, rural mail delivery, the extension of the telephone service into the rural districts and many other improvements and innovations which improve the social condition of the country people all tend to increase the wants of the rural communities, to raise their standard of living and hence to increase the real wages of the dwellers in those places. Here stands revealed one of the positive forces which is stopping the drift of population from country to city. The standard of living of the rural population has been lower than that of urban communities. The wants of the farmer have been few and simple; but better facilities for communication, for travel and for intercourse with his fellow men are improving his social and economic condition. Those who have been most ambitious, whose standard of living has been the highest, have been forced, of necessity, to migrate first to the town and then to the city or to forego the gratification of their wants and desires, both material and social. The hours of labor have been very long in rural communities, not only for the farmer, but for the women and children as well. Little leisure has been allowed the farmer and his wife in which to develop new wants. New inventions, new methods and better opportunities to reach markets for buying and selling are decreasing the necessity for long hours and are giving the farmers better social and intellectual advantages. All forces which gradually improve the social, moral, intellectual or economic condition of the farmers as a class tend to improve their standard of living and will in turn decrease the rate of migration from country to city.



Geo. W. Melville.
Rear Admiral & Engineer
in Chief U.S.N.

REAR-ADMIRAL G. W. MELVILLE, U.S.N., AND APPLIED SCIENCE IN CONSTRUCTION OF THE NEW FLEET.

BY THE LATE PROFESSOR R. H. THURSTON.

AS remarked by the editor of *The Nation,* the retirement of Rear-Admiral George W. Melville merits more attention than it has received. The final withdrawal of the engineer in chief of the United States Navy is an event of importance, not only as affecting the efficiency of the naval service, the value of its fleet and the usefulness of its personnel, but also, in hardly less degree, as liable to influence the progress of applied science in that essential branch of the public service. The retiring officer has held his position, despite all political changes, for the extraordinary period of sixteen years. His fourth term expired on August 8 and, although his retiring age was attained in January, he was, under a provision of the law allowing the President that option, retained and permitted to serve out his term.

It has been during the term of service of Admiral Melville that the 'new navy' has been created and all the modern scientific methods and all the resources of the applied sciences have been availed of in its construction and operation. In this work of application of modern learning, conspiring with recent invention, Melville has been responsible for the most extensive and vitally essential innovations, those of the department of machinery of propulsion. That his administration has been attended with the highest success is sufficiently evidenced by his long retention in his office and by the unanimous agreement of our own and foreign naval experts in a high rating of our fleet. The comments of the past summer upon the occasion of the visit of the *Kearsarge* to European waters, the earlier verdict on the performance of our fleet during the Spanish-American war and particularly on the *Oregon* and her work, are illustrations of the opinions of foreign as well as of our own experts. For the whole mass of machinery with which these ships are laden, and for their performance under steam, the Chief of the Bureau of Steam Engineering of the Navy Department is ultimately responsible. Melville has carried this responsibility for sixteen years and retires with honor and appreciation by all who have officially dealt with him or who have been professionally familiar with his work. The transformation which he has witnessed and in which he has taken so large a part is only comparable to that of the original introduction of steam into the navy, and the only comparable career is that of Engineer-in-Chief Isherwood, who was similarly responsible for the efficiency and reliability of the fleet of 1861–5 and later. But, while the latter has great interest for all as an element of the success of the government in suppressing the southern confederacy, the former is more impressive in its illustration of the application of modern science to the revolutionizing of the construction of the fleet.

The career of Admiral Melville has thus been one of peculiar interest, and I am glad to be able to review it from the standpoint of the contemporary and professional colleague, of one who entered the navy in 1861 in the same class and, with commissions of similar date, served for many years in the same corps, and later, professionally, in civil life in such capacities as permitted constant touch with the 'chief.'*

Melville's services to science as an arctic explorer antedated his appointment as chief of bureau. He was appointed 'chief' by Mr. Whitney, secretary of the navy, on August 8, 1887, and served sixteen years, the longest period of service on record for a chief of bureau. He immediately took up his task of preparing plans for the machinery of the 'new navy,' gathering about him the ablest available members of his corps. The department had meantime bought plans from foreign builders for the *Baltimore, Charleston* and *Texas;* but the work of the new bureau-chief and his corps made it quite unnecessary to experiment in that direction further. The existing fleet is, as a whole, the production of the engineers and naval architects and ordnance officers of our own Navy Department; the whole system of steam propulsion and its accessories being designed under the direction and supervision of the hero of the Lena Delta.

Among other innovations and improvements was the installation of the previously almost untried marine water-tube boiler of the general type long familiar on land. John Stevens, a century ago, asserted that the proper construction of a steam-boiler, on the score of safety, was that which divides the steam and water spaces into many small chambers, in such manner that the rupture of any one should be in minimum degree dangerous.† He invented a water-tube boiler and used it in a screw steamboat, 1804. The famous British engineer, Fairbairn, asserted the principle: A steam-boiler should be so constructed as not to be liable to explosion.‡ The modern water-tube boiler of good design combines the principle that a steam-boiler should not be liable to disruptive explosion with that which asserts that, if rupture does occur, it shall be in minimum degree dangerous. It was asserted by the writer, a generation ago, that this class must ultimately displace the older forms of 'shell-boiler' which are liable to destructive ex-

* See *Cassier's Magazine*, September, 1903, for an admirable and detailed account of the work of this distinguished officer, by his former assistant, Mr. W. M. McFarland, formerly chief engineer, U. S. N.

† 'History of the Growth of the Steam Engine.'

‡ 'Manual of the Steam-Boiler,' R. H. T.

plosion.* In fact, the list of boiler explosions, with their attendant loss of life and property, is a list of failures of the shell-boiler. Admiral Melville brought this 'new' boiler into permanent employment a hundred years after Stevens and made its value and necessity evident. The battle-ship or cruiser of to-day could not be constructed of equal speed, and equal efficiency of armor and armament, without it, and all navies are now adopting it. It gives a minimized weight and space for the unit of power, is safe against the disastrous explosions characterizing so frequently the termination of the work of the shell-boiler, and it is economical. It may be employed for pressures of any degree of intensity . The battle-ship of to-day could not attain its actual effectiveness without its employment, at least as a battery for high speeds. At cruising speeds, the older boiler is often retained; the later type being brought into operation when driving the ship up to emergency speed. The water-tube boiler requires more skill in handling than the fire-tube.

Melville introduced the triple-screw system for large ships, in which it was becoming difficult to secure safe construction of the enormous propeller-shafts demanded, and where it seemed to him desirable to secure a better hold upon the water by enlarging the area of the current utilized in propulsion. The success of the *Columbia* and the *Minneapolis,* fast cruisers, was complete, breaking the record for naval craft of large size and exceeding by a knot the speed anticipated even by their designer. He introduced the 'repair-ship,' a floating machine-shop, and the 'distilling ship,' in the war with Spain, as adjuncts to the fleet, innovations, both, of great value, often of vital importance.

In the details of his work, the chief of bureau has always exhibited the most thorough familiarity with its scientific side, and his plans have always involved the employment of every expedient known to science for promotion of efficiency. He has advocated increased thermodynamic range, higher ratios of expansion and greater piston-speeds for his engines, to give increased thermodynamic efficiency; has made effective provision against those extra-thermodynamic wastes which constitute the most serious tax upon heat utilization and has adopted every sound system of improvement known to modern science as bearing upon his work.

One of his most important movements was that in promotion of the merging of the old engineer corps of the navy into the line. The battle-ship has long been recognized as what the writer has called the

* 'Report to American Institute,' 1871, *Ibidem.*

† Water-tube boilers have been built to sustain from one to two thousand pounds on the square inch. The boiler of a quadruple-expansion experimental engine constructed as 'thesis-work' in Sibley College, and the engine attached which holds the world's record for economy in its class, has been operated at above one thousand pounds.

'Engineer's War-Engine,'* simply an engine devised for destructive rather than productive purposes in contest with others of its kind, and demanding maximum possible offensive and defensive power. The naval officer, whether he will or no, must therefore be an engineer, actually, if not nominally, and whether on deck at the guns or below at the source of power. The design, the construction and the operation of this now complicated and powerful and enormously costly machine are alike tasks in engineering, and whether the mind which produces its part of the work is that of the mechanical and electrical engineer, the naval architect or the ordnance deck-officer. This fact became officially recognized when the famous 'Personnel Bill' was enacted, at the suggestion of a board on which Admiral Evans and the then Assistant Secretary of the Navy Roosevelt were strongly influential in supporting the view held by Melville. This radical change was effected and we are still awaiting the outcome.

The education of engineers at the U. S. Naval Academy, commenced nearly forty years ago, is now become an essential feature of the course for all its pupils. The 'fighting officers' of the navy have now all necessarily become engineers, and the future of that service will largely depend upon whether our ships are manned and officered by amateurs or by experts of knowledge, experience, courage and judgment. At present, the number of officers in the latter class is far too small; but this defect should remedy itself promptly. The new Naval Academy is the most complete and perfect institution of its class, perhaps of any class in the educational world, which has ever been seen or conceived; we are sending there for technical and general training as fine a body of young men as can anywhere be found, and the future history of our steam navy is likely to do no discredit to its past, either in the days of Paul Jones or in those of Farragut.

The successor of Admiral Melville is Rear-Admiral Charles W. Rae, a graduate of the Rensselaer Polytechnic Institute and an alumnus of the Naval Academy, where he graduated with the first class in engineering organized at that institution.† An officer of great ability and of high distinction, he is well fitted to continue a progress based upon modern science as well as upon advanced professional practise, and which was so admirably illustrated during Melville's period of service. The naval service has come to be perhaps the most impressive and extensive field of application of science of modern times.

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* *N. A. Review*, December, 1897, 'The Engineer and his War-Engine.'

† This class of sixteen young men, coming from the colleges and technical schools of the country, was organized during the period of service of the writer at the Naval Academy and was one in which every naval officer felt peculiar interest. Its members justified every hope and expectation of the promoters of this new departure and showed admirably the value of a scientific training for their work.

SHORTER ARTICLES AND DISCUSSION.

AN UNUSUAL AURORA.

In the October number of the Popular Science Monthly, Mr. A. F. A. King has called attention to the remarkable display of aurora borealis on August 21 and has figured it as seen at York Harbor, Maine. I had the privilege of witnessing this aurora from Intervale, New Hampshire, and it corresponded very closely to the description given by Mr. King with a single exception, so remarkable that it seems to me worthy of note. At York Harbor the western half of the arch was made up of the comet-like pennants while the eastern half of the arch was continuous. This is clear, both from Mr. King's description and from the accompanying cut. As seen from Intervale this was reversed, the western half of the arch being continuous and the eastern broken. When I first saw the display, perhaps a little after half-past nine, the top of the arch was about ten degrees *south* of the zenith, and it slowly descended till about thirty degrees south. This was about half-past ten, and at this time the arch had so faded as to be hardly distinguishable.

Jas. Lewis Howe.

Washington and Lee University, Lexington, Va.,
October 7, 1903.

To the Editor: I was much interested in the account of the 'Auroral Arch,' given by Dr. A. F. A. King in the October number of Popular Science Monthly, owing to the facts that I observed the phenomenon and wondered what it was, and that Dr. King's observations differed somewhat from mine.

It was about 8 P.M. that I first saw the aurora. To me and others who observed it, it seemed in no way unusual save that we had not seen the 'northern lights' for several years, and we thought it was rather a poor display. No more notice was taken of it at this time. It was about nine o'clock that we were called out to see 'a peculiar appearance in the sky.' It was a band of nebulous light extending from the eastern to the western horizon, and it seemed to be about three feet wide (to me wider than the apparent diameter of the full moon). It was of nearly uniform width and intensity throughout its extent.

At nine o'clock I took the direction of the band with a pocket compass and the time by my watch. At this time the band had begun to break up at the zenith and eastern end into the 'comet-like,' slowly wavering bodies as described by Dr. King. The band continued to break from the east to a little west of the zenith until the whole eastern arc was composed of these bodies, which was at about 10 P.M., when I returned to the house. Then the western arc was intact save that it seemed to have faded somewhat.

The phenomenon as described here was seen by five others at the time and place that I saw it. I was ignorant of the nature of the display, but thought it could not be the aurora borealis, so watched the papers for the next few days to ascertain if others who might explain the phenomenon had observed it, but found nothing satisfactory until I received the October Popular Science Monthly.

W. C. Kendall.

Robert Henry Thurston.

THE PROGRESS OF SCIENCE.

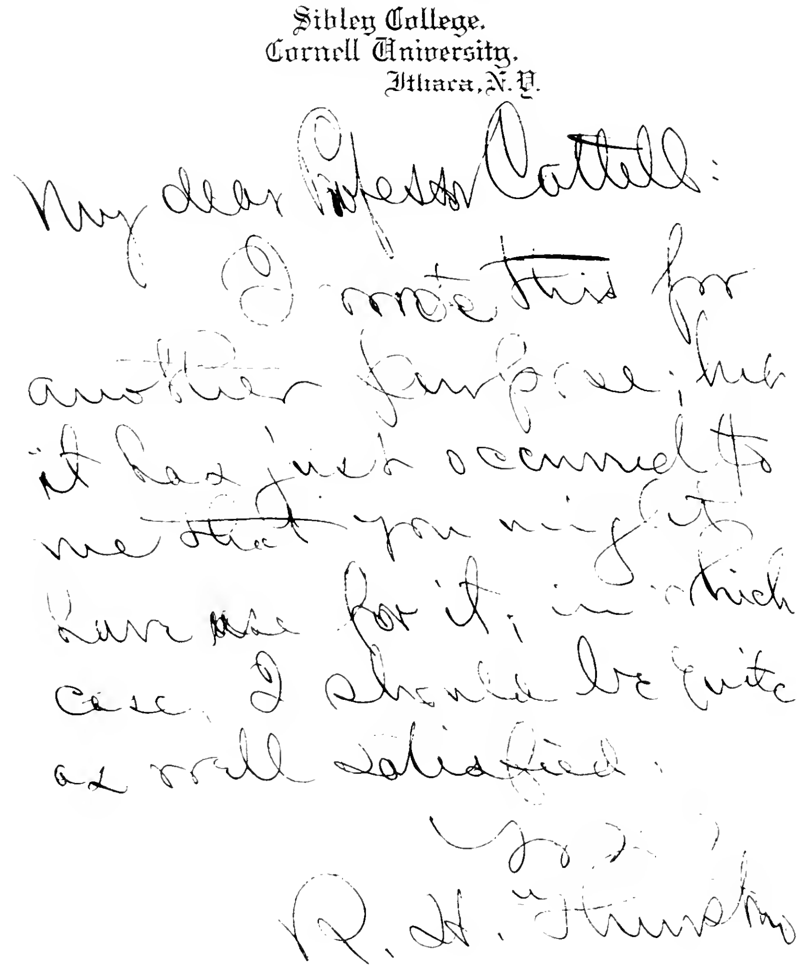
ROBERT HENRY THURSTON.

By the death of Professor R. H. Thurston education and science suffer a serious loss. His activity was wide-reaching and entirely beneficent. As a physicist he was not the peer of Gibbs and Rowland, but his work covered such a broad field and was so large in quantity that the highest exactness could scarcely be attained. His special researches in thermodynamics and their applications to the steam-engine have given him an eminent place among scientific men, while his conduct of Sibley College has proved him to be one of the educational leaders of the country. While thus carrying on the work of two men, he devoted himself unsparingly to every good cause. Innumerable demands on his time and patience were met cheerfully and helpfully. His death is a personal loss to every one who knew him, and is at the same time a public misfortune.

Thurston was born at Providence, R. I., on October 25, 1839. His death from heart disease occurred with entire suddenness on his sixty-fourth birthday, while he was awaiting guests whom he had invited to his house. He was educated at Brown University and in his father's shops. At the outbreak of the civil war he enlisted in the naval engineer corps, and served with distinction. He was on the *Monitor* in its famous engagement with the *Merrimac* and later was first assistant in charge of the ironclad *Dictator*. At the end of the war he became professor of natural philosophy in the U. S. Naval Academy, and in 1871 accepted the chair of engineering in Stevens Institute of Technology. In 1885 he accepted a professorship in mechanical engineering at Cornell University and the directorship of Sibley College. Under him the college was organized and, chiefly through his personal efforts during the past eighteen years, it has attained its present preeminent position. There are this year nearly a thousand students in the college, and its courses of study have set standards for other institutions. While thus engaged in constant teaching and arduous administrative work, Thurston was equally occupied with investigation and publication. He was the author of eleven books and of some three hundred papers. In this journal will be found many of his more popular articles, and in the present number we have the sad privilege of publishing his last paper. He was one of the editors of *Science* and of Johnson's and Appleton's Cyclopædias. He was constantly engaged on committees and commissions, and took an active part in scientific and educational societies. He was three times president of the American Association for the Advancement of Science and was first president of the American Society of Mechanical Engineers.

INTERNATIONAL EDUCATION.

Science and education have always ignored the boundaries of nations and have been important factors in promoting peace and good-will. It is a most extraordinary fact that there should have been 10,000 students from all parts of Europe at Bologne in the thirteenth century. The origin of the words 'university' and 'college' appears to have been in the separation of the students from different countries into guilds, and the organization of the *studium generale* was definitely based on the division into 'nations.' Teachers, as well as students, migrated from


Sibley College.
Cornell University.
Ithaca, N. Y.

My dear Professor Cattell:
I wrote this for another purpose; but it has just occurred to me that you might have use for it; in which case I should be quite as well satisfied.
Yours,
R. H. Thurston

university to university in a manner rather difficult to reconcile with the general conception of the 'dark ages.' This movement had an important effect on the development of European civilization. It has never since been equaled, though there have been significant migrations of students, the most interesting of which from our point of view being the large number of Americans who studied in Germany during the latter half of the nineteenth century. This movement reached its culmination about 1890, when some five hundred Americans were pursuing nonprofessional graduate studies in German universities. But the students who went earlier to Germany had a greater effect on our educational system, as witnessed in the development of Harvard College and the establishment of the Johns Hopkins University. The movement has now become widespread, and we have some thirty universities and 5,000 students carrying on graduate work on the model of the German university. There are now a few European students attracted to our universities and at least one professor in an American institution has been offered a chair in Germany. Numerous students have come from Japan and a considerable number from South America.

The American college was directly modeled on the corresponding institutions in England and Scotland, and it would probably have been an advantage, both educationally and from the point of view of international relations, if we had kept in closer touch with the British university. The will of Cecil Rhodes was an attempt to promote artificially such relations, and there is every reason to believe that it will meet with a fair degree of success. Ninety students from the United States residing at Oxford will contribute to the development of the university and will bring back to America the traditions of English education and culture. From the point of view of this journal, the entrance requirements and part of the curriculum at Oxford are a medieval survival, and the opportunities for advanced work in science are limited. But no one who has been brought intimately in contact with the Oxford life can fail to realize its charm. The influence on a few American students scattered over the whole country will surely be of advantage to them and to our relations with Great Britain. The American university presidents who have been given control of the administration of the Rhodes scholarships have decided to require residence at an American college before the student proceeds to Oxford. This is contrary to the intentions of Mr. Rhodes and appears to be scarcely justifiable from an educational point of view. For undergraduate work, Oxford possesses peculiar attractions. It would be better for a student to go through the B.A. course at Oxford and then pursue graduate studies in Germany or America, rather than to reverse the order. It may be remarked incidentally that Cambridge now offers admirable opportunities for research students in the natural and exact sciences, quite equal to those of the German universities, and that these should be more largely used than is at present the case.

A few years since America was almost outside the limits of European vision. In order to meet foreign scholars it was necessary for us to go abroad. But these conditions are changing rapidly. European men of science, and scholars singly and in groups, are continually going up and down over the land. The most eminent representatives of science and learning from Great Britain, Germany, France and other nations visit us in order to teach and to learn. Just now, for example, we are entertaining the educational commission organized by Mr. Mosely. Some thirty of the more active and eminent British educators were invited by Mr. Mosely to visit America as his guests, in order to make a study of our educational system from the primary school to the university. The commission includes scientific men, such as Professors Armstrong, Ayrton, Frankland and MacLean. A visit of this character will conduce to Anglo-American amity and the improvement of educational methods. An even more interesting event is promised for next year, when more than a hundred leading European men of science and scholars will visit the United States to take part in the Congress of Arts and Science, organized in connection with the St. Louis Exposition.

MENTAL AND MORAL HEREDITY.

THE POPULAR SCIENCE MONTHLY has had the privilege of printing two of the four Huxley Memorial Lectures, given before the Anthropological Institute of Great Britain—that on Huxley by Lord Avebury and that on the 'Improvement of the Human Breed' by Dr. Francis Galton. The latter subject is continued by the last lecture of the series given by Professor Karl Pearson, who in general is carrying forward the quantitative work on heredity which owes so much to Dr.

Galton. Professor Pearson sent circulars to a large number of teachers asking them to grade pairs of brothers and sisters for mental and moral traits, such as popularity, conscientiousness, probity, vivacity and general ability. There proved to be a remarkable fraternal resemblance, represented by a regression line of one to two, exactly the same as that found for physical traits such as the cephalic index. Professor Pearson concludes that mental and physical heredity are equally potent; mental traits are bred in the bone and are not the result of training. Great Britain could not help its position among the nations by improving its schools or by increasing technical education. The trouble is that the less able and the less energetic are more fertile than the better stocks.

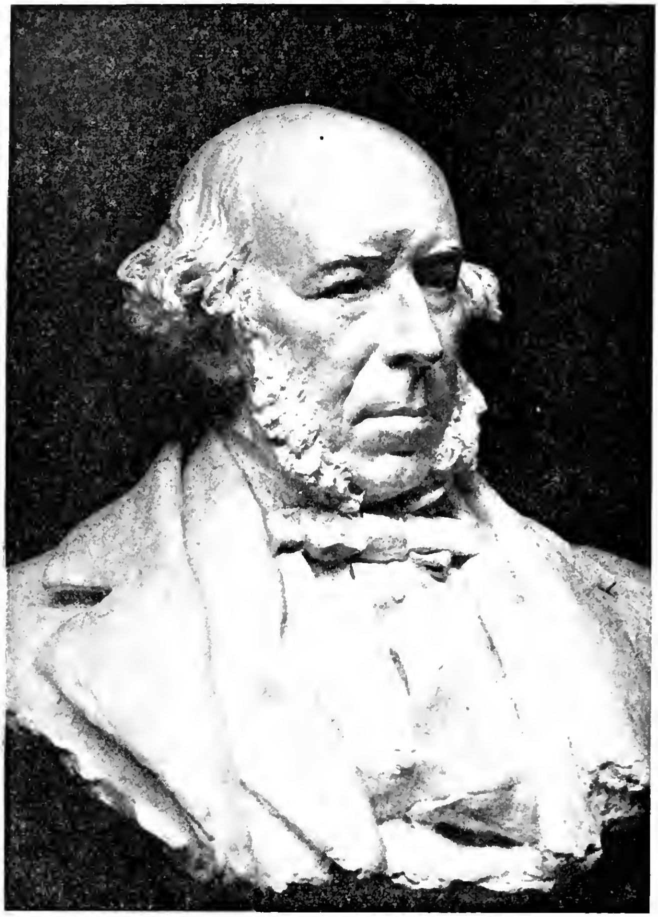
Professor Pearson's figures require confirmation. The writer of this note once remarked on the resemblance of some children to their mother; the resemblance became less obvious when he was informed that she was their stepmother. The fact that two children are brothers may lead a teacher to regard them as similar in mental traits. But Professor Pearson's figures in any case appear to be misinterpreted. If the resemblance of brothers in physical and mental traits is alike, we must conclude, contrary to Professor Pearson, that the inheritance of physical and mental traits is not equal. Association and similar home life have some influence, however slight, on traits such as temper and honesty. It would be possible to argue from the figures that mental traits are not hereditary, the effects of similar environment being equal in amount to physical heredity.

SCIENTIFIC ITEMS.

The American Association for the Advancement of Science with a large number of affiliated societies, including the American Society of Naturalists, The American Chemical Society, The American Physical Society, The Astronomical and Astrophysical Society of America, the Botanical Society of America, The American Anthropological Association, The American Psychological Association and others, meet at St. Louis in convocation week, beginning on December 28. We shall give in the next issue a forecast of the meeting, at present only calling attention to the importance of this meeting and to the admirable arrangements that have been made and urging the privilege and importance of attendance, both for professional scientific men and for those who are interested in the progress of science.

The Lawrence Scientific School of Harvard University will receive a very large sum, said to be more than $4,000,000, from the estate of the late Gordon McKay.

President Schurman, of Cornell University, has proposed the erection of a new building for Sibley College, in memory of the late Professor Thurston, to be known as Thurston Hall. The students of Sibley College have voted to erect a bronze memorial tablet in honor of Professor Thurston.—An obelisk of unpolished grey granite has been placed over Virchow's grave in the old Matthäi graveyard, Berlin. It bears on one side a black marble tablet, on which is inscribed 'Rudolf Virchow' and the date of his birth and death. A statue of Virchow will also be erected near the place where his scientific work was conducted.



Herbert Spencer
when 76

THE
POPULAR SCIENCE
MONTHLY.

JANUARY, 1904.

A CASE OF AUTOMATIC DRAWING.

By Professor WILLIAM JAMES,
HARVARD UNIVERSITY.

'AUTOMATISMS' have recently been made a frequent topic of investigation by psychologists, and although the exact reason why some persons have them and others do not remains as little explained as does the precise character and content which they may affect in a given individual, yet we are now so well acquainted with their variety that we can class them under familiar types.

The rudiment of all the motor-automatisms seems to be the tendency of our muscles to act out any performance of which we may think. They do so without deliberate intention, and often without awareness on our part, as where one swings a ring by a thread in a glass and finds that it strikes the number of times of which we think; or as when we play the willing game, and, laying our hands on the blindfolded 'percipient,' involuntarily guide him by our checking or encouraging pressure until he lays his hands upon the object which is hid.

The next higher grade of motor automatism, involving considerable subconscious action of intelligence, is found in the various alphabet-using forms of amateur mediumship, such as table tipping, the 'Ouija-board,' and certain other devices for making our muscles leaky and liable to escape from control.

'Graphic' automatisms, of which planchette-writing is the most popularly known example, is a more widespread accomplishment than ordinary people think. We have no statistics, but I am inclined to suspect that in twenty persons taken at random an automatic writer of some degree can always be found.

The messages are often elaborate, and surprise the writer quite as much as they do the bystanders by their content. The upper consciousness seems sometimes to cooperate in a faint way, sometimes merely to permit, and sometimes to be entirely ignorant of what the hand is doing. Occasionally the subject grows abstracted, and may go into a sort of reverie or trance if the writing or drawing is prolonged. Sometimes, but apparently in a minority of cases, the hand becomes insensible to pricking and pinching. Of the matters set down and their peculiarities I will say nothing here, these words of mine being merely introductory to a case of automatic drawing which may be interesting to the general reader from its lack of complication and its oddity.

The subject, C. H. P., married, fifty years old, made his living as a bookkeeper until the autumn of 1901, when he fractured his spine in an elevator accident. Since the accident he has been incapable of carrying on his former occupation.

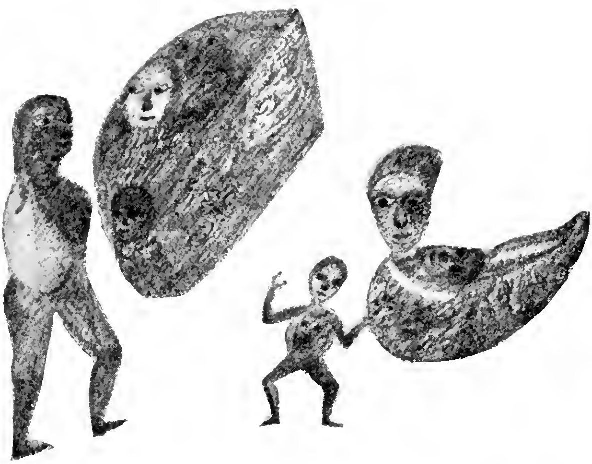
For several years previous to the accident, automatic hand-movements, twitchings, etc., had occurred, but having no familiarity with automatic phenomena Mr. P. thought they were mere 'nervousness,' and discouraged them. He thinks that 'drawing' would have come earlier had he understood the premonitory symptoms and taken a pencil into his hand.

The hand movements grew more marked a few months after the elevator accident, but the subject sees no definite reason for ascribing to the accident any part in their production.

They were converted into definite movements of drawing by an exhibition which he witnessed in February, 1903. The account which follows is in Mr. P.'s own words.

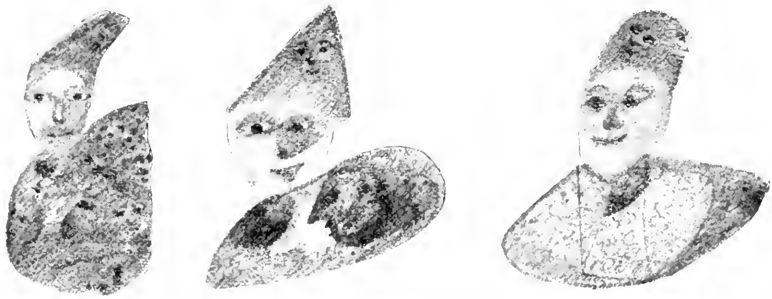
A friend who was interested in hypnotism introduced me to a man who had some power as a hypnotist, and this man gave for our amusement a sample of automatic drawing, a man's face in dotted outline, no shading or detail.

The movement of his hand reminded me of the way my own hand frequently acted, so the next day I sat down to a table with a pencil and paper, and tracings were directly made; but it was some days before I made an object that could be recognized, and I have never made dotted outlines like the man who



performed before me. For some days the movements were violent, and the traces left by the pencil were erratic, the lines being drawn with seemingly no aim, but finally rude forms of objects were executed.

Gradually my hand moved with more regularity and the pictures produced became interesting. Among these were dark-skinned savages, animals and vases of ancient type usually ornamented fantastically with curious faces.



A large proportion of the drawings were human heads, at first very crude in design and execution.

In the course of about two months the pictures assumed an artistic appearance, especially the heads. Most of the heads were quite small and dim in outline and detail.

My hand executed these without volition or direction from my natural self. My mind directed neither the design nor the execution. A new power usurped for the time being the functions of my natural or every-day mind. This power directed the entire performance.

Many times I tried to produce pictures of familiar faces, or scenes familiar to me by long association. I could produce nothing in this direction, but confusion was the result of the attempt. My hand continued to be guided by the unknown power. Weird, fantastic pictures were produced in abundance, many of them artistic in execution, but mostly of ancient type.

Sometimes the face would be so covered with strange devices as scarcely to be recognized as being intended for a face. Frequently a rock would be drawn with faces hewn in it.

While drawing these pictures I became drowsy, so much so that after finishing an artistic one I would sometimes go into an hypnotic sleep, and always would, after a long sitting, if I did not combat the influence.

My pencil moved sometimes so rapidly as to make it difficult to follow it with my eye. At other times it moved slowly. Some of the best effects were produced by rapid movements. I never knew what my pencil would make when it commenced, and often did not know until finished. Sometimes a design would be entirely changed.

Small pictures were frequently produced by a few rapid movements of the pencil from side to side, the pencil apparently not being lifted, yet the features of the face and general contour of the subject in hand would appear plainly. Voluntary suggestion has little effect on the drawings. After repeated suggestions I have sometimes been able to obtain an allegorical picture, as for instance when I asked for a message from my son, who resided at a distance, a carrier pigeon, having a ribbon around its neck with a letter attached, was produced.

I have tried hard to account for the power or directing mind that produces these pictures, but so far with no satisfactory result. I must say, however, that evidence to me is strong that, in order that the unknown power should have sway, the natural or earthly mind must be for the time being set aside, either entirely, or (what seems to me more reasonable) the unknown power is for the time being the dominant one, but acts in conjunction with the earthly mind. Although while drawing I feel more or less drowsy, my senses seem in some respects to be very keen. To my eyes the pictures usually appear highly exaggerated in beauty as well as in distinctness.

So much is this the case that on the completion of a picture and having taken it up to examine it, the distinctness and beauty which were so apparent while drawing, have departed. Frequently, while drawing, the picture will be illuminated by delicate colors; and a feeling of great disappointment occurs when, on the completion of the picture, I find that not only the colors have disappeared, but the fine points of the picture also.

One strong feeling is left in my mind that whatever directs the pencil is all-powerful, and that nothing is too difficult for its performance if it only chooses to assert its power.

I ought to add that the style of design which my hand draws is strange to me. I have never observed anything like them anywhere. Neither do I know of any influence, suggestive or otherwise, that could have given me this power, with the exception (as I have stated) of having seen a man make a slight exhibition of automatic drawing, but this exhibition was long after I had noticed movements of my own hand. However, that exhibition gave me the idea of taking a pencil into my hand to try for results.

One point I might state clearly. While drawing, my eyes are fastened intently on the point of the pencil in contact with the paper, following the course of the pencil as if they were fascinated by it.

Of automatic *writing* I have done little. Occasionally the name of a near relative will appear, sometimes with figures attached. Sometimes an incoherent sentence will be commenced, but not finished. The name and figures usually appear either on a face or under or over it. Occasionally a word or

line is written in (as I suppose) some ancient language, under or close to a drawing. I have never been able to discover what language this is. Perhaps it is, like the drawings, imperfect.

I had never been interested in hypnotism or kindred subjects before, nor ever attended any meetings or exhibitions in these lines, having always had a disbelief in anything of the kind.

P. S. Three months having elapsed since writing the above, I have but little to add in explanation. Pictures are still produced by the same mysterious power. The artistic appearance is better and the human form is more in evidence. I still think the drawings come from involuntary suggestion, that is, suggestion from the inner mind. Perhaps it would be better to call it impulse rather than suggestion.

I saw Mr. P. make one drawing. His hand on that occasion moved very slowly in small circles, not leaving the paper till the drawing had, as it were, thickened itself up. He seemed to grow very abstracted before the close of the performance, but on testing his hand with a needle, it showed no anesthesia.

It is evident that with a little more system, a little more handwriting, and possibly some speaking under 'control,' this gentleman (whose narrative seems absolutely sincere) would exemplify a case of mediumship of what one might call the 'Martian' type. It would then remind one somewhat of the case so admirably studied by Professor Flournoy in his book 'From India to the Planet Mars.' As the case stands, it is peculiar only for the monotony and oddity of the designs drawn by the hand. As in many other cases, we have no means of guessing why the subject in his drawings follows so peculiar a type. His own statement that he never saw anything like them before, must be taken with a grain of salt; for memories which have lapsed entirely from the upper consciousness of a subject have again and again been proved to actuate his hand in automatic writing. This case may be one of such a memory simply developing and confirming its habits. It may possibly on the other hand be the expression of a 'secondary personality' of some sort, in which (or in whom), if we could make exploration, a systematic context of ideas would be found.

THE COLLEGE COURSE.

By Professor JOHN J. STEVENSON,
NEW YORK UNIVERSITY.

MUCH of the discussion respecting utility of college training is irrelevant, for success in life proves nothing on one side or the other. Every observing man knows that the qualities on which success depends are inborn. College instructors can not impart brains or common sense, can not convert the sluggard into a model of industry; can do little toward removing the vanity which resents advice. They can make only an honest effort to cultivate the material provided by nature.

The discussion has been too nearly academic, and the parties have been wary of coming down to definite issues. The opponent of college training is cautious about too detailed attack upon that with which he is not familiar; while teachers, though united in defense of their work, are not wholly agreed either as to its final purpose or as to the method of attaining it. The lack of consensus respecting the meaning of the term education, whether preparatory or collegiate, is a weakness which opponents have been quick to see and to attack. The purpose in mental training should be as definite as is that in physical training. The latter is a new branch of educational work and the instructors, fettered by no traditions, aim to make the man physically good all around, without any reference whatever to his future calling. In mental training there seems to be no longer any such clear-cut purpose. All agree, of course, in the abstract proposition that the aim is to make the man useful—but, for what?

The medieval theory of education looked to the utilization of the individual for himself. Education being for the privileged few, to fit men for the proper enjoyment of leisure, for the Latin priesthood or to expound Roman law, the relations and the duties of the few to the many were ignored. There resulted a narrow curriculum with close attention to detail, which gave accuracy, certainly very wonderful, but, like that of the microscope, in a very limited field. The modern theory, developing slowly after men were emancipated from the thraldom of the church, more rapidly after the study of nature by observation was born again, regarded the individual not as the whole, but as part of the whole, recognizing the basal principle that 'No man liveth unto himself.' It demanded that man be so trained as to be of the utmost use not to himself only, but to his fellows also. It asserted that a man must earn the right to live by being of service, and denied that training along the prevalent narrow lines was education in the proper sense. It ridiculed the pretensions of a system which boasted of its success in producing men whose scholarship was proved by volumes filled with quotations illustrating the use of Latin or Greek particles; it demanded a training which should develop all sides of the man and fit him for the exigencies of active life as contrasted with that of the cloister.

Efforts made in our country sixty years ago to remodel the curriculum so as to satisfy both sides are spoken of as absurd, because they were not radical. They were not absurd; they were the first steps along an untried way. Educational institutions were controlled by medievalists, and the doctrine was ingrained that instruction belonged to the province of the christian minister as much as did the pulpit; the whole system had grown up under the requirements of the church and under the limitations permitted by the church; so that, in considering the change, those in charge found themselves at a loss. Their Latin was no longer a 'modern' language, it was no longer the common tongue of learned men; Greek, at best, had been only a luxury. The study of material things, having led men to doubt respecting some matters of religious belief which had come down without challenge from antiquity, was tainted with suspicion of sacrilege; of its true nature they were wholly ignorant. The best that could be done was done; within college walls, the classical languages gradually ceased to be living languages, came to be regarded as dead languages, their words were used as medium for teaching a kind of universal grammar, and the average student, after spending a round dozen of years in the so-called study of Latin, thought himself uncommonly accomplished if he were able to read his diploma without resort to a lexicon or grammar. The course leading up to the degree, for there was but one degree, was broadened gradually so as to embrace additional subjects. But until fifty years ago it consisted in most colleges of linguistics, that is to say, Latin and Greek with practical neglect of English, a notable amount of pure mathematics, a medley of courses in history and philosophy, with a trifle of natural science. In some institutions, additional branches were inserted, the courses were differentiated and a new degree was granted to those who, neglecting the classical languages, had taken instead modern languages and somewhat extended work in natural science.

The concessions to the claims of natural science were made grudgingly; the study of nature was looked upon by 'educated' men generally as a rather low-lived pursuit, not to be encouraged, as it led men away from man, 'man's noblest study.' But there were those who felt intuitively that it was not safe to entrust the education of their children to men whose circle of vision was so contracted. A reaction came; and when it came, the pendulum, as was to be expected, swung too far in the opposite direction. Semi-technical schools were established, which soon became either purely technical or purely scientific, in each case thrusting aside almost wholly the literary studies of the older system. These appeared to meet the requirement of the time and quickly grew to great importance, in some cases overshadowing older institutions near at hand. They gave degrees, commonly the scientific baccalaureate, of the college; in many cases they were incorporated with universities and at length stood on the same footing with the schools of law, medicine or theology. They admitted students at the same age as did the colleges, though the entrance requirements in some directions were less rigid. But those requirements were made more and more severe until it became necessary to increase college requirements; and this in turn led to increased requirements as well as to elevation in grade of instruction in law and medicine with, as a final outcome, a lengthening of the course in these two departments—while in some institutions a bachelor's degree became a prerequisite for the professional diploma. The results of these varied changes have been disastrous in several ways to the college and to college training.

The outcome was inevitable in one direction. Two schoolmates, leaving the preparatory school together, go for advanced study to the same institution; one enters the college on the scientific side, to take a course in cultural studies; the other enters the technical school to become an engineer. The boys meet on the same campus almost every day; for a time, they may meet occasionally in the same class-room; they speak in both cases of being at college. At the close of four years, each receives the degree of B.S., one in pure science, the other in engineering. To their friends, the degree is the same in both cases; but it is not, as the friends quickly discover; the engineer has now a profession and is ready to begin his life's work, whereas the other is still confronted with a course of three or four years, if professional work be his aim.

It was natural that a demand for shortening of the college period should be made, that there should be a cry to save the early years of the man's life. It was said that increased requirements for entrance had made it impossible for men to graduate at sixteen or eighteen as they did fifty years ago; that the advance in grade of instruction had made the man who completes the junior year fully equal to the graduate of fifty years ago. But this argument can not hold. The average of college graduates, as appears from study of alumni catalogues, is very little greater to-day than it was thirty or forty years ago, and, in any event, there is no reason why it ought to be greater. That requirements along some lines have been increased is true, but one must not forget that opportunity for preparation has been increased to a much greater extent. Fifty years ago, schools offering good preparation for college were rare in agricultural districts, and young men in such districts were dependent upon the country clergyman for preparation. Now, however, secondary schools are within reach in almost all parts of our country and a farmer boy can be made ready for college at almost as early age as the city boy. Despite these facts, the cry was heeded, the college period was shortened and, in a number of our universities, professional study during the last year of the college course counts toward both college and professional degree; so that from entrance into college to final graduation with professional degree in law, the period is the same as it was years ago, when the course was one year shorter, or one year less than it was forty years ago in institutions where the course has not been lengthened; forty years ago, the medical degree was reached in six years, now it is obtained in seven, though the professional course has been lengthened by two years. The suggestion has been made that the time spent at college should be shortened still further and that mere training should be thrown back upon the secondary schools. This plan, if adopted, would bring little relief, for, no doubt, the secondary schools, in their anxiety to avoid oppressing their pupils, would find it necessary to insist on still shorter lessons and on ampler time for recreation, so that nothing would be saved in time unless the college period be shortened still further—at last to extinction.

The injury has been more serious in another direction.

In all fairness, one must concede that the 'regular' college course of twenty or twenty-five years ago, despite the preponderance of classical teaching, had gained so far by the introduction of new subjects that it did give a broad aspect of things to the average student. It offered such a thorough taste of many branches of learning as to let him find where his strength lay. Even forty years ago it had developed much along the same lines in the larger colleges as well as in the newer of the small colleges. But specialization grew up rapidly in the scientific schools and this example, reinforced by a popular demand for broader opportunities of selection, led to specialization in college work. Practically the old college course has disappeared in many of the more prominent institutions, and in its stead one finds broad election in some, narrow groups in others. In some, a compulsory broad course is the freshman's lot, but in higher classes the student follows a chosen group, in which some special branch absorbs most of his time, all others being subordinate; in others, election begins with the sophomore year and is nominally almost unfettered, though adroit manipulation of the recitation schedule may impose serious limitations.

University methods of instruction have been introduced and laboratory work is made an important feature, to the exclusion of information courses, which should go toward making the student a well-informed man. Even the high schools have been infected, and in one city, at least, the lad of fourteen has the opportunity to elect a considerable part of his studies.

The whole system of groups or of wide election in the earlier years is based upon an erroneous conception of the proper aim of college work. No considerable proportion of American students are competent to decide at the outset of the college career or even at the close of the freshman year what studies they should pursue; nor in the vast majority of cases are the parents competent to decide the question. One is told that the German student is but nineteen years old when he enters the university, where all courses are open; and then is asked if he is prepared to assert that the American boy is less capable than the German boy. The question of capability or non-capability has nothing to do with the matter. When American secondary schools attain to the grade of the German gymnasium and American boys are compelled to undergo severe preparatory training such as is given in the gymnasium, they will be at least as competent to make a choice as are the German boys. But that matter is neither here nor there in this connection, for the training in our secondary schools is too frequently such as to cause only pain and annoyance to college instructors. The whole system is wrong, in view of the imperfect preliminary drill received by our students. No physical director would permit a hollow-chested, slender-armed sophomore to confine himself to leg exercises, merely because he has chosen book-canvassing as his life's work. Yet such freedom is allowed in the vastly more important matter of mental training; a sophomore who thinks he intends to become a clergyman is permitted to confine his attention to classics and literature; another, who finds mathematics distasteful and acquiring a vocabulary irksome, is permitted to select a course omitting those subjects, because he expects to be a lawyer; while another has the opportunity to select a still narrower course because he has medicine in view. So men pass through college, some to reach the ministry as 'leaders of thought' and at the same time to be laughing stocks for the children of the parish, because ignorant of the works of the God whom they preach; others to become lawyers and to find themslves shut out from the most important branches of practise, because ignorant of the fundamental principles of science; others still to become physicians and to find themselves handicapped in the race by inability to communicate their thoughts in direct language; while most of them enter life's struggle with a stock of ignorance utterly discreditable to a young man of the twentieth century. The error throughout is due to forgetfulness of the fact that the college is a training not a professional school.

That our present method or lack of method is successful, no one asserts. The practical shortening of the college course to three years and the proposition to shorten it still further are in themselves confessions of failure. They are more than that; they are acknowledgment that, in the competition between colleges, the race for degrees has been made so easy that all the mental training given in the four years' course can be given readily in three if not in two. And this acknowledgment appears to be not wholly unreasonable. As matters now stand, there is ample time even in the three years for men to complete the course for A.B. or B.S. creditably, while in addition they take elaborate courses in glee clubs, baseball, football, amateur journalism and other branches of learning, which require not only much time at home, but also frequent absences and excursions during term time. The correctness of the conclusion is made more evident by the fact that men following these collateral pursuits are required to maintain a fair standing in their classes. A fine degree of skill in determining the minimum degree of required work is attained by many of them; and their example is not altogether without influence upon their fellows, for it is well known that among students the 'dig' is a somewhat disreputable character. There is no room for surprise when one discovers that business men often look upon the college course as four years of training in the science of shirk and regret that social requirements compel them to send their boys to college.

The evil can not be corrected by shortening the college period. In truth, this proposition to shorten the period evidences another erroneous conception of the purpose of the college itself—a conception which seems to be gaining wide currency. The college is not an institution whose chief function is that of conferring degrees. This certainly seems to be the conception of many outside of the colleges as well as of not a few within, for there appears to be no end of ingenious methods whereby those who can not attend college may find a way of passing examinations, of receiving degrees and of becoming enrolled among the alumni, meanwhile adding to the glory of their college by swelling its numbers.

A thoughtful consideration of the conditions in American colleges reveals the fact that, during the last forty years, a great change has come about in the relations of instructors and students. In many respects this has been greatly to the advantage of both, but in others very much to their disadvantage. College matters have been adapted largely to accord with wishes of the students; the young men determine almost wholly the details of their courses; they regulate in no small degree the general conduct of matters so that a positive assertion of faculty authority causes surprise and is apt to arouse resentment; athletic associations complain bitterly because stringent rules are made by the authorities; editors of college publications rebel against rebukes or censures for indecent or scurrilous attacks upon officers of the institution and are ready to denounce them as interference with the liberty of the press. It would appear as if the college faculty, in the opinion of too many students, is an inconvenient and somewhat disagreeable, but unfortunately necessary, appendage to the student body.

Clearly enough, the change has not been altogether for good. The old adage says 'He who would command must first learn to obey.' It is but the expression of human experience. That American lads are sorely in need of such training is only too evident; but they can not get it in secondary schools dependent upon tuition fees for their support. Such training means more—training to think, to reason. Lads too often fail to receive this training in secondary schools, as any instructor who has to deal with freshmen can testify. In any event, the secondary schools of to-day can not give this training in its completeness, for they have not become fully adjusted to the suddenly expanded requirements for admission to college or scientific or technical school, and in their present state of development are little better than cramming houses to fit pupils to answer odds and ends of questions in papers for entrance examinations. Loose thinking and restlessness under constraint characterize the American student in the lower classes at college; lack of home training may be responsible in part for the latter characteristic; inferior teaching in secondary schools is largely responsible for the former.

The corrective for the evils which beset our colleges is not transfer of the training to secondary schools, which can not give it, but a return to the college organization of twenty-five years ago, to the college with a course four years long, mainly compulsory, with little election prior to the senior year—not to the old course in its narrowness but to the old course with its compulsion and with increased severity. Four years are none too long for the necessary moral and intellectual discipline, and the graduate, who afterward enters law or medicine, will still be so young as to make clients and patients hesitate to employ him. If the cry for earlier admission to professional schools must be heeded, lessen the entrance requirements for the college—though even that might fail: the increasing solicitude of parents for the health of their sons and the schoolmasters' canny dread of pushing pupils too rapidly are familiar phenomena. The course should be a broad one, embracing linguistics, philosophy, mathematics and natural science, each term being used in its wide sense, and each group in proper proportion to its importance to-day. Every branch should be so taught as to give mental training and at the same time knowledge, that at graduation the faithful student may have laid the foundation for becoming a 'well furnished' man. Throughout, it should be remembered that college is not intended only for those who look forward to professional life.

And this means also a change in the preparation of men for college chairs. Men go through college as specialists; they follow graduate courses as specialists; they become college instructors as specialists. Such training does not fit men for college teaching, however well it may fit them for university teaching. Having never had symmetrical mental training, they can not understand the true purpose of college work, and they are liable to make the college student narrower than themselves. There must be a return to the older type of professors, men whose studies were not confined to the immediate area of their chairs. We are accustomed to laugh at the notion that a college consisting of a boy at one end of a log and Mark Hopkins at the other was complete—and we are right; but the conception underlying that notion is true in no small degree. The graduate of such a college had learned to think and the information which he had received was correlated, was his own. The writer reveres the memory of such a teacher in his college, Benjamin N. Martin, who, teaching philosophy well, succeeded also in welding together for the student mathematics, history and science into a well-related body of knowledge. His pupils learned to think and, as far as in them lay, to think for themselves.

Not the classics but the method of training made the men in the older colleges; students learned to think and they were compelled to obey. They learned much of self-control in college—an easier school than that of the world, where college students of to-day must learn the same lesson—or fail.

THE FUNCTIONS OF MUSEUMS: A RE-SURVEY.

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WE are rapidly approaching, and some parts of the world have already reached, that millennium desired by the writer—was it not Professor E. S. Morse?—who exclaimed 'Public libraries in every town! then why not public museums?' With this increase in number has come a change of function, or at least an added function or two. Such a change is in the nature of an adaptation to the new surroundings, and is necessary for the vigorous life and propagation of the modern type of museum. How great the change is may be realized by contrasting, let us say, the American Museum of Natural History, which not only arranges attractive exhibits, but makes them known by its popular *Journal,* with some museums in Europe that still appear to be maintained in the interests of their staff, while the public is only admitted for a few hours each week, to gape at an unorganized crowd of objects which it can not comprehend. The student of science or of art who has to make his living as a curator in a public museum, which is public in fact and not merely in name, often envies those colleagues who, undisturbed by the *profanum vulgus,* spend a peaceful life in original research, such as he can only squeeze in at the close of a hard day's work. But in America and Britain we can never go back to those old days when visitors, after securing tickets by prayer of some high person, assembled at the gate of the British Museum and were conducted around it by a verger with a livery and a black wand as his chief qualifications for the task. Nor indeed can we now find ourselves in the position of that eager spinster, who, after many a vain attempt, journeyed from her suburban residence through mire and fog to those giant portals. 'Which department, Madam?' said the majestic policeman on the threshold. 'Oh! just a general look around, thank you.' 'Museum closed to-day, Mum, except for students.' Back on a 'bus to Brompton, and 'No more British Museum for me!'

No, the times have changed and are still changing. A stage in the advance was marked when Flower and Brown Goode gave us their masterly surveys of museum organization. They laid down the lines on which we have all been working. But still the outer conditions are changing, and in some respects we fail to keep pace. The occasion for a re-survey of the situation recently presented itself to me, and I was led to the conclusion that a redisposition of our forces was required if we were to cope adequately with the difficulties of the present situation. On that occasion, however, I had another object in view, and alluded to this question only so far as was necessary to explain certain proposals with regard to art-museums.* The subject is too important to be dealt with as a side-issue, and so I wish to discuss some aspects of it a little more fully.

Let us then consider the main purposes of museums, and see first how each of them may best be worked out, and secondly how they may be combined when necessary.

First, then: What are the functions of museums? Multifarious though they are, the more important of them may be placed under three heads:

(*a*) The collection and preservation of material for study by experts, so that they may widen the bounds of knowledge. The ultimate aim of this function may be summed up in one word—investigation.

(*b*) The collection, preservation and exhibition of material for the education of less advanced students and for the assistance of amateurs. The provision for students covers such collections and exhibitions as samples of textiles for the use of weavers, specimens of wood-carving and of wrought iron for the workers in wood and in metal, plaster cases, paintings and engravings for students of the plastic and graphic arts, anatomical preparations for medical students, series of natural objects or of physical apparatus and the like for young people taking their B.Sc. The term 'amateurs' is a convenient one to include the field-naturalists who come to a museum to identify their captures, the collector of coins, of postage stamps or of china, who wishes to verify some recent acquisition, and, in short, the many lovers of art, who without being artists, art critics or connoisseurs, yet enjoy the examination of even inferior productions of some school or period in which they have assumed an interest. For students and amateurs alike, this function of the museum may briefly be expressed as instruction.

(*c*) The selection and display of material in such a way as to attract the general public, to provide for its members intellectual and esthetic pleasure, and so eventually to interest them in noble things outside the daily groove. Any one who visits a museum, or any portion of a museum, not as a specialist or student, but as a sight-seer, is to be regarded as one of the general public. To every such layman, learned or unlearned, the museum should help to give that higher and broader

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* Museums Association. Aberdeen Conference, 1903. 'Address by the President,' *Museums Journal*, III., pp. 71–94, 110–132 and 36 plates; September and October, 1903.

outlook on life for which we have no better name than culture. In a word, the third great function of a museum is inspiration.

It must be recognized clearly that these three functions—investigation, instruction and inspiration—are quite distinct from one another. Their point of contact lies in the fact that all are carried out by institutions in which material objects are assembled; and that there is any contact at all depends partly on the convenience of utilizing the same objects for different purposes, and partly on the economy of employing one staff of curators (or one curator) instead of three. But the distinctness of the functions will be realized by taking the standpoint of the several visitors; for they constitute separate and mutually intolerant groups: the specialist disdainful of the amateur and ignoring the public, the amateur and college student with an absurd reverence for those specialists whom they have not yet found out, and the public gaping at the spectacled enthusiast with a mildly contemptuous pity. The same individual may come into each of these classes, but, so far as any one branch of knowledge is concerned, he does so at different periods: first, as a member of the public, he receives the inspiration; then, after learning something in the field or in the classroom, he comes to the museum for further instruction; finally, he advances to the ranks of the researchers and finds in our cabinets material for investigation.

From what has been said it follows that, in considering how a museum may best fulfil these main functions, or, in other words, best serve these three classes of visitors, we shall do well to treat them distinctly.

Beginning with the function of investigation, we see that a museum serves investigators by collecting and preserving fresh material for research, or by accumulating standard historical specimens, such as those which in systematic biology are known as types.

An enquiry into the methods of collection scarcely falls within the scheme of this survey; but I should like to express my conviction that, in general, the best results are obtained when a definite purpose is clearly kept in view. If expeditions are sent out, they should be specially equipped and informed towards the acquisition of particular specimens. If purchases are made, they should be, not of miscellaneous collections, but of preselected objects. The curator should know what his museum wants, and should bend his energies to obtaining those things and those alone. He should resist the temptation of cheap bargains. But when temptation comes as a present, and the donor is a patron who may not be offended—what then? Well, then the curator without a settled plan must open his mouth and shut his eyes, take what the millionaire sends him, and pray for a speedy release. But donors generally mean well, and even a millionaire may have common sense. Therefore, the curator with a plan, and with a little tact, will say "My dear Mæcænas! This is a charming thing you offer; I only wish we could accept it. But you will understand at once that it does not fall within the scheme drawn up for our museum and sanctioned by the authorities [here he will drag in the most imposing authorities at his command]. On the other hand, there are many sad gaps in our collection, and there is now in the market a most desirable rarity, which I should rejoice to have in our museum with your name attached. When you see it you will agree that it will bear perpetual witness to your discrimination no less than to your generosity." But it is possible that those 'authorities,' on whom the curator ought to rely, may themselves be the difficulty. Then the curator must stiffen his back and, with as much dignity as is politic, say "Gentlemen, you have yourselves appointed me to a position of trust, and it is my duty towards you and the public to advise you on these matters. If you dispute my competence, you stultify your own action."

This need for keeping to a plan in the acquisition of material applies to all museums, whatever be the nature of their contents and whichever function they profess to fulfil. But chiefly does it apply to the smaller museums and to those of limited scope, since it is the best way, I will not say to prevent overcrowding, but at least to put off that evil day. And among such museums it applies most forcibly to those that make their chief appeal to the great public.

But to return to the investigators. What methods of preservation are the most favorable to their studies? Preservation includes both the technical processes by which objects are saved from decay and the disposition or storage of the objects within the museum. It is with the latter division of the subject that I am now concerned. The methods adopted must be such as to permit readiness of access to the specimens, readiness of comparison and readiness of handling. The investigator must be afforded quiet, light, space, and facilities for using such apparatus as may be required for his study, such as books, microscopes, measures, brushes, reagents, and the materials for drawing, painting and writing. Clearly the exhibition of the specimens in galleries visited all day long by the public is opposed to every one of these wants. They are best met by keeping the specimens, when their size and constitution admit, in a series of interchangeable drawers.* Such drawers can readily be removed to a private workroom for study, and may, while there, be stacked in a spare cabinet body kept for the purpose. The specimens may then be examined and replaced without disturbance of their order, and with the least possible trouble to the museum-staff.

But in almost all departments of a museum we are met by objects

* There are many excellent models. Some are described in Appendix II. of the address above referred to.

too large for such treatment, or otherwise incapable of being kept in drawers. The usual solution (if so it can be called) is to place such objects on public exhibition, because in the public galleries alone can room be found for them, or the show-cases are the only receptacles big enough for them. This method of storing such specimens is opposed to all the requirements of the investigator, and has the additional defects of disturbing the harmonious arrangement of the exhibition-gallery, and of distracting the public with a multitude of unsuitable objects. For all parties, then, it were better to shut off a portion of the exhibition space and to devote it to storage alone.

Passing now to the function of instruction, we have to see how a museum may best serve students and amateurs. To its activities of collecting and preserving, it must add a third—that of exhibiting specimens.

The remarks on collecting need no repetition. As regards the other activities, two essentials must be kept in view. First, the need of the student to handle specimens in certain instances. Secondly, access for him to a fairly large series of accurately labeled specimens, the handling of which is not as a rule required.

The objects to be handled, which need not be very numerous, must be kept in such a way that their removal does not interfere with the exhibited series, does not require the prolonged attendance of a member of the staff, and does not give much trouble in unlocking, checking and so forth. For this purpose, therefore, it is as well to have a sample collection, stored in a workroom, or placed on its walls; and in this room might be posted an attendant, who would usually be carrying on his regular work.

The series not as a rule to be handled might be kept either in cases or in stop-drawers, under glass. What is important is that it should not interfere with or encroach on the public exhibits, for the following reasons: The public distracts the student; the student, with his chair and his own specimens, or his note-books, or his easel, gets in the way of the public; the explanatory labels useful to this class of student are too advanced for the general public and act as a deterrent; and here again the mere multitude of specimens, frequently of restricted interest, is but a source of weariness to the lay mind.

On these grounds the rooms for the technical series should be set apart, and should be in connection with a library whence books might be taken into them. The specimens on exhibition might be as numerous as space allowed, so long as needless duplication was avoided. There would be no need for elaborate methods of mounting; it is only essential that each specimen, with its label, should be clearly visible.*

* Only to those familiar with museums will this remark appear a needless truism.

The last function, that of inspiring the layman with an interest in the subject-matter of the museum, demands adherence to two leading principles. First, only a few specimens should be shown, and those the best obtainable. Secondly, the arrangement of the objects must both arrest attention and give pleasure, so that the visit may be repeated. Here, then, we speak not so much of 'collection and exhibition' as of 'selection and display.' In these two respects, as well as in minor details, such as the nature of the labels, the spaciousness of the rooms and the absence of any need for handling, the requirements of the lay public are, if not always opposed to, at least different from, those of either investigators or students.

Thus far then, we are, I trust, agreed not only that museums have three distinct classes of visitors, but that the proper methods of fulfilling those functions are likewise distinct. Possibly these considerations may help the curator to find an answer, when he asks the question: 'What exactly is the object of my museum and how nearly do I attain it?'

The curator, however, may fear that, since museums are so various, and the activities even of a single museum so numerous and diverse, therefore the question can only admit of a confused and futile answer. This complexity may be partly disentangled if he realizes that museums may be classified in various ways. For instance, according to their subject-matter, as of geology, fine-art, archeology, sanitation and the rest. So far as this is concerned the answer to the question is in each case obvious and needs no discussion here.

Another point of view is that of their financial relations to the community. A museum may be under national, provincial or municipal control; it may be run by some semi-public body,—a university, a local society, or a trade guild; it may be a purely private concern —the secluded treasure of a dilettante, the money-making show of a company, or the freely open halls of a philanthropist. This classification indicates the class of visitor for whom the museum is intended: the guild museum for the members of a trade, the university museum for the university student, and the state museum for 'all sorts and conditions of men.' But the connection is not inevitable.

Omitting other possible classifications, we find that the only one bearing on the curator's problem is that according to the visitors either actual or desired. In its main lines this follows our classification of the functions of a museum under three heads. Few museums, however, have their scope so rigorously defined, though in some cases, as just suggested, it is, or should be, defined by circumstances.

Perhaps the most usual restriction is to that group of functions above comprehended under instruction. Here and here alone come the teaching collections of a university, the technological museum for artisans, and the gallery of plaster casts for art-students. Frequently, too, the museum of a local society is intended solely to preserve natural or artificial objects for reference by the collectors and amateurs who constitute its members.

Scarcely any museum can nowadays be regarded as the strict preserve of investigators. In fact, the total number of museums whose main function it is to amass vast collections for the advancement of knowledge can never be very great; indeed, the smaller the better. The scattering of material and of the necessary literary apparatus through thousands of towns would not conduce to either economy or efficiency. Concentration permits of comparison, better equipment, a larger and more highly trained staff, while it necessitates the intercourse of fellow-workers and leads to interchange of ideas. Such a museum should be a great organization for research, with laboratories, libraries, studios and publications, with a staff of investigators, preparators, artists, photographers, copyists and the usual servants. I have not mentioned curators, believing any attempt to separate them from investigators to be a false economy.

Museums entirely devoted to the inspiration of the lay public are hard to find. But they exist in theory if not in practice; and theorectically too the encouragement of art and science among the populace is the main reason for the establishment of most museums, especially the municipal.

Now, where museums come to grief is in attempting to sit on these three stools, or rather through not distinguishing clearly enough that the stools are three and that they are of very different nature.

A small museum with small means should make the choice of not more than two out of the three; and the function to be dropped should, in my opinion, be investigation. Not that the curators of small museums should be warned off the field of original work; but the museum should neither amass nor preserve specimens of interest chiefly to specialists. From the two remaining functions, instruction and inspiration, it should select the one more appropriate to the conditions of its existence and spend its energies on that.

Many a large museum, on the other hand, is able to undertake all three functions, and if it be supported out of public funds, it is its duty so to do. It is not enough to provide admirably for two classes of visitors, and to suppose that the same provision will satisfy the third class. On the contrary, the more thoroughly the wants of any two classes are supplied, the more will the third class be left out in the cold.

Take the case of a large museum of any subject. Usually an attempt is made to combine all three functions in one series of rooms and cases. For the sake of the collectors and amateurs, a large number of objects is exhibited; and this perplexes the public. For the sake of students, too, technical terms and labels are introduced; these are above the ordinary visitor and disgust him. For the sake of the public, on the other hand, much space, time and money are devoted to elaborate mounting of the objects. This, in itself to be commended, and practicable when restricted to a selected series, sets a standard that is far too high for application to all the thousands of exhibited specimens, since this extension of it absorbs energy that were better employed in other directions, and renders the specimens less accessible to both investigator and student. Again, much of the material amassed for the specialist is not readily stored, and, finding its way into the show-cases, detracts from their effect and overweights both layman and student.

For such a museum then, I suggest a tripartite arrangement of the collections, corresponding with the three functions.

First, there would be a stored series, in drawers, or special cases, or private rooms, so arranged as to be easily transferred to the work-rooms, and reserved for the use of specialists or researchers.

The series for students may assume two forms. One, a collection of objects to be handled, best stored in a private room and immediately accessible to accredited students. The other, a large exhibited series, under glass when advisable, arranged systematically and properly labeled, but without superfluous niceties of mounting. This should be kept in galleries to which access could be had on application to an attendant. The general public should not be permitted to wander freely through them, and especially should loving couples and infants in arms be warned off. It would probably be a sufficient barrier if each visitor were required to write his or her name and address in a book kept at the entrance.

Finally, there would be other rooms for a smaller series of carefully selected objects, so arranged as to make the utmost appeal to the great public.

The fundamental distinction between the series for research and that for public exhibition has long been realized by directors of natural history museums, and has been strenuously urged by Flower and Brown Goode. The directors of art-museums are just beginning to apprehend it; but even the best museums of natural history are still far from the ideal upheld, not for the first time, in Flower's address to the British Association fourteen years ago. If I may judge from my own limited experience, the chief reason for this failure is the existence of those two distinct types of visitor, the layman and the student. We are obliged in self-defence to exhibit far more specimens than we know to be good for the public, because if we did not we should be doing little else than answering the enquiries of amateurs, and unlocking drawers for all manner of students. Moreover, in the absence of proper store-cabinets, and especially of interchangeable drawers, our reduced and over-worked staff finds it less trouble to thrust a new acquisition into a show-case than to make room for it in the confused and crowded study-series.

It is to obviate such difficulties that I propose the further division of the exhibited series. In this way more specimens can be exhibited for the student and amateur with less trouble and expense, and in a more practical manner, as, for example, on interchangeable trays or frames, which can as needed be removed for the use of the specialist. The student will no longer be disturbed by the loud-voiced pastor or by urchins at hide-and-seek, and the elimination of crowds will permit a saving in floor and cubic space. The public galleries in their turn will be freed from students with their apparatus and from inappropriate specimens, while such objects as remain can be displayed in a more becoming manner.

It is easy enough to see where we have gone wrong. The advance towards democracy has been too rapid, the revolution too complete. We have thrown open everything to the public, to the public's bewilderment and our own undoing. The lot of a curator in a large museum is not altogether a happy one. Surrounded by the treasures that his heart longs for, he must maintain them for the use and enjoyment of others, while, Tantalus-like, he himself is unable to reach them. He consoles himself with the thought that he is a martyr for the good of humanity, and he has not seen how to shift his ever-increasing burden. The suggestions here made will, I believe, benefit the specialist, the student and the man in the street; but the argument most likely to secure their adoption is that they will also benefit the curator. If consistently and boldly carried out, they would result in a saving of expense on architecture and installation, so leaving more money for actual work on the collections; and they would, in the various ways that I have indicated, effect a saving of time, thus permitting the curator to make better use of the material at his command. In this firm belief, I ask for these proposals the serious consideration of the large number of people who to-day are interested in museums.

THE ERUPTION OF PELÉE, JULY 9, 1902.

By Professor T. A. JAGGAR, Jr.
HARVARD UNIVERSITY.

A DESCRIPTION of the scene of devastation in Martinique was published by the writer in this magazine in August, 1902. Some of the readers of The Popular Science Monthly may be interested in the details of a great eruption, and scientific deductions from observation of the same; the present article aims to present the results of such observation. The writer returned to Martinique from Barbados in June, 1902, and had the good fortune to see an eruption of first magnitude on Mount Pelée. On the evening of the ninth of July, he was in Fort de France, and the commission sent out by the Royal Society, Drs. Tempest Anderson and John S. Flett, were living on board the sloop *Minerva* near Carbet; thus the scientific record kept of this eruption was unusually complete.

At 8:15 in the evening, just at twilight, there was seen from Fort de France a very high column of black dust with the characteristic cauliflower surface, boiling straight up from the direction of the volcano to an enormous height (compare Fig. 1). The blackness of this dust cloud increased, the bulbous profile gave place to a smooth balloon-shaped outline slightly flattened above, and from the moment that the interior of the cloud first became obscure, small spicular lightnings were seen dancing like a myriad of bright white sparks all over the cloud surface. At first this whole extraordinary display was perfectly silent; the writer was called out from the public library in Fort de France by an attendant at about 8:20 P.M., and there was a singularly oppressive stillness noticeable. When the phenomenon was first observed in the streets, some slight disturbance akin to panic had been audible, but the people as a whole had grown so callous to these happenings, that after a few moments very few individuals seemed to take any note of the extraordinary phenomena in the northwestern sky.

At 8:30 the cloud had the form of a balloon, swelling rapidly to the zenith, and filling with its diameter perhaps 70° of the sky north-northwest. The wonderful coruscations grew more brilliant, leaping rapidly from place to place over the surface of the cloud, but at first they had the form of points of light, rather than lines. There was no thunder accompanying these early flashes, and their frequency was incessant, the whole cloud surface fairly scintillating with dancing lights.

Gradually a sound became perceptible, which at no time developed into loud detonations. It was rather a bubbling growl, far away, different from thunder, and continuous. It lasted an hour, and varied in intensity; this noise was undoubtedly occasioned by the expansion of steam released from the crater's throat, accompanied by the tumble of a volcanic avalanche on the flanks of the mountain and at the crater. The distance of Fort de France from the crater, as the crow flies, is fourteen miles. The weather was very calm, with only a faint breeze from the direction of the volcano during the early stages of the eruption.

The writer climbed to the ridge-pole of the roof of the Hotel Ivanes, while an attendant held a candle at the open dormer window below, and the flame was not disturbed by any considerable breeze. On the high roof, the stillness of the tropical night was relieved by nothing but the simmering hum of tree-toads and crickets, and the very faint distant rumble, at that time barely audible. Here, remote from the odors of the town, there was an extremely faint odor of sulphur (sulphurous acid). At 8:50 a wave was noticed on the wharves at Fort de France, the water receding and returning through a total vertical distance of about two feet. About the same time the recently repaired cable of the telegraph company ceased to make connections; it was probably broken by submarine landslips.

During the next twenty minutes the balloon or spoon-shaped cloud spread rapidly southward until nearly the whole horizon was obscured with the exception of a narrow strip of starlit sky, the middle of which lay S. 20° E. To the north-northeast could be seen fringing showers, four or five in number, showing as vertical streaks against the horizon in that direction. These were believed at the time to represent local dust falls. At 9:10 a similar curtain was seen N. 60° W. At 9:15 some rain fell at Fort de France, but this lasted only about five minutes. At 9:18 the smoothly curved edge of the dust lowered to and merged with the horizon S. 30° E. A very remarkable flash of lightning at this time shot across the northern sky, making a complete loop overturned to the northeast with the ends downward towards the volcano. It was described by one of the bystanders as 'balloon lightning,' and had somewhat the aspect of a huge incandescent bulb, outlined by a streak of light that swept in a tremendous curve across the zenith. The bulbous effect was probably produced by the illumination of one of the cloud billows within the lightning circle. It occurred to the writer that possibly the change in the lightning forms during the two hours, from points to short lines, and from these to long serpents, was due to a change in the perspective of the cloud billows. The first view when the mushroom was expanding was 'end on,' so to speak, with reference to the individual nodes or mamelli.

When the cloud spread over Fort de France these necessarily rolled out into long billows and irregular kidney-shaped forms, the lower surface of which might sometimes be seen when illumined by the lightning flashes. Discharges from node to node, with the 'end on' view, would be small points of light, like the sparks between the electrodes of an induction machine when the two are pushed together. They would also be very numerous and incessant as the individual nodes were numerous, small and possessed of intensest vertical velocities over the direct discharge from the volcano's throat. As the mushroom spread to a distance the individual dust eddies became larger and more diffuse, and the discharge between them would become less frequent and more irregular, giving rise to the worm stage. With further increase and more massive movements within the cloud, the same continually growing in volume and rising to greater height as well as spreading across the line of vision of the observer below, the lightning flashes decreased in frequency, and increased in length, intensity and irregularity, producing finally the long orange-colored serpents described below—the color being due to the dust layer which partially obscured the dazzling flashes.

Whatever the cause, the lightning clearly showed a gradual change in character; from incessant, shifting, scintillating points it changed to less frequent worm-like lines and short forking discharges, the divergence being at first downward toward the crater. One flash was noticed in a direction N. 30° W. having a distinct short S shape with three inflections, the ∽ lying horizontal. At no time were any lightning flashes seen to pass from earth to cloud or *vice versa;* all of these discharges were *across* the sky. At 9:30 the continuous grumbling from the volcano died away.

At 9:42 the middle of the dust arc southward had the bearing S. 20° E. This point corresponded to what at the start was the zenith point of the dust balloon.

At 9:45 very brilliant sheet lightning occurred showing no definite points or lines, but illumining the whole vault in dazzling flashes. The lightning seemed to be more concentrated on the periphery of the cloud. Meanwhile white cumulus clouds lifted towering thunder heads to the southeast and these marked the beginning of local thunder-storms over all the high points of the island. The high tops of these clouds lighted by the sheet lightning showed their billowy profiles white against the dark vault of dust above; some of them appeared to rise to a great height, but their summits were far below the black dome of volcanic dust, affording an excellent measure of the stupendous height of the volcanic cloud and its electrical phenomena —both entirely distinct from the rain-bearing thunder-storms.

At 9:52, looking southwest, the thin edge of the dust cloud against the starlit sky beyond appeared to have risen somewhat and to be thinner and more transparent where it had before been black and hard-edged. Its rise could be measured by the group of royal palms about the statue of the Empress Josephine, which lay in that direction. These notes were made from the middle of the open 'Savane' or common, while a negro boy held a candle for making compass observations and writing. The increase in sheet lightnings was accompanied by thunder claps from different directions. Some of these came from the east, and they were undoubtedly produced by the local showers.

At 10 o'clock it was pitch dark, with no horizon visible; white clouds rose high southwest.

At 10:08 heavy thunder was heard to the north in the direction of the high Pitons de Carbet. The lightning from the dust vault had grown more sparse and the short worms had gradually given place to elongate serpent-like flashes with increasing intervals. Following these thunder crashes from the north, there was a magnificent lightning display across the zenith. At 10:10, in the direction of the volcano north-northwest, long curved orange flashes rent the vault from east to west.

At 10:15 rumbling was renewed from the direction of the volcano and lightning was also seen. This rumbling resembled rather a slight renewal of the steam explosions than local thunder. It is worthy of note that the sound at Martinique under the dust cloud was different from that observed at great distances. At Barbados this eruption of the night of the ninth was heard distinctly as a series of heavy detonations in quick succession, resembling heavy ordnance close at hand. The distance, over one hundred miles, and the angle by which the sound traveled, probably from above the dust vault, produced a different acoustic effect from what was observed in the immediate vicinity of the volcano. Probably only the louder explosions carried so far, which would account for the discontinuous quality of the detonations. At Fort de France the effect was as though the dust billows had a muffling effect.

At 10:25 there was a cessation of active phenomena for nearly a half hour.

At 10:50 a breeze sprang up from the south.

At 10:55 there was heavy thunder in the northwest, and some serpent flashes of lightning.

At 11:15 the dust dome was obscured by rain clouds, showers fell and there was occasional distant lightning.

At 11:40 thunder was heard to the south. At this time a quadrant of the southern horizon cleared, showing itself below the straight edge of overhanging cloud. After this the night settled down to a condition of quiet cloudiness with the wind southerly, and the temperature

80° F. At midnight two sheets of white paper were placed upon an open balcony and in the morning, after six hours, these showed a film of specks of volcanic dust.

At 2:30 A.M. the moon appeared through the dust cloud with a dim reddish-yellow glow.

The next morning, July 10, at 6:30 the writer took a small steamer north, along the west coast of Martinique to Carbet, where an excellent view was obtained of the slopes of Mt. Pelée, with their newly deposited load of dust and volcanic débris. The morning dawned with high banks of cumulus cloud and a hazy sunrise; there were some light showers. When the volcano came in sight, the usual dark dust veil was seen lowering upon the ocean far to the west (Fig. 2), and the summit was veiled in billowy clouds. From a point near Morne aux Boeuf northward, the vegetation and the beach stones showed a coating of gray dust, which became more conspicuous on approaching the volcano.

The slopes of the mountain, seen at first enveloped in a rain shower, were steaming in two places along the Rivière Blanche, and a long streak of steaming deposits was seen on the high slopes above the Rivière Sêche—the Rivière des Pères was also steaming. The slopes were covered everywhere with patches of light greyish-yellow sand and gravel, hot and dry, which blew up in whirling dust clouds now and then under the puffs of easterly wind. Along the water front, at the mouths of the various rivers, there were occasional steam jets; the dust clung to the cliff surfaces of the high rock walls, outlining the rugged surface in patterns like a fresh snowfall on a cliff face in the Alps. The greatest masses of dry deposit were accumulated in drifts along the course of the Rivière Blanche. This fact is important, showing that along this gulch there accumulates in the course of a series of eruptions a very great thickness of hot dry gravel and sand, which is the cause of the violent explosions along the gorge whenever water rushes down from above.

At Carbet there had been a dust fall on the evening of July 9, averaging perhaps one centimeter in thickness. There had been a preliminary small eruption, earlier in the evening; the great eruption at 8:15 happened quite suddenly. The scintillating lightning flashes were observed at Carbet from the start; dust and small pebbles fell shortly afterwards. At Fonds St. Dénis, on the heights back of St. Pierre, angular rocks fell of sizes up to three or four inches. There was continuous rumbling from the crater noted at Carbet, and this was quite distinct from the local thunder storms which developed later. The eruption was watched from the beach at Carbet Point by Mr. Gouyer, manager of a plantation at Carbet, and he states positively that he saw no tornado or wind blast which struck St.

Pierre. No one was hurt at either Morne Rouge or Carbet. It seems agreed among those living near the volcano, that these later eruptions were more 'fiery' than the earlier ones, indicating that there is more incandescent material ejected; thus they state that there was more 'fire' on June 6 than on May 20; and more slides or avalanches of incandescent material on the slopes of the mountain on July 9 than on June 6.

At about 8 o'clock on the morning of July 11, a vertical puff from the volcano rose 10,000 feet into the air, showing at first superb gray-brown cauliflower surfaces, and later, taking on smooth outlines, with a funnel-shape and a feathery fringe. There was only a single puff, and the cloud drifted away to leeward. A similar one was photographed on July 16 (Fig. 1).

It is of interest to compare with this record of observations at Fort de France, the notes of the British men of science on July 9 made from a vessel close to the volcano:*

From the fissure in the volcano, clouds of pale slaty vapour rose constantly. . . . (About 7:30 P.M.)

In the rapidly-falling twilight we sat on deck intently watching the activity of the volcano, . . . when our attention was suddenly attracted to a cloud which was not exactly like any of the steam 'cauliflowers' we had hitherto seen. It was globular, with a bulging, nodular surface; at first glance not unlike an ordinary steam jet, but darker in color, being dark slate approaching black. . . . Its behaviour . . . was unique. It did not rise in the air, but rested there, poised on the lip of the fissure, for quite a while as it seemed, and retained its shape so long that we could not suppose it to be a mere steam cloud. Evidently it had been emitted with sufficient violence to raise it over the lip of the crater, but it was too heavy to soar up in the air like a mass of vapor, and it lay rolling and spouting on the slopes of the hill. The wind had no power over it, fresh protuberances spurted out from its surface, but it did not drift leeward any more than if it had been a gigantic boulder.

This cloud rolled straight down, gradually increasing in size as it came nearer. The further it traveled the faster it came. It cleared the mountains slope, increasing always in size, but still rounded, globular, with boiling, pillowy surface, pitch black, and through it little streaks of lightning scintillated. On reaching the north side of St. Pierre roadstead the black mass discharged sparkling lightnings incessantly along its contact with the water. The cloud quickly lost velocity and formed a black pall, with larger, less vigorous, more globular, bulging convolutions. It lay almost like a dead mass on the surface of the sea. The black cloud rose from the fissure about 7:40, and for twenty or thirty minutes the sloop sailed southward with a gentle breeze from the east. Then the wind fell to a dead calm. The black cloud cleared, above the fissure a faint red glare was seen, which slowly increased, and bright, glowing masses were seen describing parabolic paths through the

* 'Report on the eruptions of the Soufrière, in St. Vincent, in 1902, and on A Visit to Montagne Pelée, in Martinique,' Part I., by Tempest Anderson and John S. Flett. *Phil. Trans. of the Roy Soc. of Lond.*, Series A, Vol. 200, pp. 353–553, 1903. (See page 492 et seq.)

air and then landing on the mountain slopes and rolling down the hill. These red-hot stones were projected as much as a mile from the crater.

Suddenly a great yellow or reddish glare lit up the whole cloud mass, a

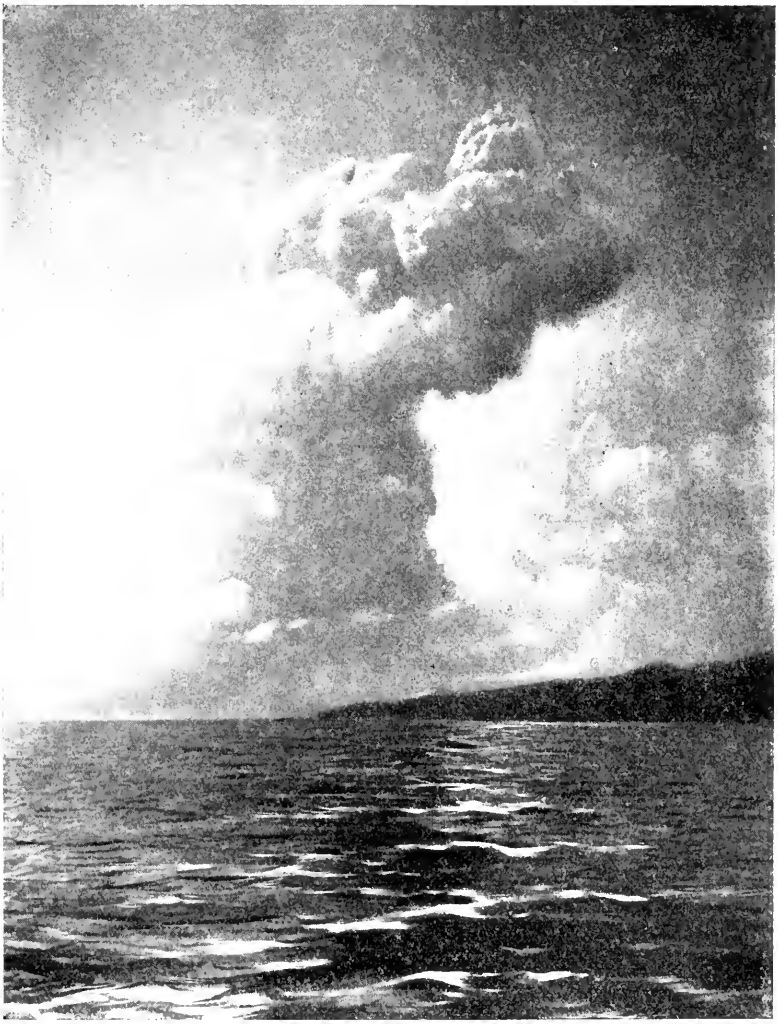

FIG. 1. ERUPTION OF MOUNT PELÉE, 4.10 P.M., JULY 16, 1902. (Photo by T. A. Jaggar, Jr.)

This photograph was taken from the S. S. *Dahome* off Fort de France, looking north. On the right is the slope of the Pitons of Carbet. The steam column was over six times the apparent height of these peaks, and its base was twelve miles away; its crest subtended a vertical angle of 29° measured with a handlevel. Allowing for bulge, its height was not less than from four to six miles. The upper portion of the cloud, bent to the right (east), has passed through the trade-wind belt and is moving with the counter-current. A 'cauliflower' wall of dust could be seen moving down to the west at the base of the column, and rolling out from the mountain over the water.

prolonged angry growl burst from the mountain, not loud, but with a 'snarling character.' A red-hot avalanche rose from the cleft in the hillside and poured over the mountain slopes right down to the sea. It was dull red and in it were brighter streaks thought to be large stones, as they seemed to give off tails of yellow sparks. They bowled along apparently rebounding when they struck the surface of the ground. The dark-red avalanche had a billowy surface, and its velocity was tremendous. "The mist and steam on the mountain top did not allow us to see very clearly how the fiery avalanche arose, but we had a perfect view of its course over the lower flanks of the hills, and its glowing, undulating surface was clearly seen." The red glow faded in a minute or two, and a round black boiling cloud rushed over the sea in front of it, filled with lightnings. This cloud was globular as seen end on, very perfectly rounded, covered with innumerable minor rounded exerescences which were filled with terrific energy. It was full of short lightnings—'A mere succession of flashing points in the great black wall of cloud.' "Many of the flashes were horizontal, others shot obliquely from one lobe to another, while along the base where the black cloud rested on the steel-gray sea, there was a line of sparkling light, constantly changing, varying in amount, but never disappearing."

FIG 2 (*a*). PUFF FROM CRATER, MT. PELÉE. FIRST STAGE.
(Photos for T. A. Jaggar, by E. C. Rost.)

A gentle puff of wind came from the southeast. The cloud lost its violence and became a gigantic wall with a velvety appearance in the moonlight, resembling a black curtain draped in folds. In size it was estimated to be two miles broad and about one mile high.* The sur-

* 'Preliminary Report,' by same authors, *Proc. Roy. Soc.*, Vol. 70, August 11, 1902, p. 443.

face shimmered like silk and the colors changed to brown and gray, and even white on the edges of the folds, and these changes spread through the whole face of the cloud. The base became darker, and the paler summits soared obliquely upwards and forwards; this was believed due to sinking dust and separated steam.

The steam cloud, with a velocity of twenty miles an hour, came overhead, gray and tongue-shaped, with a blunt rounded apex, and convolutions still forming. The lightnings, reduced in number and frequency, threaded the dark mass in every direction. "A low rumbling noise was given out as the cloud worked its way across the clear, starry sky." It spread across the vault, producing darkness; when it reached the zenith, pebbles fell about the size of a chestnut, cold, and these

FIG. 2 (*b*). SECOND STAGE THE DUST VEIL.

became a rattling hail diminishing to the size of peas. Fine gray ash followed in little moist and adherent globules, noiselessly sinking through the air and sticking to everything on which they landed. They were not warm, and there was a slight smell of sulphurous acid. After a few minutes the ash took the form of a gritty dry powder. The layer which fell on deck had a total thickness of one sixteenth of an inch.

The southerly wind rose to a fresh breeze and the naturalists took their sloop into Fort de France harbor safely. They noticed a thunderstorm to the northeast, as heretofore described.

The final comments of Doctors Anderson and Flett may be quoted in full:

The avalanche of hot sand was discharged about 8:20 P.M. In a couple of minutes it had reached the sea and was over. The second black cloud, which was all that remained of it when the heavier dust had subsided, traveled about five miles in six minutes, and very rapidly slowed down, coming to rest and rising from the sea in less than a quarter of an hour. The tongue-shaped steam and dust cloud was over our boat by 8:40. A few minutes after that the ash was falling on our decks.

The second black cloud did not differ in appearance from the first except that it was larger, had a far greater velocity and swept out at least twice as far across the sea. It was black from the first moment when we saw its boiling surface in the moonlight. Both traveled very rapidly over the lower part of the mountain, but slowed down after reaching the sea, and came to rest comparatively suddenly. The lightnings on the two clouds were similar in all respects.

No blast struck us—in fact, we were becalmed—and it seemed that when the black cloud ceased the blast was all over. Nor did the sea rage around us as some have described who were overtaken by the dust storm. When the cloud was passing overhead there was a slight rolling sea, but as the breeze freshened the boat steadied, and there was no unusual disturbance. We watched carefully for a strong indraught, such as was described by more than one observer, but the wind that rose from the southeast was very gentle, and increased gradually to a full-sail breeze. . . .

In the cloud there was a dull, low rumble, but we heard no detonations, and saw no sheet of flame, so that we both agreed that there had been no sudden ignition of quantities of explosive gases. The lights in the cloud, in our opinion, were lightning and nothing else. When the slopes of the mountain were seen two days later it was evident that 'the avalanche had come down approximately along the line of the Rivière Sêche.'

Comparing the records of these observers with the observations made at Fort de France, we find the following simultaneous phenomena:

Anderson & Flett.	*Jaggar.*
7:40 P.M. First black cloud.	7:40 P.M. Not watching.
8:00 P.M. Glare and glowing stones.	8:00 P.M. Not watching.
8:20 P.M. Red-hot avalanche.	8:20 P.M. High balloon-shaped column of dust.
8:35 P.M. Avalanche cloud had come to rest and risen from the sea.	8:35 P.M. Column spreading to zenith, lightnings and rumblings.
8:45 P.M. Avalanche cloud reaches zenith and pebbles fall.	8:50 P.M. Wave observed and cloud spread out to horizon.

The dust-balloon seen from Fort de France was at least five miles high when first observed, its summit subtending an angle not less than 30°. It rose to heights so great that, after spreading out to the horizon, the dust vault was entirely above towering 'thunderhead' cumuli which developed over the mountains of the island. Its first appearance at Fort de France was coincident with the fiery avalanche seen off Carbet;

the British geologists saw no upright shaft of dust, but a cloud projected horizontally two miles broad and one mile high. They state that mist and steam obscured their view of the mountain, and it does not appear that they saw the great vertically projected column of dust at any time. This was because they were too close to the volcano to see it, and the up-jet was obscured by the down-jet.

This leads to certain theoretical considerations. Flett and Anderson consider these eruptions unique with respect to the hot sand avalanche and the black cloud, speaking of the 'Peléan type' of eruption. I do not believe that these features are exceptional, nor that they were wanting in the Vesuvian eruption of '79, nor in Tarawera, Krakatoa or Bandai-san.

Anderson and Flett believe the motive power which drives the lower black cloud forward horizontally to be the falling weight of the mass. Discussing the possibility of the out-blast being caused by the resistance offered by falling materials to the ascent of subsequent discharges—an explanation offered by the writer* in 1902—they write:

> This is quite incompetent to explain the behavior of the black clouds we saw on the night of the ninth of July. Before the first black cloud arose no very great amount of dust had been projected into the air, and the steam clouds were drifting steadily westwards. . . . The black cloud took a different path, and once it had rolled a short way down the mountain there was nothing above it to prevent it rising in the air: but it hugged the surface of the ground so closely that the conclusion was inevitable that it flowed down merely because it was too heavy to ascend.

That no great amount of dust *was seen at Carbet* projected vertically, prior to the first black cloud, may be accounted for in the same way as at the time of the incandescent avalanche—it was dusk, and the mountain's summit was veiled in clouds. I have no question but that there was a preliminary up-puff, not seen by observers close to the crater. And because of the peculiar acoustic conditions mentioned, no sound would be heard, either, though at a distance this puff might have been noticed as a distinct detonation. Without disputing the possibility of dust giving weight to a vortically charged steam-cloud, it is difficult to understand how mere gravitational movement could produce destructive velocities on such gentle slopes—the slopes of Pelée and Soufrière average only 15° to 17° (Fig. 3). The horizontal discharges appeared to move with greater and greater velocity until they struck the sea, then they slowed down and came to rest almost suddenly. The motion was compared to that of a toboggan on a snow-slide.

The appearance of slow movement at the crater's lip I believe to have been only apparent, probably because the mass was end on and

* The Popular Science Monthly, August, 1902, p. 366.

there was no means of judging forward motion. The discharge from a cannon would 'roll, squirt and seethe' without showing any forward motion, if we were looking into the cannon's mouth. There can be no question, however, that there was an avalanche of solid materials which accompanied the second black cloud seen by Anderson and Flett, and I am tempted to ask, may there not have been a similar non-incandescent avalanche with the first cloud, representing the relatively cool material which cleared the crater's throat?

Fig. 3. St. Pierre from High Slope of Pelée: showing Course of Blast as seen from the Crater.

(Photo for T. A. Jaggar, by E. C. Rost.)

If this were true we should have with each puff a sequence of events somewhat as follows:

1. Straight puff upwards.
2. Avalanche of heavy materials downwards.
3. Horizontal dust-cloud outwards.

The sharply differentiated horizontal and vertical blasts had been noted in all the eruptions of these volcanoes. They may be seen in the photograph of the eruption of July 16, where one cloud lowers over the water, the great column is upright, and its crest is bent to the east by the high counter trade-wind. (Fig. 1.)

The three stages above mentioned, in an explosive discharge from a fissure upward, might have been expected on purely *a priori* grounds.

Following such reasoning further, we find: (1) A rending explosion raises some very coarse and heavy material, (2) this material falls soonest and nearest the crater, (3) such falling material would have very high velocity, but would come very quickly to rest on cone slopes of 17°. Its fall would certainly deflect upward discharges of lesser intensity, and its rush down the mountain with such deflected vomitings would have the aspect of an avalanche, sending forward an avalanche blast capable of short-lived but very fierce destruction. A deflected discharge from the crater would be propelled by the same force as the up-blast, and thus become both an avalanche and a down-blast with the energy of the volcano behind it. It seems probable that such a deflected mass of incandescent gravel and bowlders formed the avalanche seen by Anderson and Flett. On this hypothesis, both gravity and deep-seated explosion contribute to the tornado violence of the black cloud, and the displacement of the air before the avalanche resembles that frequently seen in high mountain districts, where snow-slips project an air blast capable of leveling forests. Such snow-slides have a tendency to hug the slope, to move very rapidly above and to come to rest quickly below, and such movement was noticed in the eruption which destroyed St. Pierre and in the eruption of Bandai-san. In the latter also, the discharge changed from upward to horizontal, the change being gradual as the upper air became overcharged with solid matter. The other eruptions of Pelée and Soufrière showed the same general characters, and that of July 9 may be taken as an example of an eruption of first magnitude. Its direction was more to the westward than on May 8, hence the escape of Carbet and St. Pierre. The materials ejected in the fiery avalanche were believed by Anderson and Flett to be the products of exploded molten lava, which welled over the lip of the crater and was blown to shreds by expansion of gases. This view I can not accept, for I have as yet seen no glass fibers or sherds, nor any evidence of new molten lavas in any way connected with these eruptions. The angular bits of andesite and coarser rocks found on the mountain after eruption are pieces of country-rock. In some cases 'bombs' have been formed from old andesites with half-molten surfaces. All the evidence so far goes to show that these volcanoes are great steam crushers, comminuting and distributing ancient volcanic materials.

In conclusion, I wish to record my admiration of the excellent work done by the Royal Society's commission, recalling with pleasure association with Dr. Anderson and Dr. Flett in Barbados and Martinique. Their memoir is by far the most thorough and scientific work that has been published as yet on the West Indian eruptions.

IMMIGRATION AND THE PUBLIC HEALTH.

By Dr. ALLAN McLAUGHLIN,

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THE popular belief that immigration constitutes a menace to the public health is not without foundation. Newspapers and magazines contain graphic accounts of the squalor and insanitary conditions of the tenement districts of our great cities. Recent newspaper reports and comments upon the remarkable spread of trachoma in the public schools of New York and other great cities add to the popular feeling of distrust, and the opinion is gaining ground everywhere that more stringent means must be devised for keeping out the undesirable class of immigrants which augments the frightfully overcrowded population of the tenement district of New York and other large cities.

In the consideration of danger to the public health from immigration, three factors must be taken into account: (1) The physique of the immigrant; (2) his destination, and (3) the presence or absence of communicable disease.

The first mentioned, the physique of the immigrant, is by far the most important factor. Good physique was much more general among immigrants a quarter of a century ago than among the immigrants of to-day. The bulk of the immigrants previous to 1880 came from the sturdy races of northern and western Europe, and, not only was good physique the rule, but loathsome, communicable or contagious disease was extremely rare. The immigration from Ireland, Germany and the Scandinavian countries is insignificant to-day compared with the thousands of Slavs, Italians, Hebrews and other immigrants from southern or eastern Europe, which now crowd American-bound vessels and pour through the ports of this country in an ever-increasing stream.

With the change in the racial character of immigration, most marked in the past decade, a pronounced deterioration in the general physique of the immigrants, and a much higher per cent. of loathsome and dangerous disease is noticeable. Thousands of immigrants of poor physique are recorded as such by the medical inspectors at Ellis Island, and a card to this effect sent to the registry clerk or immigrant inspector with the immigrant, but this mere note of physical defect carries little significance under the present law, and the vast majority of them are admitted by the immigration authorities, because it does not appear that the physical defect noted will make the immigrant a public charge. When the physical defect or poor physique is so marked that it seems to the medical inspector likely to make the immigrant a public charge, the immigrant is detained, and a certificate is made stating his disability, which certificate goes to the board of special inquiry with the detained immigrant. About two thirds of the immigrants so certified as likely to become a public charge are admitted because of the latitude allowed by the phrase, 'likely to become a public charge.' Under the present law, therefore, the immigrant certified as suffering from a loathsome or dangerous contagious disease, or as being idiotic or insane, is deported. The immigrant recorded as having a 'poor physique' or other physical defect is usually admitted.

Destination is scarcely less important than physique, and it is the rule that aliens of a race having a low physical standard will invariably herd together in the overcrowded insanitary tenement districts of our great cities, while the sturdy races of unskilled laborers are scattered over a wide territory and tend to establish little homes of their own in the country or in the suburbs of manufacturing towns or cities.

The following table indicates the relative physical strength of the various races under discussion, and also the percentage of each race giving New York as their destination. Statistics of the Irish and Scandinavian races are given in this table for the purpose of comparison.

Race.	Ratio Sent to Hospital on Arrival to Total Number Landed.	Ratio Deported on Medical Certificate to Total Number Landed.	Percentage Remaining in New York.
Hebrew	1 to 90	1 to 393	70 per cent.
Italian	1 to 177	1 to 535	50
Slav	1 to 200	1 to 575	15
Irish	1 to 645	1 to 1450	33
Scandinavian	1 to 715	1 to 3280	18

The third factor to be considered is the presence of communicable disease among immigrants. The ordinary quarantinable disease are eliminated from the question by efficient quarantine methods, but certain communicable maladies, classed as loathsome or dangerous contagious diseases, exist among immigrants, and constant vigilance and considerable skill are necessary on the part of medical inspectors of immigrants to detect these cases and separate them from the healthy immigrants.

The most important of these diseases, because of its frequency, is trachoma. Of the total number of cases of loathsome or dangerous contagious disease found in immigrants, 87 per cent. are due to trachoma and 10 per cent. to favus.

Several years ago the prevalence of trachoma in the poorer districts of our large cities, and particularly among the foreign-born population, caused numerous requests from medical men engaged in eye work in varous parts of the United States that trachoma be placed in the list of excluded affections. This was done in 1897, with the result that a great many suffering with the disease were taken from among the steerage immigrants and deported. It was then discovered that ordinary steerage aliens suffering from trachoma were being transferred to the cabin, while *en route*, or after being refused passage in the steerage at the port of departure, would be sold a cabin passage, with the assurance that cabin passengers were not inspected at the port of arrival. To check this practise and to make the inspection of aliens complete, an inspection of cabin passengers was instituted in the fall of 1898. The cabin inspection has been very successful in preventing evasion of the law, but many steamship companies were still apparently careless of the diseased condition of immigrants to whom they sold tickets. By the last immigration law (1903) a penalty of $100 is imposed upon the steamship company for each diseased alien brought to our ports, provided the disease evidently existed at the time of the immigrant's taking passage and could have been detected by ordinary medical skill. This penalty has had a salutary effect in causing the steamship companies to institute a more rigid medical inspection at the European ports of departure. Formerly the presence of a diseased alien in the steerage was a matter of more or less indifference to the steamship companies, as they could carry him back to Europe, if deported, and still make a profit on the price of his original passage.

Two points about trachoma have occasioned considerable discussion. These are its contagiousness and its likelihood of causing permanent injury to sight. The contagiousness of trachoma is recognized and conceded by those who have seen a sufficient number of cases of the disease to form an accurate impression. Striking examples of its contagious character can be seen any day on Ellis Island. The Annual Conference of State and Provincial Boards of Health, held at New Haven, October, 1902, placed trachoma in the category of diseases communicable and dangerous to the public health.

Permanent injury to sight is most likely to occur in cases where early treatment is neglected. Among immigrants with trachoma, ignorance of personal hygiene and inability to secure proper treatment make the spread of this disease alarming and the consequences to sight disastrous.

The area in Europe where trachoma is most prevalent extends from the Gulf of Finland on the north to the Black Sea and the Mediterranean on the south, and from Moscow and the Volga on the east to the Carpathian Mountains on the west. In addition, it is prevalent in Greece and southern Italy, probably because of commercial intercourse with Syria, Egypt and the Barbary States. The first-mentioned area is occupied by Finns, Lithuanians, Russians, Poles, Russian-

Germans and Hebrews. The statement is made in some text-books that trachoma is prevalent among the Irish. Observation of immigrants shows that this statement is not true. There is less trachoma among the Irish than any other race of immigrants. The table given below indicates the ratio in which this disease was found among the immigrants landed in 1902.

Race.	Ratio of Cases of Trachoma to Number Immigrants Landed.
Syrian	1 to 66
Armenian	1 to 192
Lithuanian	1 to 375
Finn	1 to 496
Hebrew	1 to 539
Greek	1 to 667
Slav	1 to 758
German	1 to 772
Scotch	1 to 1,216
Magyar	1 to 1,243
Italians	1 to 2,066
Scandinavians	1 to 3,486
English	1 to 3,623
Irish	1 to 4,173

Favus for several years has been included in the list of excluded diseases. If the disease had existed for any length of time, it is, of course, easily detected by the loss of hair and changed character of the individual hairs and the scalp, but in cases of recent origin detection is often difficult because of shrewd efforts at concealment. The immigrants are often prepared for inspection, the tell-tale yellow crusts carefully removed and the scalp cleansed.

Tuberculosis of the lungs is rarely found among immigrants on arrival. Thousands of immigrants are examined whose poor physique suggests to the medical examiner the possible existence of tuberculosis, but out of the many thousands thus examined at Ellis Island last year, only fifteen cases were certified as suffering from tuberculosis of the lungs.

This apparent freedom from tuberculosis is partly explained by the fact that tubercular diseases are notoriously diseases of the cities, while the bulk of our immigration comes from the agricultural communities and small towns. The remarkable prevalence of tuberculosis among recently landed immigrants is the effect of horrible over crowding in infected, filthy tenements by immigrants whose poor physique makes them ready prey for communicable disease. In addition to the horrible congestion of the tenements, the insufficient food and insufficient fuel and clothing, especially among immigrants from Mediterranean countries, must be considered as factors in the development of tuberculosis.

The danger to the public health from immigrants suffering from communicable disease is at present comparatively slight. The United States Public Health and Marine-Hospital Service is charged by law with the medical inspection of all incoming aliens at ports of the

United States. Officers of the service receive special training for their work as medical inspectors of immigrants. Ellis Island, New York, is used by the service as a great school of instruction where young officers, before being detailed for immigration duty at one of the other ports of entry, are trained in the detection of the particular diseases and defects likely to be found in immigrants. Canada has always been a favorite route for undesirable immigrants wishing to evade the law, and officers of the Public Health and Marine-Hospital Service are stationed for immigration duty at Quebec and other Canadian ports, and at various points upon the Canadian frontier. Certain steamship lines make a regular business of carrying to Canada, for subsequent entry to the United States, aliens who have been rejected and sent back from an American port, or who manifestly belong to the excluded classes, or who have been rejected by other steamship lines who have some regard for our laws.

The officers of the Public Health and Marine-Hospital Service stationed at Quebec, Halifax, N. S., and St. Johns, N. B., have authority to examine only those aliens manifested as destined for the United States through Canada. Immigrants so manifested do not differ materially from immigrants ordinarily received at United States ports, and are given certificates of physical fitness which admit them to the United States through any of the border points. Thousands of immigrants evade this inspection at Quebec, Halifax or St. Johns, by being falsely manifested as destined finally to Canada. They have no certificates of inspection by United States officers at Quebec, Halifax or St. Johns, and upon attempting to cross the border are sent back to Montreal for examination.

In order to show the quality of the immigration brought by the Beaver Line and other lines engaged in this nefarious business, it is only necessary to state that 50 per cent. of the immigrants attempting to cross the border in 1902 were rejected, whereas the usual percentage of rejection at United States ports is only one per cent.

A regularly organized system of smuggling diseased immigrants across the border has been exposed by the United States immigration authorities at Montreal, and although the border inspection maintained by the United States Immigration Service is doing splendid work, it is impossible to guard effectively every point of over 3,000 miles of frontier. A more perfect system of exclusion is now possible, and consists of a rigid inspection of all aliens landing at Canadian ports under an effective Canadian law similar in character to our own, which has recently been enacted.

The real danger to the public health from immigration lies in that class of immigrants whose physique is much below American standards, whose employment is in the sweat-shop, and whose residence is the East

Side tenement in New York City. The Mediterranean races, Syrians, Greeks and southern Italians, who are unused to a cold climate, and who often have insufficient clothing, also establish in their crowded 'quarters' splendid foci for the dissemination of disease. The Hebrews, Syrians, Greeks and southern Italians, invariably crowd the most insanitary quarters of the great centers of population. And the various filthy and infected, though perhaps picturesque, foreign 'quarters' constitute to-day the greatest existing menace to the public health.

There are many view points from which our immigrant problem may be judged. There are extremists who advocate the impossible —the complete exclusion of all immigrants, or the complete exclusion of certain races. There are other extremists who pose as humanitarians and philanthropists and who advocate an act of lunacy—removing all restrictions and admitting all the unfortunate—the lame, the halt, the blind and the morally and physically diseased—without let or hindrance. Neither of these extreme positions is tenable. The debarring of all immigrants, or the unjust discrimination against any particular race, is illogical, bigoted and un-American. On the other hand, the indiscriminate admission of a horde of diseased, defective and destitute immigrants would be a crime against the body politic which could not be justified by false pretense of humanity or a mistaken spirit of philanthropy.

The sane, logical position must fall between these two extremes. It is necessary for us to restrict and debar, if possible, all undesirable immigrants. A jealous regard for the public weal may demand measures and standards which seem to the humanitarian and philanthropist selfish and inhuman; but charity begins at home, and it is the right of Americans to exclude the undesirable and to employ whatever measures and set whatever standards may seem necessary to exclude any class which menaces the social or physical welfare of the country.

If we debar any undesirable class of immigrants under the law, we should endeavor to make the law as nearly perfect as possible and debar all undesirable classes. We debar the immigrant with trachoma, syphilis, leprosy or favus; also the insane, the epileptic and the idiotic, but we admit the immigrant with poor physique, unless it is so marked as to make him undeniably a public charge.

There should be but one standard of physique for the immigrant, no matter whether his destination be the Pennsylvania mines or the New York sweat-shops. The skilled laborer should be expected to possess the same rugged physique as is now expected of the unskilled laborer. The standard should be fixed by law by comparison with other well-recognized standards of physique, and should be sufficiently high to exclude all who could not beyond doubt make a living at hard manual labor. The wording of the law should be definite enough to make the medical certificate of poor physique equivalent to deportation.

This requirement of a definite physical standard in immigrants could be exacted without undue hardship of all unmarried male immigrants within certain age limits, for instance eighteen to forty-five. In regard to families, comprising women, children and old men, in addition to males between the ages of eighteen and forty-five, each family should be required to have at least one member constituting its chief support who could comply with the physical requirements of the law. The law need not apply to parents coming here to join their children, provided the children had established a home here and presented evidence of ability to care properly for their parents.

If the thousands of recruits for the sweat-shop army which arrive each year could be thus checked for ten years, the present existing tenement house problem would solve itself. The terrible congestion of the tenements would be relieved; the scale of wages for the sweat-shop worker would be elevated, and the general sanitary conditions of life in such districts as the Lower East Side, New York City, could be improved sufficiently to reduce the menace to the public health from this cause to a minimum.

THE SUCCESSFUL WOMEN OF AMERICA.

By AMANDA CAROLYN NORTHROP,

NEW YORK.

IT is now half a century since a few women began with the most insistent perseverance to demand a place in the political, professional and economic world. They made this demand on the ground that woman's brain is equal to man's, and, given a fair chance, women could successfully compete with man in every field, except where physical strength and endurance were necessary. Man's opposition to this demand, though at times bitter and determined, has been so far overcome that to-day woman has every opportunity for gaining the best educational and professional training, and has already taken her place in the ranks of every profession except that of the armed defenders of her country. Either with or without the consent of her brother, she has got most of the things she has asked for, and some things which she neither asked for nor wanted. She has accomplished much, but her achievements are still looked upon with misgivings by many, as is seen in the frequent discussions of 'The New Woman,' 'The Unquiet Sex' and the 'Evils of the Higher Education.' In all these discussions there is the constant comparison of the two sexes in ability, perseverance and poise. But since they entered the race with the tremendous advantage of centuries of mental training and experience on the side of the men, it is most unjust to draw comparisons.

Putting therefore all comparisons entirely aside, it seemed worth while to make a study, as far as was possible, of those women who have achieved in public or professional life that measure of success sufficient to give them a place among the successful men and women of America, for the purpose of finding out in what lines of work the greater probabilities of success lie, and what part educational training seems to have had.

The material used as a basis of this study is found in the latest edition of 'Who's Who in America.' It would be difficult to find any two persons who would quite agree as to what constitutes success. And this book admittedly has sins of both omission and commission, still it is probably as nearly complete as a book of this kind could well be. The points considered will be found in the following table. The blank spaces and small figures show the incompleteness of data in many cases. The conclusions therefore are only tentative.

The 1902 edition of 'Who's Who in America' contains the names of 11,551 living men and women together with brief biographical sketches giving, as far as possible, birth, parentage, education, marriage and profession. Of these names 977 are women, a ratio of 1:11⅔. Sixteen out of this number are well-known actresses and opera singers who are Americans neither by birth nor residence; six are ladies of social prominence, wives of distinguished men; and one is a deposed queen, which leaves 954 to be considered in this paper.

A careful study of these practically self-written biographies has revealed many interesting facts and tendencies. This is especially true so far as they answer two important questions: First, what professions seem to give the greatest opportunity for success; and second, what educational preparation seems most helpful and necessary. In the order of numbers, they stand as follows: Authors, including novelist, essayist, writer, poet, historian, 487; artists, including painter, sculptor, engraver, etcher, illustrator and architect, 103; educators, including lecturers, 91; journalists, including editor, critic and correspondent, 65; actresses, 59; musicians, 43; social reformers, including club-women and settlement workers, 27; physicians, 21; scientists, including naturalists, 17; ministers, including salvation army and missionary workers, 13; philanthropists, 12; librarians, 9; lawyers, 9; miscellaneous, 3. These figures, it will be seen, amount to five more than the whole number of persons classified, because that number of women are represented as actively engaged in more than one vocation.

The accompanying table shows both the number and the per cent. of those married in each profession, the average age, so far as given, and the general education as well as the particular colleges represented.

The tendency of successful women to marriage does not seem great, the per cent. being only 54. In every case, except the minister and lawyer, the table shows less than sixty per cent. married, and it seems probable that a large number of the women in these professions married before they entered professional life. The journalist comes next in the per cent. married, while the artist falls to 42 per cent., and the educator runs very little risk—if she considers it a risk—her chances of matrimony being only 26.3 per cent. or a little over one to four. The cause of this invites speculation. Is it merely disinclination on her part, or is it because she has less opportunity for meeting congenial men; or can it be that her acquisition of knowledge and possibly the *instructive habit* makes her less attractive to men? At any rate, success and matrimony do not seem to go hand in hand with the educator. It will doubtless cause surprise that the table shows only about half the successful actresses married. This may be due to their omitting the fact of their marriage, because they find it to their advantage professionally to be supposed unmarried, and it may possibly be due to the fact that they seem to *unmarry* with so much ease.

		Number Who gave Age.	Per Cent. Who gave Age.	Average Age.	Number Married.	Per Cent. Married.
Authors	487	345	70.4	53.3	287	58.9
Artists	103	63	64.	44.4	44	42.7
Educators	91	69	75.8	49.2	24	27.3
Journalists	65	46	70.7	50.8	44	67.6
Actresses	59	33	55.9	44.4	31	52.5
Musicians	43	31	72.	40.7	25	58.2
Social reformers	27	22	80.	60.3	16	55.1
Physicians	21	16	76.2	60.7	9	42.8
Scientists	17	11	58.8	50.2	10	58.8
Clergy	13	12	92.3	52.6	12	92.3
Philanthropists	12	9	75.	60	7	58.3
Librarians	9	7	77.7	47	3	33.3
Lawyers	9	6	66.6	58.5	8	88.8
Financier	1	1	100	67	1	100
Life saver	1	1	100	61	1	100
Seed grower	1	1	100	57		
Total.		659	69	52.6	522	54 +

	Educated in Public Schools.	Per Cent.	Private School.	Per Cent.	College.	Per Cent.
Authors	55	11.3	201	41.3	62	12.7
Artists	5	4.8	19	18.4	4	2.9
Educators	25	27.4	30	32.9	42	46.
Journalists	8	12.3	26	40.	12	18.5
Actresses	1	1.7	10	16.9	1	1.7
Musicians	5	11.6	10	23.3	1	2.3
Social reformers	3	11.1	16	59.3	4	14.4
Physicians	2	9.5	7	33.3	7	33.3
Scientists	5	29.4	4	23.5	7	41.
Clergy	2	15.4	2	15.4	5	38.5
Philanthropists	1		5		0	
Librarians			3		2	22.2
Lawyers	2		3		1	11.1
Financier			1			
Life saver						
Seed grower			1			
Total.	111	11.7	325	34	148	15.5

	Vassar.	Wellesley.	Smith.	Radcliffe.	Bryn Mawr.	Other Colleges.
Authors	7	8	6	2	1	38
Artists	1					3
Educators	7	3	2	2	2	26
Journalists	1					11
Actresses						1
Musicians						1
Social reformers				1		3
Physicians	2					5
Scientists	1			1	1	4
Clergy						
Philanthropists		2		1		1
Librarians						2
Lawyers						
Financier, life saver and seed grower						
Total.	19	13	8	7	4	95

As to age, the table shows that only 69 per cent. gave their age, so that the conclusions drawn are not perhaps of great value. Still if a woman's inclination to tell her age does not increase with age, it would seem fair to draw the conclusion that the path to what the

	Number born before 1850.	College Graduates.	Per Cent.	Number born between '50 and '60.	College Graduates
Authors	179	36	20	83	40
Artists	22	1	4.5	14	1
Educators	21	9	42.8	27	19
Journalists	20	3	15	10	3
Actresses	10	0		4	0
Musicians	3	0		10	0
Social reformers	15	0		4	1
Physicians	11	3	27.2	3	3
Scientists	5	1	20	3	1
Clergy	6	2	33.3	3	2
Philanthropists	6	0		1	0
Librarians	1	0		4	1
Lawyers	3	1	33.3	3	0
Financier	1	0			
Life saver	1	0			
Seed grower	1	0			
Total.	305	55	18	169	31

	Per Cent.	Number born between '60 and '70.	College Graduates.	Per Cent.
Authors	48	60	35	58.3
Artists	7.1	14	2	14.1
Educators	70.3	17	10	58.8
Journalists	30	8	1	12.5
Actresses		11	0	
Musicians		12	0	
Social reformers	25	3	2	66.6
Physicians	100	2	1	50
Scientists	33.3	3	0	
Clergy.	66.6	3	1	33.3
Philanthropists		2	1	50
Librarians	25			
Lawyers				
Financier				
Life saver				
Seed grower				
Total.	18.3	75	20	26.6

	Number born between '70 and '80.	College Graduates.	Per Cent.	Number born between. '80 and '90
Authors	21	10	47.6	2
Artists	13	0		
Educators	4	4	100	
Journalists	8	1	12.5	
Actresses	8	1	12.5	
Musicians	6	0		
Social reformers	0	0		
Physicians	0			
Scientists				
Clergy.				
Philanthropists				
Librarians				
Lawyers				
Financier				
Life saver				
Seed grower				
Total.	39	16	15.4	2

world calls success is long and full of obstacles for the woman who attempts it. The musician seems to reach the goal first, her age averaging 40.7 years, and the actress and the artist stand next. They each average 44.4 years.

In the matter of education, the technical education is not considered, the object of the writer being to find the importance which general education and college training hold in the making of a successful woman. It is true, however, that most of the artists and the musicians and many of the educators studied abroad in their special lines. Where no mention whatever is made of education, the writer concludes that it must have been slight.

The table indicates that college training has played a small part in woman's success, only 148 or 15.5 per cent. The largest percentage of college bred women is found among scientists, ministers and educators, but even the number of educators who have had college training is less than half, while in all the other professions, except the ones already named, the table shows less than one fourth to be college women. Some of these women have taken more than one degree, and others have studied in one or more colleges and universities without having taken a degree in any. The question, however, is not so much what place college training has occupied in the past, as it is what the tendency toward extended study and investigation seems to be. By arranging those who gave their age in separate columns according to the date of birth, one may get a fair idea of the tendency towards a higher education, and the relative value it bears in the successful life. All those born before 1850 are classed together and the others by decades. The two columns following the date of birth show respectively the number and the per cent. of college women. Among authors there is an increase of college women who were born during the fifties, over those born before 1850. The next decade shows a further increase of ten per cent., but of those born between sixty and seventy there is a *decrease* of ten per cent., or from 58.3 per cent. to 47.6 per cent. Educators, as has already been said, have the largest number of college women. The last decade considered shows only four names, but they are all college bred. If, however, all the professions are considered together, the reader will see that the per cent. of college bred women born between 1860 and 1870 is less than in any preceding period.

The table also shows the chief woman's colleges represented in comparison with coeducational colleges. Vassar, Wellesley, Smith, Radcliffe and Bryn Mawr each count authors and educators of note among their daughters, but beyond these professions they are scarcely represented at all. The other colleges represented are with few exceptions, the coeducational colleges and state universities east of the Mississippi River. With the exception of the philanthropists, the number who were educated in coeducational institutions is in every case larger than that of all the woman's colleges combined. That is, the majority of these college women were educated in institutions where their instructors were almost exclusively men. If then colleges and especially woman's colleges play so small a part in the success of the women who have been invited to enter the doors of 'Who's Who,' the question naturally rises, where have they received their education?

The prevailing idea seems to be that the private school is all very well for the girl who wants some knowledge of the so-called 'accomplishments' and a sufficient amount of general knowledge to make her fairly intelligent, that they are of value only to those parents who wish the school associates of their daughters to be as nearly as possible among their own social class, but as for giving a pupil anything like thoroughness in the subjects studied, that the private school standards are far below those of the public school. A glance at the table, however, seems to tell quite another story.

The scientists educated in the public school stand to those educated in the private school in the ratio of 5:4, but in every other profession the number educated in private schools far exceeds that of the public schools. Even among educators where thorough knowledge is certainly essential to success, the ratio of those educated in the private school is to those educated in the public school as 6:5; the journalists over 3:1; the physicians 7:2 and the authors over 4:1.

While the public school should not for a moment be undervalued, these figures would seem to give one a reason to believe the private schools of the country to be a valuable educational factor in fitting a woman for a successful career.

It is greatly to be regretted that the biographies investigated are in many cases so incomplete. The results of the investigation are therefore only partly conclusive, or perhaps suggestive. But so far as they go they speak with a degree of authority and nothing is true beyond that point.

SOUTHERN AGRICULTURE: ITS CONDITION AND NEEDS.

By Professor D. D. Wallace, Ph.D.,
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THE south is one of the two great agricultural sections of the United States; the other is the great prairie region of the northwest, a little smaller than the south in area and a little larger in population. By the south is meant what is really the southeastern quarter of the country, skirted on the north by Pennsylvania, the Ohio River, Missouri and Kansas, and sweeping in a broad belt, with a length of about twice its breadth, from Delaware to Texas. The northern borderlands of this region differ so in population and products from the other states of the group that we shall count them only in making general statements, but never in citing illustrative examples.

The Relative Importance of the South.

The relative importance of the south in American agriculture is greater than seems to be recognized by the rest of the country, while it is doubtless less than her own people commonly assume. By comparing the two great agricultural sections of the United States, we discover that the farm property of the south comprises 43 per cent. of the total farm acreage of the country, but only 21 per cent. of all farm values; while she furnishes only $28\frac{7}{10}$ per cent. of the total products. The value of farm products in the south, therefore, is low as compared with the acreage, and the value of farms is still lower. In the northwest, on the other hand, exactly the reverse is the case; that section comprises only 38 per cent. of the total farm acreage of the country, but 56 per cent. of all farm values and 50 per cent. of all farm products. This disadvantageous comparison of the value and products of southern farms is very largely accounted for by the fact that a much greater proportion of lands in that section is still uncultivated than is the case in the northwest. Yet when this has received its due allowance, the southern farmer and the southern statesmen have many lessons to learn from the northwest as to progressive agriculture, both from the standpoint of the individual and from that of the commonwealth.

Georgia and Iowa may serve as typical examples of the greater productivity of the northwest. The two states are about equal in area and population; yet Iowa feeds her live stock annually all but as much as the total value of farm products in the state of Georgia; while the total value of all Iowa's farm products lacks only one third of one per cent. of equaling the combined totals of Virginia, North Carolina, South Carolina, Georgia and Florida. Only Texas can compare in the volume of her agricultural output with this banner state of the northwest, and even she falls short more than $135,580,000.

We must concede, therefore, that the south occupies the second place among the great geographical divisions of the country as a producer of agricultural wealth.

The Southern Farmer in 1893 and in 1903.

The condition of the southern farmer has immensely improved in the last ten years. To-day he stands, for the first time since the war of secession, in a position promising permanent betterment of his farming and of his social position. Until recent years three causes, any one of which was a fearful incubus, combined to pull him down, viz., low prices, the lien system and bad farming, including under this head poor management and antiquated methods.

Scarcely any impediment is heavier to bear up against than producing for a long term of years for a continuously falling market. Sir Guildford Molesworth estimates that between the years 1872 and 1894 the prices of general commodities fell 50 per cent.; the price of wheat 60 per cent.; that of cotton 70 per cent. In manufactures this depression of prices was in large measure offset by new inventions and economies in production; but the agriculturist, from the nature of his occupation, is almost entirely cut off from such retreats.

To add to the hardship of his salable commodity's constantly falling in price at a rate so rapid that we may say that the value of his cotton appreciably diminished even while the boll expanded, the southern farmer was drawn by circumstances into doing business under a system which subjected him to a ruinous usury and left him almost completely robbed of his freedom as to planting profitable or unprofitable crops. Along with the rest of the structure of southern industry, the war of secession shattered the system of agricultural credit. There was no longer a class of large planters possessed of valuable estates to whom banks of immense capital or wealthy factors stood ready to lend at fair interest. Ready money existed only in the traditions of the past; the southern farmer found himself without the means to buy even the seed to put into the ground. Then the crop lien law came to his assistance and remained to his destruction.

This system of industrial peonage known as the lien law works as follows: The farmer prepares in February for planting. He goes to the proprietor of an establishment, which in its typical form is a crude department store dealing in every article from medicines to wagons that he is likely to need in his simple existence. He requests the merchant to 'run' him during the year, that is to say, to sell him supplies on credit until the crop is harvested. He promises the merchant to plant a certain acreage of cotton and signs a mortgage upon this yet unplanted crop. He is now at liberty to buy on credit from this particular merchant anything he requires; but he can not buy anywhere else, for he has no cash, and his credit and security are all pledged to his patron merchant. The merchant has two scales of prices, cash and credit, the latter much higher than the former, the excess constituting interest which the lien farmer must pay. With a few merchants the credit prices are scaled down each month, so that the rate of interest remains approximately the same on all goods purchased on lien; but ordinarily the prices remain unchanged up to the last day before settlement, so that the rate of interest rapidly increases as the time before settlement diminishes. On goods which the farmer gets late in the summer, he frequently pays interest above the cash price at the rate of 200 per cent. per annum. For the whole term of credit, extending from February to October, he pays on the average, in different localities, from 40 to 80 per cent. per annum. The usury law forbids the bank to lend him money at a higher rate than 8 per cent., but 'protects' him by allowing the merchant to charge him 200 per cent., on the principle, apparently, that a man may consent to pay any price he chooses for capital in the form of merchandise, but that he is not at liberty to offer more than a moderate price for capital in the form of money, no matter how badly he may need it or how great the benefit to be derived from its possession.

Some large merchants employ a sort of traveling inspector of securities, on whose report of the condition of each customer's crop the question of further advances is determined. Possibly by July the farmer has so much charged against him that the merchant considers it unsafe, in view of the uncertainty of seasons, to allow the crop to cover any further credits, and accordingly declares himself under the painful necessity of declining further sales except on additional security. The farmer then gives a mortgage on his slight furniture, bedding, cows, everything. The law does not allow him to give a mortgage on his wife and children.

Late in the summer the crop is sold. Not to lay the price upon the counter of the lien merchant is, in law, a misdemeanor; but in farming it is starvation for the next year—or at least, the farmer thinks so. Very commonly in good years, and as a general rule in bad ones, the price of the crop does not equal the amount on the merchant's books against the farmer. Sometimes the sheriff is called in to supply the deficit from the real and chattel additional security; but not generally. The lien, at least in some states, contains a clause requiring the farmer to enter into a similar agreement the next year with the deficit charged against him if he does not succeed in paying out the first year's account.

The iniquity of such a system is exceeded only by the suffering of the farmer under it. To observe its operation makes plain the ground for the Biblical injunction given three thousand years ago to an agricultural people against usury. And the pathos of the lien farmer is that he is always only twelve months from freedom. Better that he should eat but one coarse meal a day and wear his cheap clothes to the last frazzle of decency, and by one unremitted struggle break his chains.

This lien system goes far to account for the amazing fact a few years ago of the southern farmer's persistently planting a full acreage of cotton in the face of an already glutted market. Those who then berated him for his folly little understood his predicament. For the southern cotton farmer, cotton is the only money crop; but for it there is absolutely certain sale, for there exists from the field to the factory a market unexcelled for its thorough and sensitive organization in the commerce of the world. Government bonds can sooner fail of a purchaser than can a bale of cotton. When a lien merchant sells goods with cotton as security, he sells practically for gold paid in hand and by the same act invests his gold at an enormously profitable dividend. If cotton has fallen in price, the merchant requires the farmer to increase his acreage, as more bales are necessary to equal a given sum; and as the farmer's necessities do not diminish with the price of his product, he submits; and so we behold the paradox of men's planting more and more of a certain crop for the sole reason that to plant it is becoming less and less desirable.

The effect produced upon the character of a people by rack rent is well known; where the tenant promises a rent equaling or exceeding the surplus product of the land above what is necessary to keep him alive, he has no inducement to good farming, as the total surplus produced will be taken from him whether it be great or small. His fields present the most miserable appearance. The same is true of the farmer whose lien just suffices to secure on credit the bare necessities of food, clothing and farming material. Not infrequently he even neglects to harvest his crop, and the merchant has to send his own men to pick it from the field.

The hard times from 1891 to 1896 were of incalculable benefit to many southern farmers. The terrible experience of usury, depressed prices and industrial peonage led many to resolve to be free from the lien system; and the enforced economy of those years taught how alone that resolution might be realized, viz., by the accumulation of a certain reserve capital beyond the necessities of each day's living. To save one dollar is better than to earn ten. An indispensable prerequisite to the progress of any people is their learning, by self-denial, to save from this year's consumption something of this year's product. Those farmers who learned this lesson have emerged to a greater or less degree from the shackles of the usurious lien system, and in many instances what formerly went in 80 per cent. interest to the advancing merchant is now drawing 4 per cent. in the savings bank.

Some explanation is necessary of the southern people's continuing a system so bad. It is favored by a large class who could, by proper exertions, live without it, but whose indolence deters them from the supreme effort which would assure their ultimate prosperity; and by a still larger class, generally tenants, whose unfitness to manage farms would require them to become hired laborers if they could not get supplies in advance under the lien law. Thus the system is an evil in three ways: it puts land under the management of earth butchers who destroy the natural resources of the country and reduce its production of wealth; it leads men capable of better into a system of indolence, destroys their credit and self-respect, and robs them of interest in their lifework; and lastly, it proves a terrible master to the man who has once fallen into its subtle, tightening embrace, and who desires independence and progress.

Systems of Farm Tenure.

The development of farm tenures in the south has been from simple to complex. Before the war the system of ownership was dominant; but within that there were two classes—owners who attended to their estates and owners who committed them to salaried managers. Managers, once so common, now operate less than one in a hundred farms in the south—a smaller proportion than in any other section of the union. A southern farmer who is sufficiently trustworthy to have extensive lands committed to his care will give his employer no rest until he consents to sell; or failing in that direction, he buys some old plantation whose proprietor family has either become extinct or moved away in their itching for town life.

The impoverishment of the large planters and the disorganization of the labor force by the war of secession necessitated large plantations being broken up into units sufficiently small to be operated on a limited capital and with a minimum of laborers. Between 1868 and 1873 in Georgia, 32,824 small farms were thus created, and the same process was in operation throughout the south. Thus the immediate tendency of the war was to the distribution of the land in small tracts into more hands; and in this was cause for gratulation; for not only did it open immense new possibilities of social progress and industrial independence to thousands of white men whose lives had been one of woeful sacrifice to the slave-worked plantation economy, the tragedy of whose wretched existence has never yet been written, but it was calculated vastly to increase the wealth of the country; for, to a point not yet reached in the United States, the productiveness of farms rises exactly as their acreage decreases.

But no sooner had the more enterprising of the southern population begun to succeed than the tendency to a wider distribution of land met a counter tendency towards the increase in the size of estates, doubly augmented by the prosperity of some and the misfortunes of others. It may be safely asserted that to-day the best type of southern farmer either owns a large estate, or is paying for tracts recently added to his plantation, or is expecting to make such additions. He has set a thousand acres as the goal of his ambition. In many localities this feeling has grown into such an insatiable land hunger on the part of wealthy planters as seriously to handicap young farmers who have not inherited property.

One bulwark protects, but not completely, the country from serious injury from this tendency: there are so many men with this same ambition and with the same chances for gratifying it.

The vast majority of southern farmers, 93½ per cent., are included in the three classes of owners, cash tenants and share tenants. Owners operate 47 per cent. of the whole number of farms; cash tenants 17½ per cent., and share tenants 29½ per cent. The desirability of these three classes is in the order of their enumeration, as is also their wealth-producing capacity, even to a degree beyond what appears from glancing at the figures. It is the universal rule that small farms of any given tenure are more productive than large farms; so that when we consider that notwithstanding the fact that cash tenant farms are one third larger than share farms and owner-operated farms are two and one third times larger than share farms, yet the productivity of owners and of cash tenants exceeds that of share tenants, while that of owners almost equals that of the much smaller cash-tenanted farms, the relative superiority of the different forms of tenure is more thoroughly revealed.

TABLE I.

TENURE, AREA AND PRODUCTIVITY OF SOUTHERN FARMS.

	Owners.	Cash Tenants.	Share Tenants.
Number of white farmers.	1,060,559	187,088	491,655
" " colored "	158,078	271,702	280,699
Total number of farmers.	1,218,637	458,790	772,354
Average acreage.	146.9	85.6	62.6
Percentage of all farms.	46.9	17.5	29.5
Percentage of total farm area.	49.5	10.6	13.7
Product per improved acre.	$10.44	$11.48	$10.29

Average size of farms operated by white farmers of all tenures, 173 A.
" " " " " " colored " " " " 53 A.

Share tenants, if they furnish implements, stock and feed, generally give the landlord from one fourth to one third of what they produce; if these are furnished by the landlord, he gets one half the gross product. These proportions sometimes vary in different sections and with different crops. It is simply what in Europe is known as metayer farming.

The status of the renting farmer and his landlord throughout the United States has occasioned some anxiety for the future of the American yeomanry. In the country at large the percentage of owners is appreciably larger than in the south, and both classes of tenants respectively are appreciably smaller; for of the total 5,737,372 American farmers, 54.9 per cent. own the farms they operate, as against 46.9 per cent. in the south. It must be acceded in addition that the tenant system in the south is much more indicative of evil consequences than in other sections. In the northwest, for example, the number of 'tenants' is swelled largely by the sons of aged retired farmers in whom the titles still rest, and by enterprising men who have made the second step in the gradation of hired laborer, tenant, owner. This is true to a much less extent in the south. The tenant class there is composed mainly of shiftless whites who have definitely settled into what has come to be known as the 'tenant class' and of earth-butchering negroes. All the alertness of a landlord close at hand, who is himself strong-willed and a good farmer, is required to save land from deterioration after several years under such tenancy. The safest method has been found to be for the landlord to retain the right to supervise authoritatively every detail of the farming, not only by specific stipulations in the contract, but continually during its execution. Absentee landlordism in the south means, almost inevitably, land butchery.

The Tenant's Outlook.

What is the tenant's chance to attain the ideal of farm life—ownership of the land upon which he works?

The southern farm tenant has the best opportunity of any renter in the world to become an independent proprietor. If, under the improved agricultural conditions which promise to continue, he does not enroll himself among the owners, it will rest as a heavy indictment against his worth of character.

Last year I was driving through one of the richest agricultural sections of the south. A place better fenced and kept than the ordinary impressed me. 'That man was a tenant five years ago,' said my companion. 'He made a small cash payment on that $5,000 cotton and tobacco plantation; he lived hard for four or five years, and now he has paid the last cent of the price.'

A few miles farther on stood a rusty hut of doll house dimensions, jammed up jealously against the railroad track. In the yard a woman of comely but unclean person washed clothes. The slouchy individual in blue shirt and no suspenders was her husband. Most likely neither of them could distinguish the English language in its printed form from the inscription on an Aztec monument. These tenants might have bought a good farm for less than the clerk in the city would pay for his cottage home; for the average value of farms in the south is only $11.79 an acre, as against $36.25 for lands in the northwest frequently not so productive.

Farm Labor.

The dwellings and wages of southern farm laborers have both improved, the former in the greater degree. No progressive southern planter would to-day build such quarters as were erected twenty years ago. Experience indicates that good quarters attract a better type of laborer and hold him more steadily, and so prove a good investment. In some parts of Louisiana dwellings furnished to a family free of charge (as is throughout the south the universal rule) cost $400. Comfort is subserved in better floors, glass windows and secure ceiling; and decency, in a larger number of rooms.

The condition of the agricultural laborer seems to have improved most in the distinctly staple states, such as Louisiana, Alabama and South Carolina, rather than in those whose agricultural interests are scattering, such as Maryland and Kentucky.

Wages to the laborer are less in the south than in any other section; but there is ground for believing that the cost of labor is greater to the southern farmer than to the northern, western or northwestern; that is to say, a hundred dollars expended for labor in the south brings less return than in any other region of the country. The low efficiency of farm labor is one of the heaviest impediments to the progress of southern agriculture.

One of the results of this inferior help is that the southern farmer enjoys but a small part of the benefits of agricultural inventions; first, because to hire the low priced labor is as cheap in the short run as to buy the machinery, and thus the pace is set at antiquated methods and non-participation in agricultural progress in the long run; and secondly, because such ignorant labor can neither utilize nor take care of expensive machinery.

To understand the inferior quality of southern farm labor necessitates a brief examination of the personnel of the labor force. First, there are the white laborers, comprising something more or less than half the entire number of the actual tillers of the soil. It has been estimated by respectable authorities that the major portion of the cotton is raised by white labor; but concerning a statement of such importance, I will only say, in the absence of positive proof, that it is not improbable. Certainly, far more of the hands that actually hold the plow are white than is popularly supposed. These laborers generally work for themselves or their parents; and as they do not ostensibly enter the labor market, their numerical importance goes unnoticed.

Secondly, there is the negro farm hand, who contributes the great bulk of the hired labor and is a sort of pace-maker to the white laborer.

Negro Labor in Southern Agriculture.

I shall speak later of the better qualities of the negro; but at this point I must call attention to the widespread prevalence of certain evils which constitute a serious problem in southern agriculture. The generation of the race not yet sobered by middle age, who have never known, on the one hand, the fine discipline of the ante-bellum masters, nor have yet, on the other hand, learned self-discipline in the more trying conditions of freedom, have degenerated to a level lower than any occupied by their race since its African barbarity, and lower, let us hope, than it will ever occupy again. Not only the morals, but —what bears more directly on the present inquiry—the efficiency and reliability of the mass of the negro laborers below the age of forty are injured to a considerable degree by the group of vices represented by the pocket pistol, liquor, a deck of cards and a mistress. A certain dash of wildness marks youth under all colors; but such general statements are by no means adequate to cover the case of the post-bellum southern negro.

Not only are the higher qualities of the laborer depending on character thus destroyed, but this moral degradation has necessarily incurred physical degeneration by initiating the negro into a catalogue of diseases to which his race was forty years ago a stranger. Some investigators assert that something like 70 per cent. of the race are infected with a dangerous type of disease incident to vice.* And yet he works; for his constitution offers a strange resistance to a form of poison that completely invalids the white man, but frequently injures the negro no further than seriously to impair with lassitude and weakness that splendid body his inheritance by nature.

Not only is the negro, like all ignorant labor, inefficient, expensive and unprogressive, but he is suited to only a few staple crops, to the culture of which he has been reared. The negro is an inveterate 'cottontot' and conspires with the lien system to keep southern agriculture to that staple. His preference for cotton is shown by the fact that 71.9 per cent. of the negro farmers of the south are cotton farmers, as against 28.5 per cent. of the white farmers.

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* Undeniably the condition is appalling; I would, however, accept such large per cents. with caution.

TABLE II.

PREFERENCE OF THE NEGRO FOR COTTON.

	All Farmers in South	Cotton Farmers.	Percentage of Cotton Farmers to Total.
White farmers in south.	1,869,721	531,333	28.4
Negro " " "	734,362	527,969	71.9

As a rule, not without some exceptions, those counties in the south which have a large negro population are inferior in productiveness to those of similar natural quality in which the negro population is small. The productiveness of the farms of white farmers, north and south, is, with rare exceptions, greater per cultivated acre than the productiveness of lands cultivated by negro farmers.* The fairest basis of comparison is the productiveness of share farmers of the two races; for in this class practically all the management and all the labor are done by the farmer and his own family. Not only do the financial limitations and the small fields of share farmers preclude them from hiring labor, but whites will not work for negro farmers, nor will the negro, if he can avoid it, work for the small white farmer,

TABLE III.

PRODUCTIVITY OF FARMS PER IMPROVED ACRE BY TENURE AND BY RACE OF FARMER.

		WHITE.	NEGRO.			WHITE.	NEGRO.
Ala.	Owners	$11.03	$9.70	Mo.	Owners	$9.58	$9.39
	Share tenants	10.62	9.27		Share tenants	8.24	8.99
Ark.	Owners	11.06	13.07	Neb.	All tenures †	8.83	6.72
	Share tenants	9.88	11.06	N. J.	Owners	22.11	17.85
Cal.	All tenures †	10.87	7.03		Share tenants	18.29	14.57
Fla.	Owners	13.40	8.77	N. Y.	All tenures †	15.70	14.23
	Share tenants	9.62	8.25	N. C.	All tenures †	10.82	10.28
Ga.	Owners	10.91	9.01	Ohio.	Owners	13.36	11.45
	Share tenants	10.53	9.52		Share tenants	12.76	11.63
Ill.	All tenures †	12.49	10.00	Penn.	Owners	15.74	15.43
Ind.	All tenures †	12.26	11.67		Share tenants	14.27	11.57
Iowa.	All tenures †	12.22	12.93	S. C.	Owners	11.90	11.69
Kan.	All tenures †	8.39	7.46		Share tenants	13.26	11.77
Ky.	Owners	8.94	10.29	Tenn.	Owners	10.32	10.70
	Share tenants	10.34	11.89		Share tenants	9.64	10.32
La.‡	Owners	16.71	13.98	Tex.	Owners	12.51	10.04
	Share tenants	11.77	13.28		Share tenants	10.78	9.99
Md.	Owners	12.76	8.37	Va.	Owners	8.55	8.78
	Share tenants	10.43	6.61		Share tenants	7.89	7.97
Miss.‡	Owners	13.13	13.88				
	Share tenants	12.71	14.77				

* The figures of the twelfth census are arranged in such a way as to conceal the shortcomings of the negro farmer, though there was doubtless no intention of producing such a result.

† The census tables giving production of farms of various tenures divide population into 'white' and 'colored.' In some states the number of Chinese farmers is so great as to make anything more than a mere approximation of production by negro farmers of various tenures possible; therefore I did not attempt it, but took the productivity of negro farmers of all tenures as given in a separate table.

‡ A large portion of the rich river bottoms are share-farmed to negroes.

and least of all for another man's 'cropper.' And, sad to say, thousands of white croppers are fully equal to the most benighted negroes in lack of education.

Tables III. and IV. exhibit the relative productiveness of the labor of the two races, and also very strikingly the superiority of the agriculture of owners to that of tenants.

I have selected from the four representative southern states of Alabama, Georgia, Louisiana and South Carolina, the eighty counties (except the two extremes of sea islands and mountains) having the largest and the smallest proportion of negro population. I then found the production per improved acre of the farms in each of these counties. Table IV. contains all those counties whose negro population is 75 per cent. of the whole and all whose production reached $11 per acre. A table of this kind is unduly favorable to the negro, for two reasons: First, those counties throughout the south containing the richest lands were flooded with black population during the slavery régime, and their agricultural population is to-day of the same composition; and secondly, the good farming counties having to-day from 20 to 40 per cent. of negro population generally contained almost no negroes before the war, whereas their towns grown up since have drawn a large number of negroes from a distance, while the country districts are still inhabited in about the same proportion as formerly by whites. Thus a county having 30 per cent. negro population and a large per capita production might appear to one unacquainted with actual conditions to be blessed with just about sufficient negro popula-

TABLE IV.

PERCENTAGE OF NEGRO POPULATION AND PRODUCTION PER IMPROVED ACRE IN CERTAIN SOUTHERN COUNTIES.

	Percent. of Negro Popula.	Prod. per imp. A.
Alabama:		
Baldwin.	31.5	$15.42
Bibb.	33.5	13.00
Lowndes.	86.6	9.85
Macon.	81.2	8.47
Marengo.	76	9.13
Russell.	78.1	8.05
Sumter.	82	8.85
Georgia:		
Berrien.	30.5	13.01
Burke.	78	8.93
Carroll.	18.5	11.01
Charlton.	20.7	13.24
Colquitt.	26.4	11.03
Dekalb.	33.3	11.29
Dougherty.	82.8	15.22
Douglas.	24.6	11.13
Hancock.	74.5	6.94
Houston.	75	7.34
Stewart.	74.5	8.09
Tatnall.	35.3	11.10
Louisiana:		
Acadia.	20.5	$13.77
Bossier.	78.2	11.96
Calcassieu.	19.6	11.28
Cameron.	14.6	15.43
Concordia.	87.3	19.27
East Baton Rouge.	66	12.54
East Carroll.	91.5	16.36
Lafourche.	28.3	32.33
Tangipahoa.	30.5	17.94
South Carolina:		
Anderson.	42	11.04
Cherokee.	34.6	14.91
Chester.	77.7	8.52
Fairfield.	76	8.76
Horry.	27	12.80

tion to do the heavy farm work; but closer examination will generally reveal the fact that an unduly large proportion of these negroes reside in the towns, while the white man still works the one-hundred-acre farm of his fathers. For instance, 32.3 per cent. of the population of the county of Spartanburg, S. C., is put down as negro; but the county seat alone, with a population of 11,395, contains 20 per cent. of the negroes of the entire county, and only 16 per cent. of the whites, and one may ride for hours through many of the townships and see scarcely a black face. And all this is true despite the fact, let it be noted, that during the last twenty years tens of thousands of whites and not one black have been drawn into the towns to man the twenty-eight cotton mills of the county, having an aggregate capital of ten millions of dollars. What negroes there are have largely come from the two counties on the south, which as early as 1850 had a majority of negro population.

It will be observed that only four counties of large negro population are also largely productive, of which one lies in the Flint river bottom in Georgia, being one of about two dozen spots of exceptional richness strewn midway across the state from the Savannah to the Chattahoochee; and three are in the Tensas bottom bordering the Mississippi in Louisiana; and the productiveness of these, it will be noticed, is exceeded by that of counties of large white population similarly situated, as, *e. g.*, Lafourche and Tangipahoa, La.

In conclusion, we may say that a careful study of the tables reveals the facts, first, that the white tenant working for himself usually makes more than the negro tenant working for himself; and second, that in localities in which the large majority of the labor hired by white farmers is black, the production by white owners is generally less than that of white tenants doing their own work and tends to approximate the production by black farmers. That is to say, white ownership farming barely suffices to raise black labor to the level of the efficiency of white tenants.

I am concerned with the negro only in his bearing upon the present condition of southern agriculture, and do not intend the dark pictures I have drawn of his shortcomings as 'views' upon the race question. The best element of our colored people merit sincere praise for their progress; but it can not be denied that the great mass of the negro population, in its present condition, is a fearful incubus upon the industry of the south. To contend that the negro fills such a large part of our economy is not to prove his efficiency or his necessity; for ours is the only great country of the world that is not without his aid. The immediate need of the industry of the south regarding him, whatever his final destiny, is to strengthen his character and raise his intelligence to a point adequate to the proper performance of his economic functions.

TABLE V.

SEVEN LEADING CROPS OF THE SOUTH, WITH THE POPULATION OF EACH TO THE VALUE OF ALL CROPS IN THE UNITED STATES AND TO THE TOTAL VALUE OF THAT CROP IN THE UNITED STATES, AND TO THE TOTAL CROP VALUES OF THE SOUTH.

	Value of All Crops.	Cotton Value.	Percentage of Cotton to All Crop Values.	Percentage of Cotton of South to Cotton of United States.	Corn Value.	Percentage of Corn to All Crop Values.	Percentage of Corn of South to Corn of United States.	Fruit and Vegetable Value.	Percentage of Fruits and Vegetables to All Crop Values.	Percentage of Fruits and Vegetables of South to Fruits and Vegetables of the United States.
U. S.	$2,888,839,638	$370,758,171	13.5		$828,258,326	29		$373,027,418	13.4	
N. Cent.	1,373,021,966	906,782			535,443,048			117,668,356		
South.	948,193,759	369,790,659	39	99.7	250,869,293	26.5	31.5	98,885,012	10.4	26.5

	Hay and Forage Value.	Percentage of Hay and Forage to All Crop Values.	Percentage of Hay and Forage of South to Hay and Forage of United States.	Wheat Value.	Percentage of Wheat to All Crop Values.	Percentage of Wheat of South to Wheat of United States.	Sugar and Sorghum Cane Value.	Percentage of Cane to All Crop Values.	Percentage of Cane of South to Cane of United States.	Rice Value.	Percentage of Rice of All Crop Values.	Percentage of Rice of South to Rice of United States.
U. S.	$484,254,703	16.4		$369,945,320	12.8		$26,644,738	$\frac{9}{10}$		$6,329,562	$\frac{2}{10}$	
N. Cent.	221,866,406			244,332,729			1,916,270*					
South.	59,589,664	$6\frac{3}{10}$	12.3	58,790,460	$6\frac{2}{10}$	15.9	24,693,183	$2\frac{6}{10}$	92.6	6,329,562	$\frac{7}{10}$	100

The aggregate of the above calculations, embracing 91.5 per cent, of all farm products in the south, contains an inaccuracy of only $\frac{14}{100}$ of one per cent., distributed among the seven crops.

* Only sorghum.

What the South Raises.

Such is the machinery of southern agriculture; what does that machinery do? In the first place, it produces crops to the annual value of more than a billion and a third dollars, constituting 28.7 per cent. of the agricultural output of the country. Two staples, cotton and corn, embrace 65½ per cent. of all the crop values of the south, and only seven of her crops can be called in any sense leading, viz., in the order of their value, cotton, corn, fruits and vegetables, hay and forage, wheat, sugar-yielding canes and rice. These comprise 91½ per cent. of all her crop values. Corn has come to occupy a greater acreage than any other crop, having 25,612,949 acres as against 23,518,433 for cotton, which leads us to hope that King Cotton's disastrous tyranny has been tempered to the milder sway of a limited monarch.

Agricultural Education.

The three cardinal needs of the southern farmer to-day are education, diversification and credit.

The fundamental failing of the education offered the southern farmer is that it is not adapted to the end in view. The curricula, past and present, of our schools hardly bear the evidence of being framed for a people whose prosperity depends so largely upon mastering the art and science of the tilling of the soil. The country schools should teach branches bearing upon agriculture, beginning with 'nature study' with the little tots, and extending to physics, chemistry and botany for the mature pupils. Not only should the boy learn of the lovely lea, over which the lowing herd so slowly winds, but he should have an even more intimate acquaintance with the composition of the soil and of the physiology of those cattle. The present system of educating country children fits them for the spheres they are to fill little further than by such unfolding of the intellect as necessarily results from any schooling, but rather presents the anomaly of rearing a great people to unfitness for its life work. The curriculum of rural schools should be such that farmers would feel that they could not afford to allow their children to miss its benefits.

Many southern agricultural colleges meet the need little better and fail signally to send men back to the farm. In this respect a number of schools in the northwest excel ours. The agricultural college of Michigan has sent a larger per cent. of its graduates into farming than professional schools and universities send of their graduates into the professions for which they were prepared. The only plan of agricultural education which has succeeded in any state in its object is to have the institution devoted exclusively to preparing the farmer for his peculiar life work, and at very low expense. 'Agricultural' colleges which give extensive courses in non-agricultural branches are used simply by young men desiring the shortest cut, and hence an inferior preparation, to a professional career, and the real agricultural interests of the state in question remain almost completely untouched. The 'agricultural' college in which the student can pursue a course largely non-agricultural is a monstrosity, but, unhapppily, not a curiosity.

Louisiana among southern states seems to have succeeded best in agricultural education, though she lacks much of a complete system. She has a number of schools distributed among sections of the state differing in soil, climate, topography and latitude, in which nothing but agricultural sciences and practical farm work are taught, and in which the sons of millionaire sugar planters, along with all others, are compelled to work, not to help pay their expenses, but in order to learn farming.

Diversification.

To urge the uneducated farmer to diversify crops is to make demands beyond his preparation. Tell him that it will render life more interesting, and you are talking into his deaf ear; inform him that it will preserve the fertility of the land, and he will not believe you; point out that though the fruit and vegetable crop is only 2 per cent. of the acreage, it is 8.3 per cent. of the value of all crops of the country; and he will forget it; remind him of the fact that his well-to-do neighbor plants cereals extensively, raises hogs and has a fine flock of sheep, and he will explain that his neighbor can do these things because he is rich, and will stubbornly decline the theory that his neighbor is rich, in part at least, because he does these things. Agricultural education brings agricultural diversification as inevitably as general education produces diversity of professions, and nothing else ever can secure it.

Agricultural Credit.

And lastly the southern farmer needs better facilities for obtaining credit.

Figures for the whole south are not at hand, but those for the state of South Carolina indicate that banking capital is less abundant now than before the war of secession, notwithstanding the rapid multiplication of banks all over the south during the last ten years. The capital, surplus and circulation of banks in South Carolina to-day is $11,802,584, of $8.81 per capita; whereas in 1861 these items for the twenty banks then in existence aggregated $21,031,522, equaling $29.88 per capita; while in 1850 the per capita rate for the same items was $32.73. The disreputable character of much ante-bellum banking necessitates my stating that there was not a single bank failure in South Carolina from the Revolution to 1861; her bankers won the commendation of the most exacting critics, and their notes passed everywhere for gold. Louisiana is another state with a very similar record.*

These rich banks of the slavery régime lent principally to the large planters, on personal endorsement, stock and bond security, and real estate mortgage. Substantial 'factors' also did an extensive lending business, in a way which made them a sort of predecessors of the modern lien merchant. The factor advanced cash to the planter, secured sometimes by a real estate mortgage, and sometimes only by note, with the promise (not legally enforceable, however) that the crop should stand good for the debt if necessary, and that in any event the factor should enjoy the advantage of handling it. The bank then rediscounted, perhaps at a lower rate, the planter's note as endorsed by the factor. The step to the vampire lien system was made after the war, when the factor was replaced by men who similarly borrowed from the banks upon their mercantile expectations, but who made the handling of the farmer's cotton a subsidiary business, even if they engaged in it at all, and sold him goods at enormous credit prices on such lien security that many a lien merchant has never in any true sense lost a dollar by bad debts, but has simply failed to collect to the extent of more than reasonable profits, instead of the higher ones he set as a standard.

The financial need of the south to-day is more banking capital in close touch with the farmer. Large city banks do not seek agricultural business; they dislike the farmer's business ways, the duration of loans to him, and the character of his security. It is true, however, that the farmer receives fairer treatment at any one of the several $100,000 banks in a large town than at the single very small bank in the very small town.

And rural banking facilities are wonderfully increasing. In several southern states ten years ago there were hardly a dozen banks. One thousand, three hundred and seventy-four of the 2,172 banks existing in the nine States of Alabama, Arkansas, Georgia, Louisiana, Mississippi, North Carolina, South Carolina, Texas and Virginia in November, 1902, were established between that date and January 1, 1893—a period of ten years lacking two months.

Some blundering and some unsafe banking have resulted from this sudden multiplication of untrained hands at the business; for the vast majority of these banks are chartered under state law. Yet the agricultural interests have been greatly benefited: and the evils can be remedied by the employment of expert inspectors. The fact that bank

* Banks to-day furnish a large amount of money to the business and agricultural interests by means such as rediscounts, large deposit accounts, etc., item far less important in ante-bellum banking. The relative amount of actual accommodation supplied now and formerly would be an interesting question for bankers acquainted with both past and present conditions in the south.

failures are rare even in states which maintain absolutely no inspection is conclusive evidence of the long strides forward which the public conscience and the public demands have made in banking.

Personal letters to me from bankers in representative counties in Alabama, Georgia, Louisiana, Mississippi and South Carolina corroborate testimony from other sources that the escape of the farmers from the lien system is being hastened and their independence assured just in proportion as they themselves manifest principles of integrity and promptness in their financial affairs; and secondly, as the local bankers or other lenders of cash at legal rates stand ready to make advances to farmers.

The three following typical letters illustrate the progress of the southern farmer towards independence. The first is from northwestern Mississippi and presents an agricultural population whose own shortcomings debar them from assistance:

> Our farmers are in much better condition as regards the lien system. The majority either borrow money by trust deed or personal security, usually the former. Our banks extend accommodation to farmers where they can give anything like reasonable or satisfactory security. However, this class of our business has not proven very profitable or satisfactory, for the reason that, in majority of cases, farmers do not realize the necessity of being prompt in meeting their obligations; consequently entail considerable trouble and worry in collecting same, thus in large degree offsetting the profit in interest, as well as the pleasure of business. . . . They need assistance and organization, and all the encouragement possible from such institutions as ours.

The second, from a central Georgia county, not nearly so favored by nature as many others, shows the results of energy, integrity and business methods:

> The farmers are borrowing more money from banks than in former years, probably to the extent of 40 or 50 per cent. . . . to avoid paying the large credit prices amounting to more than the bank interest. We make these loans principally upon rent notes, (or) stock and crop mortgages with warehouse and personal endorsement. Our farmers we think in better condition than at any time in twenty years.

The third is from a rich county in southwest Georgia whose farmers have learned business methods approximately as well as its merchants, and are approaching the situation in which they will borrow only to retrieve disaster or to enlarge their operations:

> The farmers in the territory supplied by this bank appear to be in better condition each year for the last two or three, and mortgages and liens are getting to be the exception, whereas they were formerly the rule. Almost all the loans to farmers are made on personal security only, and the volume of these loans is decreasing. We can not speak for other sections, but our observation of south Georgia is that the escape from the lien system is general.

Such is the condition of the southern farmer, with whose well-being is wrapped up so much of our best interests. He needs better trained and more moral labor, access to credit at reasonable rates when he requires it, and a system of education suited to his life work.

VOICE, SONG AND SPEECH.

BY WM. SCHEPPEGRELL, A.M., M.D.,

NEW ORLEANS, LA.

THERE is no physical faculty which so distinguishes man from the lower animals, and marks him more conspicuously in the image of his Maker than the power of articulate speech. That there is some means of communication among the lower animals, we can not doubt, but that faculty of articulate speech which enables us to communicate to our fellowmen not only our ordinary desires and wishes, but even the most delicate shades of our inmost thought, that faculty belongs distinctively to the human race.

This subject may be treated from various standpoints, but we will here limit ourselves to a strictly physical consideration, explaining first the general anatomy of the parts essential in the production of the voice, and afterwards the manner in which these are used in the formation of song and speech.

Before discussing the subject of the voice, we must have some conception of sound in order to understand more fully how the voice is produced and how it is modified by the various parts concerned in the faculty of speech. All sounds are due to the vibration of the surrounding air, which conveys to the ear the vibrations produced by the sound-producing object. Perhaps one of the simplest methods of producing sound is by means of the tuning fork. When this is struck the prongs are made to vibrate, and these in turn set up in the air vibrations which are carried to the drum of the ear, and thence transmitted to the brain as sound.

In sound we have three important qualities, pitch, loudness and timbre. The pitch depends upon the *number of vibrations* which the sounding body makes in a given time. When these vibrations are repeated less than eighteen times per second they produce no musical tone to the ear. When a boy strikes a stick against a paling fence we have simply a rattle. If, however, this could be done so rapidly as to make more than eighteen beats to the second, then the ear would cease to recognize each individual stroke and would perceive a musical tone. The more rapid the vibrations the higher the tone, until the limit of human hearing is reached, which is about 48,000 vibrations to the second.

The second quality of sound, which we may call 'loudness,' is due to the *range of the vibrations* made by the sound-producing body. If the tuning fork is struck lightly, it gives a certain tone, but very softly. If it be struck hard, however, it produces a louder sound, due to the fact that the vibrations are greater in length, which, being communicated to the ear, set up stronger vibrations in the drum, and we hear a louder sound. This, however, does not vary the *pitch* of the sound which remains identical as long as the number of vibrations per second remain the same.

The third quality of sound is due to the *form of the vibrations* regardless of the pitch or the loudness. The trained ear recognizes, for instance, in the note of the tuning fork, the violin, the clarionet and the piano, the same tone howsoever made. There may be the same degree of loudness, but there is a distinction—this distinction being due to the peculiar form of the wave set up in the air and thus communicated to our ear. This is known as the *timbre* of the sound.

The manner in which the ear distinguishes the loudness and the pitch is easily understood, as the vibrations of the drum of the ear correspond in degree and number to the vibrations of the air and of the sound-producing body. How it distinguishes the timbre of the sound is much more complex. This subject has been carefully investigated, and it is now accepted that with the original or fundamental tone there are always a certain number of over-tones which give this special quality to the sound.

Having now explained some of the fundamental principles of sound, we will discuss the question of how the human vocal apparatus produces that form of sound known as the voice. Undoubtedly the human voice is based upon the same principles as other musical sounds, being, however, more complete, more varied in its capacity and more adjustable to surrounding conditions, than any instrument made by human hands.

The relationship of speech to song is not well understood, many persons believing that in song some special parts of the vocal organs are utilized which are not employed in ordinary speech. As a matter of fact, however, speech is simply a modified form of singing, the principal difference being in the fact that in singing the vowel sounds are prolonged, and the intervals are short, whereas in speech, the words are uttered in what may be called 'staccato' tones, the vowels not being specially prolonged and the intervals between the words being more distinct. The fact that in singing we have a larger range of tones does not properly distinguish it from ordinary speech. In speech we have likewise a variation of tones, and even in ordinary conversation, there is a difference of from three to six semitones, as I have found in my investigations, and in some persons this range is as high as one octave. In this consideration of the voice, therefore, song and speech may be considered under one head.

In the voice, as in other forms of sound, we must have, first, a vibrating body to initiate the sound. This we have in the vocal cords of the human body. The vibrations set up in the vocal cords (Fig. 1) are not due to a violent impact, as in the case of the tuning fork, as this would injure the delicate tissues of the sound-producing organs, but are caused by the air passing between the vocal cords very much as the current of air sets up vibration in a reed instrument such as the clarionet. In the human voice this current of air is furnished by the lungs, which have therefore the double duty of supplying the oxygen to the blood and setting up vibrations in the vocal cords for the voice.

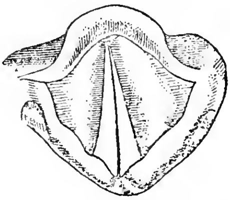


Fig. 1. Vocal Cords in Position for Speaking or Singing.

The chest is supplied with the most perfect mechanism for obtaining this current of air. The main support is furnished by the ribs, which give firmness to the chest. These are held together and supported by muscles of great strength which raise the ribs in the act of inspiration. The lower part of the chest is enclosed by a broad flat muscle known as the 'diaphragm,' which materially assists in giving its bellows-like faculty to the chest. In the act of inspiration, the diaphragm is lowered and the ribs are raised, thus creating a space in the lungs which is filled by the air entering through the nose and throat. In expiration, however, this is reversed, the ribs being lowered and the diaphragm raised, the process being assisted by the natural elasticity of the lung tissue. The thorough understanding of this function of the lungs should impress us with the importance of not hampering their action by tight clothing or lacing, which necessarily interferes with their freedom of action, and, by thus lowering the resistance of the body, make it more liable to the entrance of disease.

The two vocal cords, whose vibration forms the essential factor in the voice, are situated within the larynx, the most prominent point of which is known as the 'Adam's apple.' The larynx has several plates of cartilage which, while protecting the delicate organs within, make it less liable to fracture or injury than if they were made of bone. By removing one of the plates of the larynx, we see the edge of one of the vocal cords, which consists of a narrow band of rather hard tissue, whitish in color in health, and surmounted on a band of muscles which not only gives it support but also enables it to adjust the tension necessary for tone-formation. The vocal cords, during

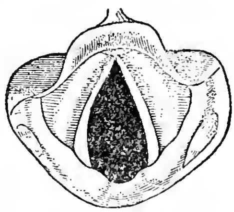


Fig. 2. Vocal Cords During Inspiration.

the act of inspiration (Fig. 2), are wide open so as to allow the free ingress of air, and even during ordinary expiration (Fig. 3) they remain sufficiently wide open not to hamper the freedom of respiration. When the voice is used, however, the lungs having obtained the necessary supply of air, the edges of the vocal cords are brought together (Fig. 1), and, as the air is forced through them by the contraction of the lungs, they are set up in vibration, thus producing the voice.

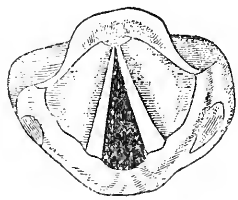
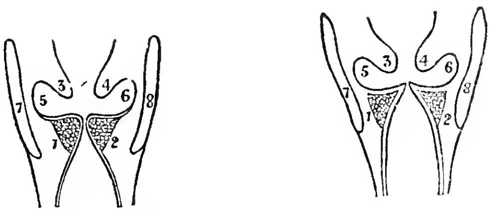


Fig. 3. Vocal Cords During Expiration.

Two vertical sections of the larynx are shown in Figs. 4 and 5 (after Merkel), the former showing the vocal cords (1, 2) in the lower register, and the latter the vocal cords (1, 2) in the high register. In both Figs., 5 and 6 represent the pockets or ventricles of the larynx, and 3 and 4, the ventricular bands, sometimes called the false vocal cords. Figs. 7 and 8 show a section of a cartilage of the larynx.

The voice, like other sounds, varies in pitch, loudness and timbre. The pitch is due to the tension of the vocal cords, the process, however, being somewhat more complicated than in a violin in which there are several strings. There being but one pair of vocal cords in the larynx, the tones are produced, first, by tightening the vocal cords, and, when the limit has been reached, so that a greater degree of tension would be injurious to the vocal cords and the muscles which control them, there is set up a different form of vibration known as the change of register. This subject of the register is somewhat compli-



Figs. 4 and 5. Vertical Sections of Larynx.

cated, but it will be better understood if we suppose that the difference between a low and a high register is due to the fact that in the latter a shorter portion of the vocal cords is set into vibration.

The bass, for instance, produces his lower tones by increasing the tension of the vocal cords until *B flat* (International Pitch) is reached when he changes his register, obtaining his remaining upper tones by contracting the vocal cords in this register. The untrained singer, however, not understanding this change of register, may attempt to reach the upper tones by simply increasing the tension in the lower register, this soon resulting in hoarseness, inflammation and perhaps permanent injury of the voice.

The ordinary method of speaking of these registers as the 'chest,' 'throat' and 'head' registers is apt to be misleading, as in every case the tones are formed in the larynx and by the vocal cords, the 'head' and other names being derived from the fact that the sound seems to be more directed to these parts of the body.

The loudness of the tone is due to the force with which the air is expelled from the lungs, thus causing a greater range of vibration in the vocal cords. The question of timbre is much more complex. It is this feature which distinguishes the singing of the amateur in music from the professional, the uncultivated from the cultivated voice, and the resonant tones of the orator from the poor voice of the ordinary speaker. As already explained, the quality of tone is entirely influenced by the number of over-tones, these being due to other parts of the throat accessory to the vocal cords in voice production.

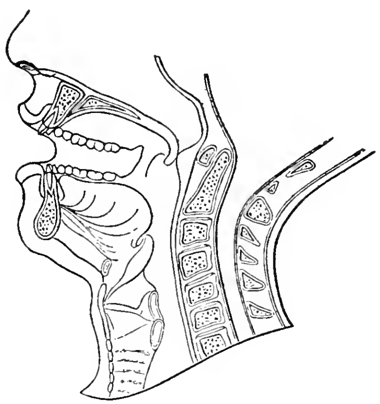


Fig. 6. Diagram of Vocal Apparatus During Pronunciation of Vowel 'ah' (Seiler).

Before explaining this point, we must first consider what other organs are essential in the production of the voice. The fundamental tones are made in the larynx as already explained, but these alone do not produce articulate speech; in fact, such tones are not limited to the human race. It is the peculiar faculty of articulating that distinguishes the voice of man from that of other animals. Articulation is due to other parts concerned in the organ of speech, such as the tongue, the teeth, the lips, the palate and the nostrils. Each of these has its influence in the formation of the voice, and a defect in any of these will be easily recognized by the experienced hearer.

The fundamental element of the voice is formed by the vowel sounds, the consonants, as the name indicates, simply modifying the vowel sounds. Although nominally the pure vowels are *a, e, i, o* and *u,* the vowel sounds are of far greater number. For instance, the *a* occurs in 'maw,' 'hat' and 'mate,' but in each it is sounded differently and the same occurs with the other vowels.

The simplest vowel is *a* (as in 'ah') which is sounded by vibrating the vocal cords, the sound issuing almost without obstruction, the tongue being lowered and the lips apart. If now, without any further change than to round the lips, the same effort be made, the *a* will be changed to *o,* and if the lips are still further contracted the *o* will be changed to *u.* The remaining vowels *a* (as in 'hate'), *e* and *i* are made from the fundamental *a* above described, by contracting and shortening the passage between the tongue and the roof of the mouth and palate. If we would suppose that the passage from the vocal cords to the lips were a tube, then we could say that in *u* the passage was the longest and in *i* the shortest, and the *o, a* and *e* sounds intermediate between these in the order stated. In these and in the examples which follow, it would be well for the reader to test the methods described, which would do much to make this subject more easily understood.

The consonants, as their name implies, can not be sounded alone but simply modify the vowel sounds. This may be done by the lips (*labial*), the teeth (*dental*), the tongue (*lingual*), the palate (*palatal*) or by allowing the air to pass through the nostrils (*nasal*). The simplest are the labial sounds (*m, b, p, f, v, w*), and these are therefore, the first learned in infancy, as 'mama,' 'papa,' etc. In sounding the vowel *a,* we first contract the lips and then allow the air to escape by opening them, the slight explosive sound forms 'ba,' and if this effort is made stronger, it becomes 'pa.' In the dental sounds (*t, d, s,* etc.), the emission of the vowel is made by the teeth and tip of the tongue, and in the palatal (*k, g, c,* etc.), by means of the middle or posterior portion of the tongue and the middle or posterior portion of the palate. In this position are formed the so-called 'guttural' sounds of the German (*ich, doch,* etc.) which forms one of the characteristics of this language.

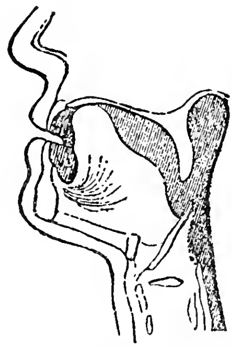


FIG. 7. DIAGRAM OF VOCAL APPARATUS DURING PRONUNCIATION OF THE NASAL SOUND 'N' (GUTTMAN).

In the above described consonant sounds, the emission of air through the nostrils has been prevented by the soft palate being brought against the back of the throat. In the nasal sounds (*n, ng*), however, the air is allowed to pass through the nostrils by relaxing the soft palate. If the nostril be closed when 'ing,' for instance, is to be pronounced, the sound will not issue unless the air be allowed to pass through the nostrils. In some cases, the nasal sound is given to words to which it does not belong, this giving a peculiar nasality of tone easily recognized. In the French, there are normally the 'nasal vowels' (*in, en, on*) characteristic of this language.

In addition to the above, we have the *aspirate,* represented by the letter *h.* In this, a partial expiration is first allowed to pass between the vocal cords before they are approximated to form the vowel, in this way changing the *a* to *'ha'* and *o* to *'ho.'* This sound is pronounced very distinctly in the German language, less so in the English, being occasionally omitted as in the words 'heir,' 'humor,' etc., and infrequent in the French and quite softly when pronounced.

The aspirate, which is sounded without approximating the vocal cords, brings us to the *whisper* in which we have all the elements of speech without the initial vibrations of the vocal cords. That these are not concerned in the whisper is demonstrated by the fact that persons, suffering from such forms of paralysis that the cords can not be brought together, can whisper, and that even where the vocal cords have been entirely destroyed by tuberculous or other disease, the patient can still whisper without difficulty.

As already stated, the modifications of the vowel sounds for articulate speech are made in the cavities of the mouth, the upper part of the throat and by the nostrils, and are further modified by the position of the teeth, lips and palate. In perfect singing or speaking, we must have all these parts in a normal condition, and where there is no obstruction, defect, congestion or inflammation, there is no interference with the free motion or vibration of the parts concerned in voice production.

The question may be asked how this information about the action of the vocal cords has been learned, since, during life, they are out of sight. The use of a mirror by the throat specialist is now so common that it no longer attracts any comment, although this method of examining the larynx of a living subject is yet comparatively recent. The method, however, by means of which these parts are inspected is not so well understood, and it would, therefore, be not without interest to explain it.

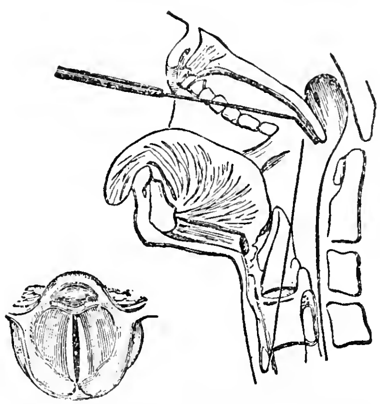


FIG. 8. METHOD OF EXAMINING LARYNX, THE VIEW OF WHICH IS SHOWN IN THE SMALL CUT AT THE LEFT (INGALS).

The interior of the larynx, being separated from without by its skin and cartilages, is, of course, dark, and must therefore first be illuminated in order to be seen. A small mirror is therefore placed in the back part of the throat, which projects the rays of light downwards into the parts to be inspected. In order to enable the operator to use the same mirror for inspecting as for illuminating the larynx, he fastens to his forehead a concave mirror which reflects the condensed light to the throat mirror, and by means of an opening in the center of the head mirror, he is enabled to see the parts of the throat that are illuminated by the throat mirror. This arrangement, which is comparatively simple, has been the foundation of the science of laryngology, as, before its invention, the investigations of the larynx were limited to the examination of the dead body, and many of the most important diseases escaped observation.

The study of the action of the vocal cords during speaking or singing is somewhat more complicated. We have already stated that in order to produce a tone, the rate of vibration must be at least 18 to the second, and the lowest tone of the human voice (low *D* of the bass) rarely falls below 73 vibrations per second. Ordinarily, then, it would be impossible to see the motion of the vocal cords during vibration, and yet this is an important matter. Human ingenuity has come to the relief of this problem in the invention of an instrument called the 'stroboscope' which is here shown.

In explaining its mechanism let us imagine a carriage wheel with a number on each spoke, the wheel being in rapid revolution around its axis. Ordinarily these numbers would be entirely obscured on account of the rapidity of the motion, and would present to the eye simply a blur. If, however, we place in front of this wheel a large piece of pasteboard with an opening opposite to one of these numbers, and some mechanism in front of this hole so that it would open only when the same number is in front of it, then we could inspect them one by one by a simple adjustment. Furthermore, it could be so arranged that instead of opening always at the same number, it would miss one revolution and open at the second number, and in this way we could see each number until the whole series had passed.

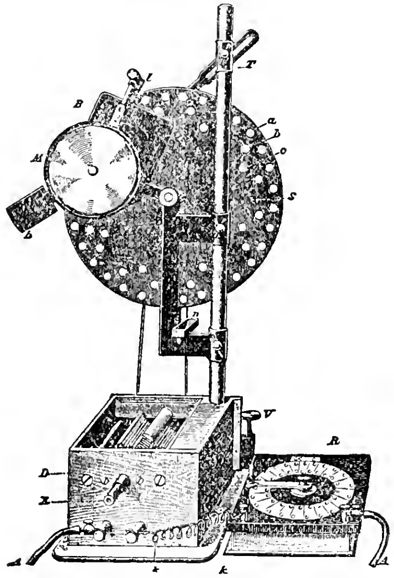


FIG. 9. STROBOSCOPE FOR EXAMINING VOCAL CORDS DURING VIBRATION.

This is the principle involved in the stroboscope. The patient is instructed to give a certain tone, and by means of a syren, which indicates the number of vibrations for any given tone, the number of vibrations per second are registered. This instrument is then so adjusted that the aperture, by means of which the vocal cords are examined, opens after every series of vibrations are complete so that the vocal cords are always in the same position. This inspection of the larynx is conducted in the same manner as with the mirror method already described.

In this way the vocal cords may be seen in any stage of their vibrations, and the instrument may also be so adjusted that one series of vibrations is omitted, and the second step of the vibration is taken up, so that we apparently have a slow motion of the vocal cords, which enables us to study their action during voice production. This has given us much useful information, especially regarding the subject of the various registers of the human voice.

Having now explained the production of the voice under normal conditions, I must now show how this is affected by abnormal conditions, and also point out some suggestions as to the care of this important organ. You will remember that the vibrations of the vocal cords produce the fundamental elements of the voice. Any condition which prevents their free vibration will therefore interfere with the normal voice. The most frequent disturbances are due to 'colds' in which the vocal cords may become congested or inflamed. This produces a thickening of the vocal cords which lowers their rate of vibration, and, consequently, lowers the tone and gives rise to the hoarse voice characteristic of an ordinary cold. When this condition, from any cause, becomes chronic so that instead of a simple swelling of the vocal cords we have a chronic thickening, it may leave, unless corrected, a permanent defect in the voice.

A more serious influence on the voice is due to growths or tumors either on the vocal cords or in some other part of the throat, and interfering with the formation of vocal sounds. In the adjoining illustration, the small tumor shown between the vocal cords had caused hoarseness by interfering with the vibrations of the vocal cords, and by irritating the throat had set up a persistent cough. About eighteen months before being seen, the patient had leaped into the Mississippi River to save a child from drowning. The exposure was followed by a severe cold, leaving a persistent hoarseness, afterwards accompanied by a cough. About a year and a half afterwards, the patient was sent to me and a careful examination revealed this small tumor on the vocal cord, which affected his speech, so that it was of an extremely husky character. The following day this tumor was removed by means of an instrument passed from the mouth into the throat, the course of the operation being followed by means of a mirror as already explained, and being rendered painless by the application of cocaine, and the tumor removed. The voice being freed from the dampening

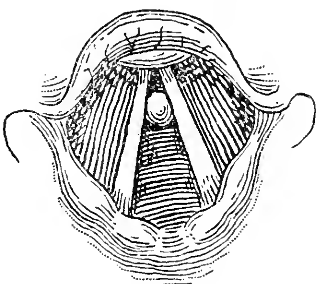


Fig. 10. Small Tumor of Vocal Cord interfering with Voice Production.

influence of the growth, was restored immediately, and the cough disappeared a few days later.

A still more serious injury to the vocal cords is due to ulceration which has destroyed some part of the vocal cord. A defect of this kind is irreparable. When an arm is diseased, no matter how seriously, there is always a possibility of saving it, but when the arm is cut off, its usefulness is ended. This is also the case with the vocal cords. By means of training, the voice may to some extent be improved, but it will always be more or less affected when there has been a loss of substance.

Paralytic conditions also have a marked effect on the voice. As already explained, in the production of sound the edges of the vocal cords are brought together. In cases of paralysis, if one or both vocal cords can not be brought to the middle line, the space is too large to resist the column of air from the lungs for setting the vocal cords in vibration, and there is no voice. In some cases, where the paralysis is on one side and not too great, the remaining vocal cord may be gradually trained to be brought over to the other side, and in this case the voice may be recovered, otherwise it will be simply a whisper. Some cases of paralysis involve only the muscles which contract the vocal cords, thus preventing tension and causing hoarseness. As there is no loss of substance in paralysis, the prospects for recovery of the voice, except in certain cases, is good.

As we have already explained, the principal parts concerned in the modification of speech are the lips, teeth, tongue, palate and nostrils, and any defect in these will influence voice production. Some defects are easily recognized, as for instance the tie-tongue, in which the band, which connects the tip of the tongue with the floor of the mouth, is too short and prevents the tongue from being brought forward in certain sounds, thus giving rise to the defect characteristic of this condition. This defect is easily rectified by a slight operation, and, unless the muscles of the tongue are otherwise defective, restoration of normal speech eventually ensues.

It must be remembered, however, that in children who have for years been accustomed to this defective method of speech, the muscles have adapted themselves to the changed condition, and a complete correction of the defective speech is a question of time. I remember an occasion, for instance, when a mother returned to me after this simple operation had been done, and complained that it had been a total failure, giving as her reason that the child's speech was just as defective as before the operation. I explained to her what I have just said, and instructed her to teach the child to use its tongue in its normal position, and this exercise was followed in a few months by an entire correction of the defect.

Missing or broken teeth, especially in the case of the front teeth which are more concerned in voice production, give rise to defects which are corrected when the teeth are replaced or repaired.

A catarrhal condition in the upper part of the throat, filling it with secretion, interferes with the free vibration of sound and gives an effect very similar to that due to an obstruction in the rear portion of the nostrils, as is sometimes the case in the later stage of a severe cold.

There seems to be much misconception regarding the tonsils as a factor in voice production. It is of common occurrence for mothers to ask the physician before an operation upon the tonsil if it will not injure the voice. As a matter of fact, the healthy tonsil has no effect upon the voice, while the diseased tonsil can have only an injurious effect either directly by its size, interfering with the free vibration of the voice, or indirectly by setting up an irritation of the throat and causing the voice to be weak. The correction, or even removal, of a diseased tonsil can, therefore, have only a good influence on the voice.

There is another unhealthy condition of the throat of children which is now receiving more attention, due to the so-called 'adenoids.' In this there is an enlargement of the tissues in that part of the throat just back of the nostrils. This growth may interfere with speech either on account of the secretion which it produces or by its size, in either case obstructing the entrance of the nasal sounds into the nostril. The presence of this abnormal growth is injurious not only on account of its effect on the voice but also on the general health, as it prevents the child from breathing in the manner intended by nature, that is through the nostrils.

The nostrils are not simply openings for allowing the air to reach the lungs, but their special function is to warm, clean and moisten the air which is intended for respiration. Proof of this is shown by the fact that if we suffer from a 'cold' so that the nostrils are obstructed, an irritated throat is a certain result the next morning, being due to the fact that the unprepared air has irritated the delicate tissues of the throat. In diphtheria, for instance, if the membrane has developed in the throat and threatens the breathing of the child, and this be overcome by a tube inserted in the throat below the false membrane, respiration must now go on without the air passing through the nasal passages. The only way to counteract the evil effects of this abnormal breathing is to place the child in a room which is warmed to almost the normal temperature of the body, artificially saturated with moisture, and every endeavor made to keep it free from impurities. Even with this, the patient may develop a bronchial affection due to the absence of nasal breathing, but without it, a bronchitis, even of a fatal character, would develop in a short time. I go to some length in explaining this matter, as the importance of the nose in respiration is not well understood. Its influence on the speech is better recognized, as most persons easily note the peculiar effect on the speech when there is an obstruction in the nasal passages.

Having now given you a description of the organs of speech in health and in disease, a few words as to its care will conclude this article. In this as in other parts of the human body, prevention is better than cure. Careful attention to any abnormal condition of the nose or throat is an effective means of preventing any disease of these parts. The same rule, which applies to other parts of the body, such as the necessity of outdoor exercise, fresh air, etc., is in general applicable here, and perhaps a little more here because the nose and throat form the vanguard of the respiration so essential to life. Any agent which irritates the delicate membrane of the throat is injurious to the voice—among these may be mentioned the use of strong liquor and the abuse of smoking, especially cigarettes. The action of the cigarette tends to produce a chronic irritation and thickening of the throat, sometimes accompanied by excessive dryness and irritability, these causing efforts to clear the throat which adds to the injurious effect. The remedy is evident.

The correct placing of the voice is of the utmost importance. No attempt should be made to do this until the voice is properly developed, and this should not be done by singing or even solfeggio practice, but by vocal exercises on the vowel sounds, especially of *a* (as in 'maw'). I have seen many voices greatly injured and even permanently ruined by being placed in the wrong class, even such egregious errors as a bass, classified as a tenor, being among the cases which I have had to treat.

The strengthening of the throat by means of vocal exercise is as important as the strengthening of the body by suitable physical exercise. Teachers and lawyers, therefore, as well as singers should practise certain vocal exercises such as loud reading, light vocal scales, etc., so that, when called upon to make a special use of the voice, it is prepared by regular practise for this unusual exertion.

WHAT KNOWLEDGE IS OF MOST WORTH?*

BY THE LATE HERBERT SPENCER.

IT has been truly remarked that, in order of time, decoration precedes dress. Among people who submit to great physical suffering that they may have themselves handsomely tattooed, extremes of temperature are borne with but little attempt at mitigation. Humboldt tells us that an Orinoco Indian, though quite regardless of bodily comfort, will yet labor for a fortnight to purchase pigment wherewith to make himself admired; and that the same woman who would not hesitate to leave her hut without a fragment of clothing on, would not dare to commit such a breach of decorum as to go out unpainted. Voyagers uniformly find that colored beads and trinkets are much more prized by wild tribes than are calicoes or broadcloths. And the anecdotes we have of the ways in which, when shirts and coats are given, they turn them to some ludicrous display, show how completely the idea of ornament predominates over that of use. Nay, there are still more extreme illustrations: witness the fact narrated by Captain Speke of his African attendants, who strutted about in their goat-skin mantles when the weather was fine, but when it was wet, took them off, folded them up, and went about naked, shivering in the rain! Indeed, the facts of aboriginal life seem to indicate that dress is developed out of decorations. And when we remember that even among ourselves most think more about the fineness of the fabric than its warmth, and more about the cut than the convenience—when we see that the function is still in great measure subordinated to the appearance—we have further reason for inferring such an origin.

It is not a little curious that the like relations hold with the mind. Among mental as among bodily acquisitions, the ornamental comes before the useful. Not only in times past, but almost as much in our own era, that knowledge which conduces to personal well-being has been postponed to that which brings applause. In the Greek schools, music, poetry, rhetoric, and a philosophy which, until Socrates taught, had but little bearing upon action, were the dominant subjects; while knowledge aiding the arts of life had a very subordinate place. And in our own universities and schools at the present moment the like

* The opening and concluding parts of an article originally printed in the *Westminster Review* and republished by Messrs. D. Appleton and Co. in 1860, with other papers, in a volume entitled 'Education.'

antithesis holds. We are guilty of something like a platitude when we say that throughout his after-career a boy, in nine cases out of ten, applies his Latin and Greek to no practical purposes. The remark is trite that in his shop, or his office, in managing his estate or his family, in playing his part as director of a bank or a railway, he is very little aided by this knowledge he took so many years to acquire—so little, that generally the greater part of it drops out of his memory; and if he occasionally vents a Latin quotation, or alludes to some Greek myth, it is less to throw light on the topic in hand than for the sake of effect. If we inquire what is the real motive for giving boys a classical education, we find it to be simply conformity to public opinion. Men dress their children's minds as they do their bodies, in the prevailing fashion. As the Orinoco Indian puts on his paint before leaving his hut, not with a view to any direct benefit, but because he would be ashamed to be seen without it; so, a boy's drilling in Latin and Greek is insisted on, not because of their intrinsic value, but that he may not be disgraced by being found ignorant of them—that he may have 'the education of a gentleman'—the badge marking a certain social position, and bringing a consequent respect.

This parallel is still more clearly displayed in the case of the other sex. In the treatment of both mind and body, the decorative element has continued to predominate in a greater degree among women than among men. Originally, personal adornment occupied the attention of both sexes equally. In these latter days of civilization, however, we see that in the dress of men the regard for appearance has in a considerable degree yielded to the regard for comfort; while in their education the useful has of late been trenching on the ornamental. In neither direction has this change gone so far with women. The wearing of ear-rings, finger-rings, bracelets; the elaborate dressings of the hair; the still occasional use of paint; the immense labor bestowed in making habiliments sufficiently attractive; and the great discomfort that will be submitted to for the sake of conformity; show how greatly, in the attiring of women, the desire of approbation overrides the desire for warmth and convenience. And similarly in their education, the immense preponderance of 'accomplishments' proves how here, too, use is subordinated to display. Dancing, deportment, the piano, singing, drawing—what a large space do these occupy! If you ask why Italian and German are learnt, you will find that, under all the sham reasons given, the real reason is, that a knowledge of those tongues is thought ladylike. It is not that the books written in them may be utilized, which they scarcely ever are; but that Italian and German songs may be sung, and that the extent of attainment may bring whispered admiration. The births, deaths, and marriages of kings, and other like historic trivialities, are committed to memory, not because of any direct benefits that can possibly result from knowing them; but because society considers them parts of a good education—because the absence of such knowledge may bring the contempt of others. When we have named reading, writing, spelling, grammar, arithmetic, and sewing, we have named about all the things a girl is taught with a view to their direct uses in life; and even some of these have more reference to the good opinion of others than to personal welfare.

Thoroughly to realize the truth that with the mind as with the body the ornamental precedes the useful, it is needful to glance at its rationale. This lies in the fact that, from the far past down even to the present, social needs have subordinated individual needs, and that the chief social need has been the control of individuals. It is not, as we commonly suppose, that there are no governments but those of monarchs, and parliaments, and constituted authorities. These acknowledged governments are supplemented by other unacknowledged ones, that grow up in all circles, in which every man or woman strives to be king or queen or lesser dignitary. To get above some and be reverenced by them, and to propitiate those who are above us, is the universal struggle in which the chief energies of life are expended. By the accumulation of wealth, by style of living, by beauty of dress, by display of knowledge or intellect, each tries to subjugate others; and so aids in weaving that ramified network of restraints by which society is kept in order. It is not the savage chief only, who, in formidable war-paint, with scalps at his belt aims to strike awe into his inferiors; it is not only the belle who, by elaborate toilet, polished manners, and numerous accomplishments, strives to 'make conquests'; but the scholar, the historian, the philosopher, use their acquirements to the same end. We are none of us content with quietly unfolding our own individualities to the full in all directions; but have a restless craving to impress our individualities upon others, and in some way subordinate them. And this it is which determines the character of our education. Not what knowledge is of most real worth, is the consideration; but what will bring most applause, honor, respect—what will most conduce to social position and influence—what will be most imposing. As, throughout life, not what we are, but what we shall be thought, is the question; so in education, the question is, not the intrinsic value of knowledge, so much as its extrinsic effects on others. And this being our dominant idea, direct utility is scarcely more regarded than by the barbarian when filing his teeth and staining his nails.

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Thus far our question has been, the worth of knowledge of this or that kind for purposes of guidance. We have now to judge the relative values of different kinds of knowledge for purposes of discipline. This division of our subject we are obliged to treat with comparative brevity; and happily, no very lengthened treatment of it is needed. Having found what is best for the one end, we have by implication found what is best for the other. We may be quite sure that the acquirement of those classes of facts which are most useful for regulating conduct, involves a mental exercise best fitted for strengthening the faculties. It would be utterly contrary to the beautiful economy of Nature, if one kind of culture were needed for the gaining of information and another kind were needed as a mental gymnastic. Everywhere throughout creation we find faculties developed through the performance of those functions which it is their office to perform; not through the performance of artificial exercises devised to fit them for these functions. The Red Indian acquires the swiftness and agility which make him a successful hunter, by the actual pursuit of animals; and by the miscellaneous activities of his life, he gains a better balance of physical powers than gymnastics ever give. That skill in tracking enemies and prey which he has reached by long practice, implies a subtlety of perception far exceeding anything produced by artificial training. And similarly throughout. From the Bushman, whose eye, which being habitually employed in identifying distant objects that are to be pursued or fled from, has acquired a quite telescopic range, to the accountant whose daily practice enables him to add up several columns of figures simultaneously, we find that the highest power of a faculty results from the discharge of those duties which the conditions of life require it to discharge. And we may be certain, *à priori,* that the same law holds throughout education. The education of most value for guidance, must at the same time be the education of most value for discipline. Let us consider the evidence.

One advantage claimed for that devotion to language-learning which forms so prominent a feature in the ordinary *curriculum,* is, that the memory is thereby strengthened. And it is apparently assumed that this is an advantage peculiar to the study of words. But the truth is, that the sciences afford far wider fields for the exercise of memory. It is no slight task to remember all the facts ascertained respecting our solar system; much more to remember all that is known concerning the structure of our galaxy. The new compounds which chemistry daily accumulates, are so numerous that few, save professors, know the names of them all; and to recollect the atomic constitutions and affinities of all these compounds, is scarcely possible without making chemistry the occupation of life. In the enormous mass of phenomena presented by the Earth's crust, and in the still more enormous mass of phenomena presented by the fossils it contains, there is matter which it takes the geological student years of application to master. In each leading division of physics—sound, heat, light, electricity—the facts are numerous enough to alarm any one proposing to learn them all. And when we pass to the organic sciences, the effort of memory required becomes still greater. In human anatomy alone, the quantity of detail is so great, that the young surgeon has commonly to get it up half a dozen times before he can permanently retain it. The number of species of plants which botanists distinguish, amounts to some 320,000; while the varied forms of animal life with which the zoologist deals, are estimated at some two millions. So vast is the accumulation of facts which men of science have before them, that only by dividing and subdividing their labors can they deal with it. To a complete knowledge of his own division, each adds but a general knowledge of the rest. Surely, then, science, cultivated even to a very moderate extent, affords adequate exercise for memory. To say the very least it involves quite as good a training for this faculty as language does.

But now mark that while for the training of mere memory, science is as good as, if not better than, language; it has an immense superiority in the kind of memory it cultivates. In the acquirement of a language, the connexions of ideas to be established in the mind correspond to facts that are in great measure accidental; whereas, in the acquirement of science, the connexions of ideas to be established in the mind correspond to facts that are mostly necessary. It is true that the relations of words to their meaning is in one sense natural, and that the genesis of these relations may be traced back a certain distance; though very rarely to the beginning; (to which let us add the remark that the laws of this genesis form a branch of mental science—the science of philology). But since it will not be contended that in the acquisition of languages, as ordinarily carried on, these natural relations between words and their meanings are habitually traced, and the laws regulating them explained; it must be admitted that they are commonly learned as fortuitous relations. On the other hand, the relations which science presents are casual relations; and, when properly taught, are understood as such. Instead of being practically accidental, they are necessary; and as such, give exercise to the reasoning faculties. While language familiarizes with non-rational relations, science familiarizes with rational relations. While the one exercises memory only, the other exercises both memory and understanding.

Observe next that a great superiority of science over language as a means of discipline, is, that it cultivates the judgment. As, in a lecture on mental education delivered at the Royal Institution, Professor Faraday well remarks, the most common intellectual fault is deficiency of judgment. He contends that 'society, speaking generally, is not only ignorant as respects education of the judgment, but it is also ignorant of its ignorance.' And the cause to which he ascribes this state is want of scientific culture. The truth of his conclusion is obvious.

Correct judgment with regard to all surrounding things, events, and consequences, becomes possible only through knowledge of the way in which surrounding phenomena depend on each other. No extent of acquaintance with the meanings of words, can give the power of forming correct inferences respecting causes and effects. The constant habit of drawing conclusions from data, and then of verifying those conclusions by observation and experiment, can alone give the power of judging correctly. And that it necessitates this habit is one of the immense advantages of science.

Not only, however, for intellectual discipline is science the best; but also for *moral* discipline. The learning of languages tends, if anything, further to increase the already undue respect for authority. Such and such are the meanings of these words, says the teacher or the dictionary. So and so is the rule in this case, says the grammar. By the pupil these dicta are received as unquestionable. His constant attitude of mind is that of submission to dogmatic teaching. And a necessary result is a tendency to accept without inquiry whatever is established. Quite opposite is the attitude of mind generated by the cultivation of science. By science, constant appeal is made to individual reason. Its truths are not accepted upon authority alone; but all are at liberty to test them—nay, in many cases, the pupil is required to think out his own conclusions. Every step in a scientific investigation is submitted to his judgment. He is not asked to admit it without seeing it to be true. And the trust in his own powers thus produced, is further increased by the constancy with which Nature justifies his conclusions when they are correctly drawn. From all which there flows that independence which is a most valuable element in character. Nor is this the only moral benefit bequeathed by scientific culture. When carried on, as it should always be, as much as possible under the form of independent research, it exercises perseverance and sincerity. As says Professor Tyndall of inductive inquiry, "it requires patient industry, and an humble and conscientious acceptance of what Nature reveals. The first condition of success is an honest receptivity and a willingness to abandon all preconceived notions, however cherished, if they be found to contradict the truth. Believe me, a self-renunciation which has something noble in it, and of which the world never hears, is often enacted in the private experience of the true votary of science."

Lastly we have to assert—and the assertion will, we doubt not, cause extreme surprise—that the discipline of science is superior to that of our ordinary education, because of the *religious* culture that it gives. Of course we do not here use the words scientific and religious in their ordinary limited acceptations; but in their widest and highest acceptations. Doubtless, to the superstitions that pass under the name of religion, science is antagonistic; but not to the essential religion which these superstitions merely hide. Doubtless, too, in much of the science that is current, there is a pervading spirit of irreligion; but not in that true science which has passed beyond the superficial into the profound.

True science and true religion, says Professor Huxley at the close of a recent course of lectures, are twin-sisters, and the separation of either from the other is sure to prove the death of both. Science prospers exactly in proportion as it is religious; and religion flourishes in exact proportion to the scientific depth and firmness of its basis. The great deeds of philosophers have been less the fruit of their intellect than of the direction of that intellect by an eminently religious tone of mind. Truth has yielded herself rather to their patience, their love, their single-heartedness, and their self-denial, than to their logical acumen.

* * *

We conclude, then, that for discipline, as well as for guidance, science is of chiefest value. In all its effects, learning the meanings of things, is better than learning the meanings of words. Whether for intellectual, moral, or religious training, the study of surrounding phenomena is immensely superior to the study of grammars and lexicons.

Thus to the question with which we set out—What knowledge is of most worth?—the uniform reply is—Science. This is the verdict on all the counts. For direct self-preservation, or the maintenance of life and health, the all-important knowledge is—Science. For that indirect self-preservation which we call gaining a livelihood, the knowledge of greatest value is—Science. For the due discharge of parental functions, the proper guidance is to be found only in—Science. For that interpretation of national life, past and present, without which the citizen can not rightly regulate his conduct, the indispensable key is—Science. Alike for the most perfect production and highest enjoyment of art in all its forms, the needful preparation is still—Science. And for purposes of discipline—intellectual, moral, religious—the most efficient study is, once more—Science. The question which at first seemed so perplexed, has become, in the course of our inquiry, comparatively simple. We have not to estimate the degrees of importance of different orders of human activity, and different studies as severally fitting us for them; since we find that the study of Science, in its most comprehensive meaning, is the best preparation for all these orders of activity. We have not to decide between the claims of knowledge of great though conventional value, and knowledge of less though intrinsic value; seeing that the knowledge which we find to be of most value in all other respects, is intrinsically most valuable: its worth is not dependent upon opinion, but is as fixed as is the relation of man to the surrounding world. Necessary and eternal as are its truths, all Science concerns all mankind for all time. Equally at present, and in the remotest future, must it be of incalculable importance for the regulation of their conduct, that men should understand the science of life, physical, mental, and social; and that they should understand all other science as a key to the science of life.

And yet the knowledge which is of such transcendent value is that which, in our age of boasted education, receives the least attention. While this which we call civilization could never have arisen had it not been for science; science forms scarcely an appreciable element in what men consider civilized training. Though to the progress of science we owe it, that millions find support where once there was food only for thousands; yet of these millions but a few thousands pay any respect to that which has made their existence possible. Though this increasing knowledge of the properties and relations of things has not only enabled wandering tribes to grow into populous nations, but has given to the countless members of those populous nations comforts and pleasures which their few naked ancestors never even conceived, or could have believed, yet is this kind of knowledge only now receiving a grudging recognition in our highest educational institutions. To the slowly growing acquaintance with the uniform co-existences and sequences of phenomena—to the establishment of invariable laws, we owe our emancipation from the grossest superstitions. But for science we should be still worshipping fetishes; or, with hecatombs of victims, propitiating diabolical deities. And yet this science, which, in place of the most degrading conceptions of things, has given us some insight into the grandeurs of creation, is written against in our theologies and frowned upon from our pulpits.

Paraphrasing an Eastern fable, we may say that in the family of knowledges, Science is the household drudge, who, in obscurity, hides unrecognized perfections. To her has been committed all the work; by her skill, intelligence, and devotion, have all the conveniences and gratifications been obtained; and while ceaselessly occupied ministering to the rest, she has been kept in the background, that her haughty sisters might flaunt their fripperies in the eyes of the world. The parallel holds yet further. For we are fast coming to the *dénouement*, when the positions will be changed; and while these haughty sisters sink into merited neglect, Science, proclaimed as highest alike in worth and beauty, will reign supreme.

THE PROGRESS OF SCIENCE.

HERBERT SPENCER.

The world loses one of its few great men in the death of Herbert Spencer. Thirty years ago there lived and worked in Great Britain a notable group of leaders—Darwin, Huxley, Browning, Tennyson, Carlyle, Ruskin, Thackeray, Gladstone and many more. One by one they have died, each time leaving an empty space that remains unfilled. We have still Kelvin, Watts, Swinburne and Meredith, but the voices of the Victorian era are now nearly silent. It is perhaps needful to go back to the Elizabethan age for a period of parallel efflorescence; and it may be that such will not again recur even after three hundred years.

Spencer believed in universal evolution rather than in miracles wrought by the individual; and it is certainly true that his own work was the result rather than the cause of certain leading tendencies of the nineteenth century. Evolution and the conservation of energy are the great legacy handed on to the twentieth century, no longer speculations of the philosophers, but part of the real life of every one. Spencer more completely and more perfectly than any other represented these truths and made them our common heritage. In the preface to the fourth edition of the 'First Principles,' he explains that the doctrine of evolution was maintained by him two or even four years before the publication of the 'Origin of Species.' As a matter of fact the idea of world evolution goes back almost to the beginning of thought; it is clearly stated for inorganic matter and living things by the Greek philosophers and again by Kant, Laplace, Goethe and Lamarck. It is a question whether even Darwin's 'natural selection,' which does not after all play a leading part in Spencer's philosophy, can not be found in Aristotle. Evolution was clearly 'in the air' in the middle decades of the nineteenth century. Thus before Darwin or Spencer, Tennyson wrote and printed the fine verses:

> 'So careful of the type?' but no.
> From scarped cliff and quarried stone
> She cries, 'A thousand types are gone:
> I care for nothing, all shall go.'
>
> * * * * * *
>
> The solid earth whereon we tread
> In tracts of fluent heat began,
> And grew to seeming random forms,
> The seeming prey of cyclic storms,
> Till at the last arose the man.

Of these ideas Spencer became the leading representative, his bold formulas appealing directly to the people to an extent that could not be expected of Darwin's patient investigations. The methods of the two men are compared in a letter from Darwin to John Fiske:

> I find that my mind is so fixed by the inductive method that I can not appreciate deductive reasoning: I must begin with a good body of facts and not from a principle (in which I always suspect some fallacy) and then as much deduction as you please. This may be very narrow-minded; but the result is that such parts of H. Spencer as I have read with care impress my mind with the idea of his inexhaustible wealth of suggestion, but never convince me.

If others were as frank as Darwin, many would say with him: "With the exception of special points I did not even understand H. Spencer's general doctrine; for his style is too hard work for me." But Spencer appealed to the emotions as well as to the intellect.

His work justified the abandonment of certain narrow dogmas, which left an exhilarating sense of emancipation. There was more truly a Spencerian religion than any resulting from the positivism of Comte. This was particularly the case in America, and THE POPULAR SCIENCE MONTHLY was largely responsible. Spencer opened the first volume in 1872, and contributed in all ninety-one articles. The editorial writings of E. L. and W. J. Youmans were always enthusiastically loyal to the Spencerian doctrines and the Spencerian religion. No greater service could at the time have been performed for the freedom of thought and the progress of civilization.

But the great representative of evolution, though he may be interpreted as regarding his own doctrines as final, must surely have rejoiced in the further progress of science and of thought. His works on biology and on psychology have been superseded. He clearly represented the conflicting tendencies of his age. He devoted his life to what is perhaps the last great system of synthetic philosophy, when the inductive sciences were becoming predominant. He was an ardent individualist, while advocating a theory that subordinates the individual to the world pattern. He leaves the problems of idealism and materialism face to face.

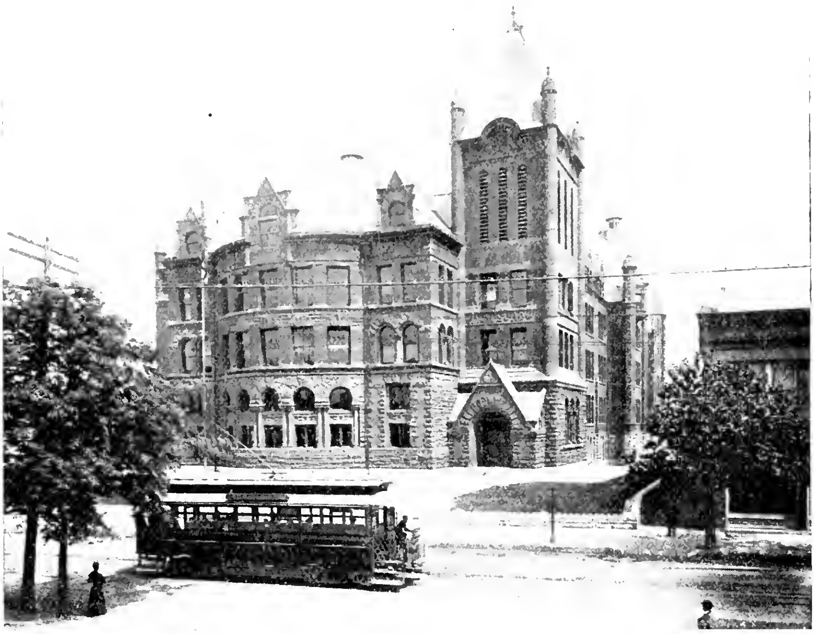
It is not necessary to enter here into details in regard to Spencer's life. Very characteristically he has left his autobiography stereotyped and ready for the press. A sketch with his portrait will be found in the issue of this magazine for March, 1876. We reproduce as a frontispiece, by the courtesy of Messrs. D. Appleton and Company, an engraving of a bust of Spencer at the age of seventy-six, modeled by Mr. Onslow Ford and presented to him by his admirers. Spencer's life was at once formal and heroic. Burdened by ill-health and comparative poverty, he would dictate to an amanuensis for fifteen minutes at a time, resulting in a productivity of some 300 words a day. Without family or intimate friends, he led a lonely life. But he never faltered in his devotion to his plans and ideals. After eighty-three years he is now dead; but his work is immortal, not only in the history of thought, but also in

> The choir invisible
> Whose music is the gladness of the world.

THE CONVOCATION WEEK MEETINGS OF SCIENTIFIC SOCIETIES.

THOSE readers of this journal who are interested in the organization of science will remember that American scientific societies and institutions of learning have set aside the week in which the first day of January falls as a time of convocation for scientific meetings. Until last year the American Association for the Advancement of Science and its affiliated societies met in midsummer, while the American Society of Naturalists and a number of societies devoted to the biological sciences met in the Christmas holidays. Certain societies, such as the American Chemical Society and the Geological Society of America, held meetings at both times. All these societies met together last year at Washington during convocation week, making the largest and most influential gathering of scientific men that this country has witnessed.

There will this year be a certain amount of division. The American Association and the Naturalists with twenty affiliated societies will meet at St. Louis. The Zoologists and four other societies concerned with biology will meet at Philadelphia, and the Philosophical Association will meet at Princeton. The Economists and Historians, who have not as yet become affiliated with the scientific societies, will meet at New Orleans. It seems evident that the American Association must be a national organization and that there should be societies for the different sciences which are national in scope. Owing to the great area of the country these societies must be broken up into sections; but the most efficient form of organization has still to be worked out. A general meeting of the scientific men of the country appears to be essential; but it is possible that this can only take place once in three years, the meetings being more local in the intervening years. There should, however, be one central place of meeting each year, where the societies of the whole country can be represented by delegates, should a plebiscite be impossible. It has been agreed that for the present this general meeting should be in the eastern states twice and in the central or western states once in three years.



Central High School, in which the American Association for the Advancement of Science and Affiliated Societies will meet during Convocation Week.

The general meeting is this year at St. Louis, and it will doubtless rival in interest and importance the Washington meeting. Counting the sections of the American Association, there will be at least thirty scientific organizations in session, and the officers alone make a representative body of scientific men. The Hon. Carroll D. Wright, U. S. Commissioner of Labor and president of Clark College, presides over the association, and Dr. Ira Remsen, president of the Johns Hopkins University, gives the address of the retiring president. Professor William Trelease, director of the Missouri Botanical Gardens, gives the presidential address before the Society of Naturalists, and the public lecture is to be delivered by President David Starr Jordan of Stanford University. It would require many pages to give details of the programs; they will be found in part in recent numbers of *Science* and in the local program issued by the association. The latter can be obtained from the permanent secretary, Dr. L. O. Howard, Cosmos Club, Washington, D. C., to whom also applications for membership should be addressed. All scientific workers in the central states and also those interested in science not now members should make the St. Louis meeting the occasion of acquiring membership.

THE CARNEGIE INSTITUTION.

The trustees of the Carnegie Institution held their second annual meeting at Washington on December 9. Nothing that has become known in regard to this meeting will tend to allay the anxiety with which men of science are watching the administration of this great trust. It is reported that Dr. Gilman presented a letter to the trustees announcing his intention to resign the presidency at the close of next year. The institution will consequently drift along for another year, and its immediate future will in large measure depend on the president then chosen. There is no reason to doubt the ultimate outcome, and even the present conditions are only what might have been expected. Special creations are no longer regarded as feasible. The reply may be called to mind of the little boy, who on being asked who made him, said 'God made me one foot big, and I growed the rest.' A new foundation such as Mr. Carnegie's can only gradually become a true organism adjusted to the environment.

Mr. Carnegie's original plan of establishing a research university at Washington was comparatively plain sailing. The trustees are now divided as to policy, some wishing to establish certain laboratories at Washington, and others perferring to distribute subsidies throughout the country. The latter plan has been adopted; it has the obvious advantage of not committing the institution as to the future. No special objection can be made to the way the subsidies have been allotted. It is quite certain, for example, that the Harvard, Lick, Yerkes, Dudley and Princeton Observatories can spend to advantage any money that may be entrusted to them. Almost any grant for research made to men of science of established reputation will bear fruit a hundredfold. There is, however, an obverse to the shield. Such grants inhibit individual initiative and local support; they are likely to produce a certain subserviency to the powers that deal out money, and may lead to jealousy and intrigues.

It is perhaps scarcely fair to object to a board of trustees consisting chiefly of prominent politicians, lawyers and business men, who meet once a year, and can not be expected to give much attention to the affairs of a scientific institution, nor to have much knowledge of its scope and possibilities. Such boards are an established American institution, controlling universities, banks, etc. Their principal duty is to select efficient officers of administration. But the Carnegie Institution has been unfortunate in its first officers. Three men were largely instrumental in persuading Mr. Carnegie to make the original gift, and they have assumed control of its administration. This triumvirate has been at the same time autocratic and feeble, and has by no means worked in harmony. Antony may be supposed to say to Octavius:

> And though we lay these honors on this man,
> To ease ourselves of divers sland'rous loads,
> He shall but bear them as the ass bears gold,
> To groan and sweat under the business,
> Either led or driven, as we point the way;
> And having brought our treasure where we will,
> Then take we down his load, and turn him off,
> Like to the empty ass, to shake his ears,
> And graze in commons.

Whether after the ensuing war Antony, Octavius or another will or should become Cæsar need not here be considered; but in the meanwhile and perhaps thereafter science will suffer. The fundamental difficulty is that no method has been found for consulting the consensus of opinion of scientific men. An American university has an absentee board in nominal control and a president as benevolent despot; but there is a faculty, which after all is the real university. The Carnegie Institution has no similar body; and until it is formed, it will drift along without compass or rudder.

BOTANY IN THE PHILIPPINES.

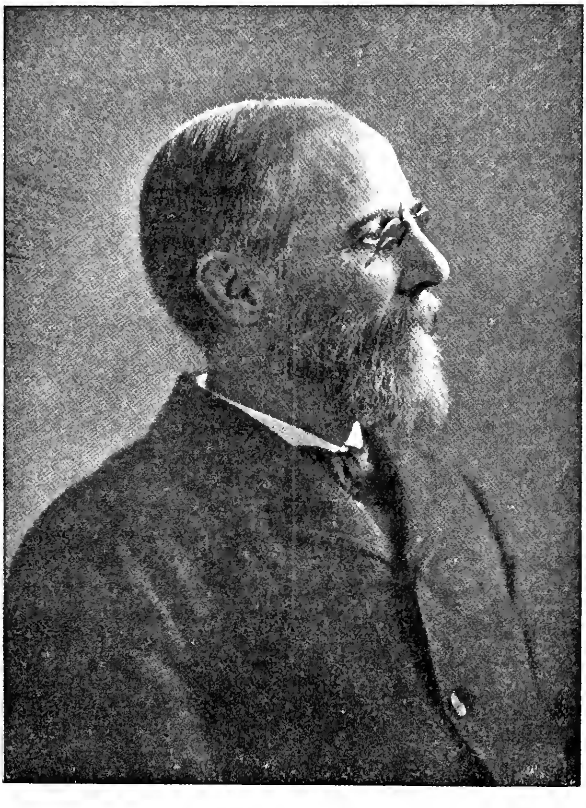
Whatever opinion may be held in regard to the advantages or dangers connected with the acquirement of the Philippines by the United States, there is no doubt but that it will result in the extension of scientific knowledge. An Insular Bureau of Government Laboratories has been organized under the direction of Professor Paul C. Freer, of the University of Michigan, and a Bureau of Agriculture under the direction of Dr. F. Lamson-Scribner, of the U. S. Department of Agriculture, and scientific work is being done in other directions. The National Academy of Sciences last spring outlined, at the request of the President, a plan for a scientific survey of the islands, and this is being carried forward in all directions. The Bureau of Agriculture has already issued eight 'Farmers Bulletins' and four 'Scientific Bulletins,' the last of which, entitled 'Botan-

Statue of Sebastian Vidal in the Botanical Gardens in Manila.

ical Work in the Philippines,' by Mr. Elmer D. Merrill, gives an interesting account of the history of botany in the islands. Prior to the advent of the Americans, various travelers had made collections in the islands, and a certain amount of work had been accomplished by the priests; but the apathy of the Spanish government is in remarkable contrast to the present activity. The priests in the early centuries were chiefly interested in collecting medicinal plants, but Manuel Blanco published a flora of the Philippines extending to 887 pages in 1837, and a revised edition by Fernandez-Villar was published in Manila between 1877 and 1883. Blanco's original work is said to be very faulty, so that De Candolle regretted that he had not confined himself to writing sermons, and the later revision, prepared without reference to existing types or authentic botanical material, will retard rather than advance the science of botany.

In 1873 Domingo Vidal went to the islands and became director of the Botanical Garden, and after his death in 1878 he was succeeded by his brother Sebastian Vidal. The latter, who died in 1889 at the age of forty-seven years, appears to have been the ablest of Spanish botanists who have worked on the Philippine flora. He was greatly respected, both as a botanist and as a man, and a life-size statue, which is here reproduced, was erected by his friends in the center of the Botanical Garden.

The garden is said to have an unsatisfactory situation, being only a few feet above the level of the sea, with no



Henry Barker Hill

protection from the fierce gales that sweep across the bay in the typhoon season, and it is now being developed as a park. It is to be hoped, however, that a botanical garden and experiment station will be established at a higher elevation. Since the organization of the Bureaus of Agriculture and Forestry last year, considerable progress has been made in the study of the botany of the islands, herbaria containing about 5,000 specimens having been made. The New York Botanical Garden has sent a special agent to the islands, and it is probable that more knowledge will be secured of the botany of the Philippines during the next ten years than during the preceding four hundred years of Spanish rule.

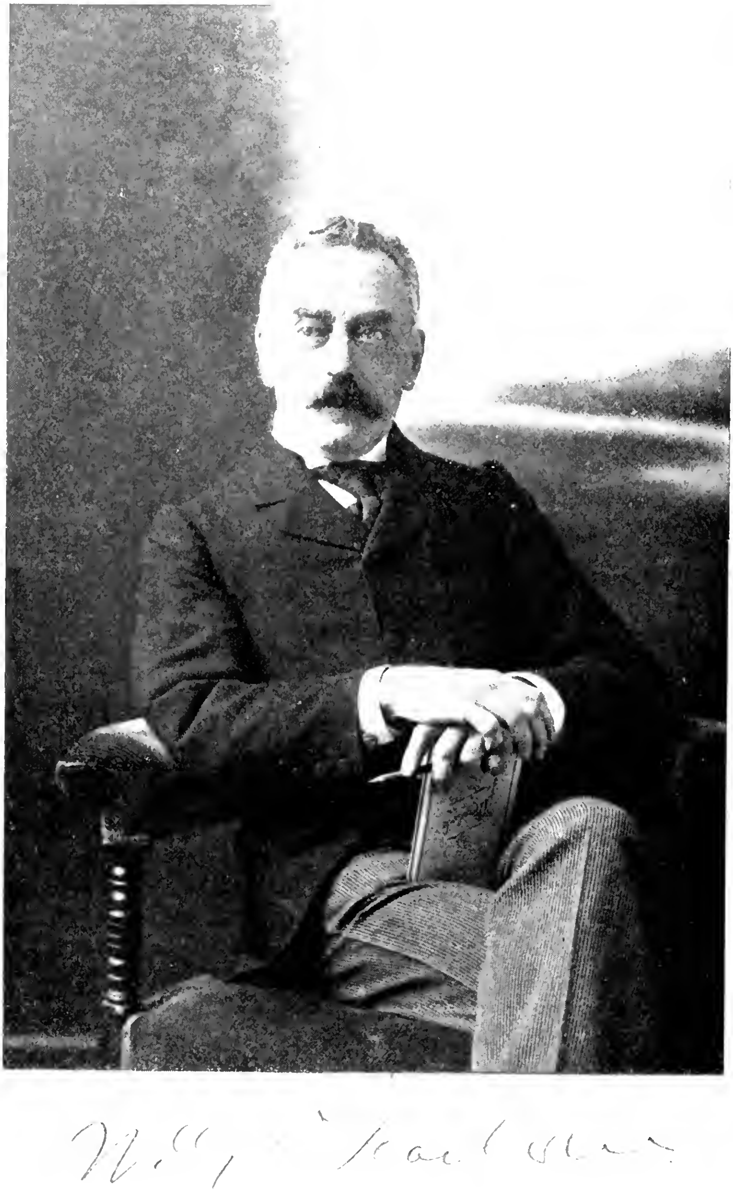
HENRY BARKER HILL.

We reproduce above a portrait of Henry Baker Hill, whose death was a serious loss to Harvard University and the science of chemistry and who died at the comparatively early age of fifty-four years. Hill inherited his intellectual and academic interests, his father being president of Harvard University, and he early selected chemistry as his special field, his commencement oration being entitled 'The New Philosophy of Chemistry.' He was a student under and assistant to Professor Josiah P. Cooke, who first introduced laboratory methods of instruction, and when he himself became professor and director of the laboratory, he maintained its high traditions. Hill's research work was very special in character, being almost exclusively confined to the group of substances derived from furfurol; but the thoroughness and exactness of these investigations take high place as contributions to the development of organic chemistry.

SCIENTIFIC ITEMS.

We regret to record the deaths, during the past month of Dr. H. Carrington Bolton, of Washington, well-known as a chemist and bibliographer; of Dr. Frank Russell, of Harvard University, a student of anthropology; of Dr. Cloudsley Rutter, of the Bureau of Fisheries; of Mr. Marcus Baker, of the U. S. Geological Survey and assistant secretary of the Carnegie Institution; of Professor Arthur Allin, head of the Department of Psychology and Education at the University of Colorado, and of Dr. George J. Engelmann, the eminent physician and gynecologist. The Popular Science Monthly has very recently published contributions from Dr. Bolton, Dr. Engelmann and Dr. Rutter.

The following is a list of those to whom the Royal Society has this year awarded medals· The Copley medal to Professor Eduard Suess for his eminent geological services, and especially for the original researches and conclusions published in his great work 'Das Antlitz der Erde.' A royal medal to Sir David Gill for his researches in solar and stellar parallax, and his energetic direction of the Royal Observatory at the Cape of Good Hope. A royal medal to Mr. Horace T. Brown for his work on the chemistry of the carbohydrates and on the assimilation of carbonic acid by green plants. The Davy medal to M. Pierre and Madame Curie for their researches on radium. The Hughes medal to Professor Wilhelm Hittorf for his long continued experimental researches on the electric discharge in liquids and gases.



PROFESSOR OF CRYPTOGAMIC BOTANY, HARVARD UNIVERSITY.
PRESIDENT OF THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

THE POPULAR SCIENCE MONTHLY.

FEBRUARY, 1904.

SCIENTIFIC INVESTIGATION AND PROGRESS.*

BY PRESIDENT IRA REMSEN,
JOHNS HOPKINS UNIVERSITY.

AT the weekly services of many of our churches it is customary to begin with the reading of a verse or two from the Scriptures for the purpose, I suppose, of putting the congregations in the proper state of mind for the exercises which are to follow. It seems to me that we may profit by this example, and accordingly I ask your attention to Article I. of the Constitution of the American Association for the Advancement of Science, which reads thus: 'The objects of the association are, by periodical and migratory meetings, to promote intercourse between those who are cultivating science in different parts of America, to give stronger and more general impulse and more systematic direction to scientific research, and to procure for the labors of scientific men increased facilities and a wider usefulness.'

The first object mentioned, you will observe, is 'to promote intercourse between those who are cultivating science in different parts of America'; the second is 'to give a stronger and more general impulse and more systematic direction to scientific research'; and the third is 'to procure for the labors of scientific men increased facilities and a wider usefulness.' Those who are familiar with the history of the association are well aware that it has served its purposes admirably, and I am inclined to think that those who have been in the habit of attending the meetings will agree that the object which appeals to them most strongly is the promotion of intercourse between those who are cultivating science. Given this intercourse and the other objects

* Address of the retiring president of the American Association for the Advancement of Science, St. Louis meeting, December 28, 1903.

will be reached as a necessary consequence, for the intercourse stimulates thought, and thought leads to work, and work leads to wider usefulness.

While in 1848, when the association was organized and the constitution was adopted, there was a fair number of good scientific investigators in this country, it is certain that in the half century that has passed since then the number of investigators has increased very largely, and naturally the amount of scientific work done at present is very much greater than it was at that time. So great has been the increase in scientific activity during recent years that we are apt to think that by comparison scientific research is a new acquisition. In fact there appears to be an impression abroad that in the world at large scientific research is a relatively new thing, for which we of this generation and our immediate predecessors are largely responsible. Only a superficial knowledge of the history of science is necessary, however, to show that the sciences have been developed slowly, and that their beginnings are to be looked for in the very earliest times. Everything seems to point to the conclusion that men have always been engaged in efforts to learn more and more in regard to the world in which they find themselves. Sometimes they have been guided by one motive and sometimes by another, but the one great underlying motive has been the desire to get a clearer and clearer understanding of the universe. But besides this there has been the desire to find means of increasing the comfort and happiness of the human race.

A reference to the history of chemistry will serve to show how these motives have operated side by side. One of the first great incentives for working with chemical things was the thought that it was possible to convert base metals like lead and copper into the so-called noble metals, silver and gold. Probably no idea has ever operated as strongly as this upon the minds of men to lead them to undertake chemical experiments. It held control of intellectual men for centuries and it was not until about a hundred years ago that it lost its hold. It is very doubtful if the purely scientific question whether one form of matter can be transformed into another would have had the power to control the activities of investigators for so long a time; and it is idle to speculate upon this subject. It should, however, be borne in mind that many of those who were engaged in this work were actuated by a desire to put money in their purses—a desire that is by no means to be condemned without reserve, and I mention it not for the purpose of condemning it, but to show that a motive that we sometimes think of as peculiarly modern is among the oldest known to man.

While the alchemists were at work upon their problems, another class of chemists were engaged upon problems of an entirely different nature. The fact that substances obtained from various natural sources and others made in the laboratory produce effects of various kinds when taken into the system led to the thought that these substances might be useful in the treatment of disease. Then, further, it was thought that disease itself is a chemical phenomenon. These thoughts, as is evident, furnish strong motives for the investigation of chemical substances, and the science of chemistry owes much to the work of those who were guided by these motives.

And so in each period as a new thought has served as the guide we find that men have been actuated by different motives, and often one and the same worker has been under the influence of mixed motives. Only in a few cases does it appear that the highest motives alone operate. We must take men as we find them, and we may be thankful that on the whole there are so many who are impelled by one motive or another or by a mixture of motives to take up the work of investigating the world in which we live. Great progress is being made in consequence and almost daily we are called upon to wonder at some new and marvelous result of scientific investigation. It is quite impossible to make predictions of value in regard to what is likely to be revealed to us by continued work, but it is safe to believe that in our efforts to discover the secrets of the universe only a beginning has been made. No matter in what direction we may look we are aware of great unexplored territories, and even in those regions in which the greatest advances have been made it is evident that the knowledge gained is almost insignificant as compared with that which remains to be learned. But this line of thought may lead to a condition bordering on hopelessness and despondency, and surely we should avoid this condition, for there is much greater cause for rejoicing than for despair. Our successors will see more and see more clearly than we do, just as we see more and see more clearly than our predecessors. It is our duty to keep the work going without being too anxious to weigh the results on an absolute scale. It must be remembered that the absolute scale is not a very sensitive instrument, and that it requires the results of generations to affect it markedly.

On an occasion of this kind it seems fair to ask the question: What does the world gain by scientific investigation? This question has often been asked and often answered, but each answer differs in some respects from the others and each may be suggestive and worth giving. The question is a profound one, and no answer that can be given would be satisfactory. In general it may be said that the results of scientific investigation fall under three heads—the material, the intellectual and the ethical.

The material results are the most obvious and they naturally receive the most attention. The material wants of man are the first to receive consideration. They can not be neglected. He must have food and clothing, the means of combating disease, the means of transportation, the means of producing heat and a great variety of things that contribute to his bodily comfort and gratify his esthetic desires. It is not my purpose to attempt to deal with all of these and to show how science is helping to work out the problems suggested. I shall have to content myself by pointing out a few of the more important problems the solution of which depends upon the prosecution of scientific research.

First, the food problem. Whatever views one may hold in regard to that which has come to be called 'race suicide,' it appears that the population of the world is increasing rapidly. The desirable places have been occupied. In some parts of the earth there is such a surplus of population that famines occur from time to time, and in other parts epidemics and floods relieve the embarrassment. We may fairly look forward to the time when the whole earth will be overpopulated unless the production of food becomes more scientific than it now is. Here is the field for the work of the agricultural chemist who is showing us how to increase the yield from a given area, and, in case of poor and worn-out soils, how to preserve and increase their fertility. It appears that the methods of cultivating the soil are still comparatively crude, and more and more thorough investigation of the processes involved in the growth of plants is called for. Much has been learned since Liebig founded the science of agricultural chemistry. It was he who pointed out some of the ways by which it is possible to increase the fertility of a soil. Since the results of his investigations were given to the world the use of artificial fertilizers has become more and more general.

But it is one thing to know that artificial fertilizers are useful and it is quite another thing to get them. At first bone dust and guano were chiefly used. Then as these became dearer, phosphates and potassium salts from the mineral kingdom came into use.

At the Fifth International Congress for Applied Chemistry, held at Berlin, Germany, last June, Dr. Adolph Frank, of Charlottenburg, gave an extremely interesting address on the subject of the use of the nitrogen of the atmosphere for agriculture and the industries, which bears upon the problem that we are dealing with. Plants must have nitrogen. At present this is obtained from the great beds of saltpeter found on the west coast of South America—the so-called Chili saltpeter—and also from the ammonia obtained as a by-product in the distillation of coal, especially in the manufacture of coke. The use of Chili saltpeter for agricultural purposes began about 1860. In 1900 the quantity exported was 1,453,000 tons, and its value was about $60,000,000. In the same year the world's production of ammonium sulphate was about 500,000 tons, of a value of somewhat more than $20,000,000. Of these enormous quantities about three quarters finds application in agriculture. The use of these substances, especially of saltpeter, is increasing rapidly. At present it seems that the successful cultivation of the soil is dependent upon the use of nitrates, and the supply of nitrates is limited. Unless something is done we may look forward to the time when the earth, for lack of proper fertilizers, will not be able to produce as much as it now does, and meanwhile the demand for food is increasing. According to the most reliable estimations indeed the saltpeter beds will be exhausted in thirty or forty years. Is there a way out? Dr. Frank shows that there is. In the air there is nitrogen enough for all. The plants can make only a limited use of this directly. For the most part it must be in some form of chemical combination as, for example, a nitrate or ammonia. The conversion of atmospheric nitrogen into nitric acid would solve the problem, and this is now carried out. But Dr. Frank shows that there is another, perhaps more economical, way of getting the nitrogen into a form suitable for plant food. Calcium carbide can now be made without difficulty and is made in enormous quantities by the action of a powerful electric current upon a mixture of coal and lime. This substance has the power of absorbing nitrogen from the air, and the product thus formed appears to be capable of giving up its nitrogen to plants, or, in other words, to be a good fertilizer. It is true that this subject requires further investigation, but the results thus far obtained are full of promise. If the outcome should be what we have reason to hope, we may regard the approaching exhaustion of the saltpeter beds with equanimity. But, even without this to pin our faith to, we have the preparation of nitric acid from the nitrogen and oxygen of the air to fall back upon.

While speaking of the food problem, a few words in regard to the artificial preparation of foodstuffs. I am sorry to say that there is not much of promise to report upon in this connection. In spite of the brilliant achievements of chemists in the field of synthesis it remains true that thus far they have not been able to make, except in very small quantities, substances that are useful as foods, and there is absolutely no prospect of this result being reached within a reasonable time. A few years ago Berthelot told us of a dream he had had. This has to do with the results that, according to Berthelot, are to be brought about by the advance of chemistry. The results of investigations already accomplished indicate that, in the future, methods will perhaps be devised for the artificial preparation of food from the water and carbonic acid so abundantly supplied by nature. Agriculture will then become unnecessary, and the landscape will not be disfigured by crops growing in geometrical figures. Water will be obtained from holes three or four miles deep in the earth, and this water will be above the boiling temperature, so that it can be used as a source of energy. It will be obtained in liquid form after it has undergone a process of natural distillation, which will free it from all impurities, including, of course, disease germs. The foods prepared by artificial methods will also be free from microbes, and there will consequently be less disease than at present. Further, the necessity for killing animals for food will no longer exist, and mankind will become gentler and more amenable to higher influences. There is, no doubt, much that is fascinating in this line of thought, but whether it is worth following, depends upon the fundamental assumption. Is it at all probable that chemists will ever be able to devise methods for the artificial preparation of foodstuffs? I can only say that to me it does not appear probable in the light of the results thus far obtained. I do not mean to question the probability of the ultimate synthesis of some of those substances that are of value as foods. This has already been accomplished on the small scale, but for the most part the synthetical processes employed have involved the use of substances which themselves are the products of natural processes. Thus, the fats can be made, but the substances from which they are made are generally obtained from nature and are not themselves synthetical products. Emil Fischer has, to be sure, made very small quantities of sugars of different kinds, but the task of building up a sugar from the raw material furnished by nature—that is to say, from carbonic acid and water—presents such difficulties that it may be said to be practically impossible.

When it comes to starch, and the proteids which are the other chief constituents of foodstuffs, the difficulties are still greater. There is not a suggestion of the possibility of making starch artificially, and the same is true of the proteids. In this connection it is, however, interesting to note that Emil Fischer, after his remarkable successes in the sugar group and the uric acid group, is now advancing upon the proteids. I have heard it said that at the beginning of his career he made out a program for his life work. This included the solution of three great problems. These are the determination of the constitution of uric acid, of the sugars and of the proteids. Two of these problems have been solved. May he be equally successful with the third! Even if he should be able to make a proteid, and show what it is, the problem of the artificial preparation of foodstuffs will not be solved. Indeed, it will hardly be affected.

Although science is not likely, within periods that we may venture to think of, to do away with the necessity of cultivating the soil, it is likely to teach us how to get more out of the soil than we now do, and thus put us in a position to provide for the generations that are to follow us. And this carries with it the thought that, unless scientific investigation is kept up, these coming generations will be unprovided for.

Another way by which the food supply of the world can be increased is by relieving tracts of land that are now used for other purposes than the cultivation of foodstuffs. The most interesting example of this kind is that presented by the cultivation of indigo. There is a large demand for this substance, which is plainly founded upon esthetic desires of a somewhat rudimentary kind. Whatever the cause may be, the demand exists, and immense tracts of land have been and are still, devoted to the cultivation of the indigo plant. Within the past few years scientific investigation has shown that indigo can be made in the factory from substances, the production of which does not for the most part involve the cultivation of the soil. In 1900, according to the report of Dr. Brunck, Managing Director of the Badische Anilin- and Soda-Fabrik, the quantity of indigo produced annually in the factory 'would require the cultivation of an area of more than a quarter of a million acres of land (390 square miles) in the home of the indigo plant.' Dr. Brunck adds: "The first impression which this fact may be likely to produce, is that the manufacture of indigo will cause a terrible calamity to arise in that country; but, perhaps not. If one recalls to mind that India is periodically afflicted with famine, one ought not, without further consideration, to cast aside the hope that it might be good fortune for that country if the immense areas now devoted to a crop which is subject to many vicissitudes and to violent market changes were at last to be given over to the raising of breadstuffs and other food products." "For myself," says Dr. Brunck, "I do not assume to be an impartial adviser in this matter, but, nevertheless, I venture to express my conviction that the government of India will be rendering a very great service if it should support and aid the progress, which will in any case be irresistible, of this impending change in the cultivation of that country, and would support and direct its methodical and rational execution."

The connection between scientific investigation and health is so frequently the subject of discussion that I need not dwell upon it here. The discovery that many diseases are due primarily to the action of microscopic organisms that find their way into the body and produce the changes that reveal themselves in definite symptoms is a direct consequence of the study of the phenomenon of alcoholic fermentation by Pasteur. Everything that throws light upon the nature of the action of these microscopic organisms is of value in dealing with the great problem of combating disease. It has been established in a number of cases that they cause the formation of products that act as poisons and that the diseases are due to the action of these poisons. So also, as is well known, investigation has shown that antidotes to some of these poisons can be produced, and that by means of these antidotes the diseases can be controlled. But more important than this is the discovery of the way in which diseases are transmitted. With this knowledge it is possible to prevent the diseases. The great fact that the death rate is decreasing stands out prominently and proclaims to humanity the importance of scientific investigation. It is, however, to be noted in this connection that the decrease in the death rate compensates to some extent for the decrease in the birth rate, and that, if an increase in population is a thing to be desired, the investigations in the field of sanitary science are contributing to this result.

The development of the human race is dependent not alone upon a supply of food but upon a supply of energy in available forms. Heat and mechanical energy are absolutely essential to man. The chief source of the energy that comes into play is fuel. We are primarily dependent upon the coal supply for the continuation of the activities of man. Without this, unless something is to take its place, man is doomed. Statistics in regard to the coal supply and the rate at which it is being used have so frequently been presented by those who have special knowledge of this subject that I need not trouble you with them now. The only object in referring to it is to show that, unless by means of scientific investigation man is taught new methods of rendering the world's store of energy available for the production of heat and of motion, the age of the human race is measured by the extent of the supply of coal and other forms of fuel. By other forms of fuel I mean, of course, wood and oil. Plainly, as the demand for land for the production of foodstuffs increases, the amount available for the production of wood must decrease, so that wood need not be taken into account for the future. In regard to oil, our knowledge is not sufficient to enable us to make predictions of any value. If one of the theories now held in regard to the source of petroleum should prove to be correct, the world would find much consolation in it. According to this theory petroleum is not likely to be exhausted, for it is constantly being formed by the action of water upon carbides that in all probability exist in practically unlimited quantity in the interior of the earth. If this be true, then the problem of supplying energy may be reduced to one of transportation of oil. But given a supply of oil and, of course, the problem of transportation is solved.

What are the other practical sources of energy? The most important is the fall of water. This is being utilized more and more year by year since the methods of producing electric currents by means of the dynamo have been worked out. There is plainly much to be learned before the energy made available in the immediate neighborhood of the waterfall can be transported long distances economically, but advances are being made in this line, and already factories that have hitherto been dependent upon coal are making use of the energy derived from waterfalls. The more rapidly these advances take place the less will be the demand for coal, and if there were enough waterfalls conveniently situated, there would be no difficulty in furnishing all the energy needed by man for heat or for motion.

It is a fortunate thing that, as the population of the earth increases, man's tastes become more complex. If only the simplest tastes prevailed, only the simplest occupations would be called for. But let us not lose time in idle speculations as to the way this primitive condition of things would affect man's progress. As a matter of fact his tastes are becoming more complex. Things that are not dreamed of in one generation become the necessities of the next generation. Many of these things are the direct results of scientific investigation. No end of examples will suggest themselves. Let me content myself by reference to one that has of late been the subject of much discussion. The development of the artificial dye-stuff industries is extremely instructive in many ways. The development has been the direct result of the scientific investigation of things that seemed to have little, if anything, to do with this world. Many thousands of workmen are now employed, and many millions of dollars are invested, in the manufacture of dye-stuffs that were unknown a few years ago. Here plainly the fundamental fact is the esthetic desire of man for colors. A colorless world would be unbearable to him. Nature accustoms him to color in a great variety of combinations, and it becomes a necessity to him. And his desires increase as they are gratified. There seems to be no end to development in this line. At all events, the data at our disposal justify the conclusion that there will be a demand for every dye that combines the qualities of beauty and durability. Thousands of scientifically trained men are engaged in work in the effort to discover new dyes to meet the increasing demands. New industries are springing up and many find employment in them. As a rule the increased demand for labor caused by the establishment of these industries is not offset by the closing up of other industries. Certainly it is true that scientific investigation has created large demands for labor that could hardly find employment without these demands.

The welfare of a nation depends to a large extent upon the success of its industries. In his address as president of the British Association for the Advancement of Science given last summer Sir Norman Lockyer quotes Mr. Chamberlain thus: "I do not think it is necessary for me to say anything as to the urgency and necessity of scientific training. . . . It is not too much to say that the existence of this country, as the great commercial nation, depends upon it. . . . It depends very much upon what we are doing now, at the beginning of the twentieth century, whether at its end we shall continue to maintain our supremacy or even equality with our great commercial and manufacturing rivals." In another part of his address Sir Norman

Lockyer says: "Further, I am told that the sum of £24,000,000 is less than half the amount by which Germany is yearly enriched by having improved upon our chemical industries, owing to our lack of scientific training. Many other industries have been attacked in the same way since, but taking this one instance alone, if we had spent this money fifty years ago, when the Prince Consort first called attention to our backwardness, the nation would now be much richer than it is, and would have much less to fear from competition."

But enough on the purely material side. Let us turn to the intellectual results of scientific investigation. This part of our subject might be summed up in a few words. It is so obvious that the intellectual condition of mankind is a direct result of scientific investigation that one hesitates to make the statement. The mind of man can not carry him much in advance of his knowledge of the facts. Intellectual gains can be made only by discoveries, and discoveries can be made only by investigation. One generation differs from another in the way it looks at the world. A generation that thinks the earth is the center of the universe differs intellectually from one that has learned the true position of the earth in the solar system, and the general relations of the solar system to other similar systems that make up the universe. A generation that sees in every species of animal and plant evidence of a special creative act differs from one that has recognized the general truth of the conception of evolution. And so in every department of knowledge the great generalizations that have been reached through the persistent efforts of scientific investigators are the intellectual gains that have resulted. These great generalizations measure the intellectual wealth of mankind. They are the foundations of all profitable thought. While the generalizations of science belong to the world, not all the world takes advantage of its opportunities. Nation differs from nation intellectually as individual differs from individual. It is not, however, the possession of knowledge that makes the efficient individual and the efficient nation. It is well known that an individual may be very learned and at the same time very inefficient. The question is, what use does he make of his knowledge? When we speak of intellectual results of scientific investigation, we mean not only accumulated knowledge, but the way in which this knowledge is invested. A man who simply accumulates money and does not see to it that this money is carefully invested, is a miser, and no large results can come from his efforts. While, then, the intellectual state of a nation is measured partly by the extent to which it has taken possession of the generalizations that belong to the world, it is also measured by the extent to which the methods by which knowledge is accumulated have been brought into requisition and have become a part of the equipment of the people of that nation. The intellectual progress of a nation depends upon the adoption of scientific methods in dealing with intellectual problems. The scientific method is applicable to all kinds of intellectual problems. We need it in every department of activity. I have sometimes wondered what the result would be if the scientific method could be employed in all the manifold problems connected with the managament of a government. Questions of tariff, of finance, of international relations would be dealt with much more satisfactorily than at present if the spirit of the scientific method were breathed into those who are called upon to deal with these questions. It is plain, I think, that the higher the intellectual state of a nation the better will it deal with all the problems that present themselves. As the intellectual state is a direct result of scientific investigation, it is clear that the nation that adopts the scientific method will in the end outrank both intellectually and industrially the nation that does not.

What are the ethical results of scientific investigation? No one can tell. There is one thought that in this connection I should like to impress upon you. The fundamental characteristic of the scientific method is honesty. In dealing with any question science asks no favors. The sole object is to learn the truth, and to be guided by the truth. Absolute accuracy, absolute fidelity, absolute honesty are the prime conditions of scientific progress. I believe that the constant use of the scientific method must in the end leave its impress upon him who uses it. The results will not be satisfactory in all cases, but the tendency will be in the right direction. A life spent in accordance with scientific teachings would be of a high order. It would practically conform to the teachings of the highest types of religion. The motives would be different, but so far as conduct is concerned the results would be practically identical. I need not enlarge upon this subject. Unfortunately, abstract truth and knowledge of facts and of the conclusions to be drawn from them do not at present furnish a sufficient basis for right living in the case of the great majority of mankind, and science can not now, and I do not believe it ever can, take the place of religion in some form. When the feeling that the two are antagonistic wears away, as it is wearing away, it will no doubt be seen that one supplements the other, in so far as they have to do with the conduct of man.

What are we doing in this country to encourage scientific investigation? Not until about a quarter of a century ago can it be said that it met with any encouragement. Since then there has been a great change. Up to that time research was sporadic. Soon after it became almost epidemic. The direct cause of the change was the establishing of courses in our universities for the training of investigators somewhat upon the lines followed in the German universities. In these courses the carrying out of an investigation plays an important part. This is in fact, the culmination of the course. At first there were not many following these courses, but it was not long before there was a demand for the products. Those who could present evidence that they had followed such courses were generally given the preference. This was especially true in the case of appointments in the colleges, some colleges even going so far as to decline to appoint any one who had not taken the degree of doctor of philosophy, which is the badge of the course that involves investigation. As the demand for those who had received this training increased, the number of those seeking it increased at least in the same proportion. New unversities were established and old ones caught the spirit of the new movement until from one end of the country to the other centers of scientific activity are now found, and the amount of research work that is done is enormous compared with what was done twenty-five or thirty years ago. Many of those who get a taste of the work of investigation become fascinated by it and are anxious to devote their lives to it. At present, with the facilities for such work available, it seems probable that most of those who have a strong desire and the necessary industry and ability to follow it find their opportunity somewhere. There is little danger of our losing a genius or even one with fair talent. The world is on the lookout for them. The demand for those who can do good research work is greater than the supply. To be sure the material rewards are not as a rule as great as those that are likely to be won by the ablest members of some other professions and occupations, and as long as this condition of affairs continues to exist there will not be as many men of the highest intellectual order engaged in this work as we should like to see. On the other hand, when we consider the great progress that has been made during the last twenty-five years or so, we have every reason to take a cheerful view of the future. If as much progress should be made in the next quarter century, we shall, to say the least, be able to compete with the foremost nations of the world in scientific investigation. In my opinion this progress is largely dependent upon the development of our universities. Without the opportunities for training in the methods of scientific investigation there will be but few investigators. It is necessary to have a large number in order that the principle of selection may operate. In this line of work as in others, many are called, but few are chosen.

Another fact that is working advantageously to increase the amount of scientific research done in this country is the support given by the government in its different scientific bureaus. The Geological Survey, the Department of Agriculture, the Coast and Geodetic Survey, the National Bureau of Standards and other departments are carrying on a large amount of excellent scientific work, and thus helping most efficiently to spread the scientific spirit throughout the land.

Finally, two exceedingly interesting experiments in the way of encouraging scientific investigation are now attracting the attention of the world. I mean, of course, the Carnegie Institution, with its endowment of $10,000,000 and the Rockefeller Institute, devoted to investigations in the field of medicine, which will no doubt be adequately endowed. It is too early to express an opinion in regard to the influence of these great foundations upon the progress of scientific investigation. As both will make possible the carrying out of many investigations that would otherwise probably not be carried out, the chances of achieving valuable results will be increased. The danger is that those who are responsible for the management of the funds will be disappointed that the results are not at once of a striking character, and that they will be tempted to change the method of applying the money before those who are using it have had a fair chance. But we who are on the outside know little of the plans of those who are inside. All signs indicate that they are making an earnest effort to solve an exceedingly difficult problem, and all who have the opportunity should do everything in their power to aid them.

In the changes which have been brought about in the condition of science in this country since 1848, it is safe to say that this association has either directly or indirectly played a leading part. It is certain that for the labors of scientific men increased facilities and a wider usefulness have been procured.

COMRADES IN ZEAL.*

BY DAVID STARR JORDAN,

PRESIDENT OF LELAND STANFORD JR. UNIVERSITY.

THE Society of Sigma Xi was founded in 1886 at Cornell University. Its godfather was Henry Shaler Williams, and its name, *σπουδῶν ξυνώνης*, companions in zealous research, comrades in zeal, indicates as well as two words can, even in that wonderful language of the Greeks, the purpose of the society. It was intended to bind together scientific thought and action, the workers in pure science and those who dignify it by its application to human affairs.

The society has now its chapters in 16 American universities. Its members number upwards of 2,500, about 500 of them active, that is, still lingering about the university which is the center of the collective efforts of Sigma Xi, the rest scattered over the world in the various avocations appropriate to the zealous comradery.

The society of Sigma Xi stands for the glory of research, the joy of knowing, the uplift which comes from 'seeing things as they really are,' and the doing the thing that such seeing shows us ought to be done. Its essence is in Huxley's phrase the 'fanaticism for veracity,' the zeal for fair play, that would not have even the least of nature's records slurred over or wrongly interpreted. It stands at the same time for the zeal for action, for the strenuous use of the knowledge already acquired in the affairs of men. For pure science and applied science it finds place alike, for each has its roots in independent research, and in each the fanaticism for veracity is fundamental to the highest work. Its purpose is to excite this fanaticism for veracity, and zeal for action among the university students of America, and to foster it by means of the fellow-feeling among free spirits, 'Gemeingeist unter freien Geistern,' which was once declared to uphold scholarship in Germany.

For the Sigma Xi is a university organization dealing with university men, and not directly with any others. Moreover, the society is not the university itself. It is a small part of any one institution —a large part only when taken in the aggregate. It gives no material aids to scholarship. It builds no laboratories, establishes no libraries, endows no fellowships, offers no prizes, grants no honors worthy of the name. In its elections it picks out youth of promise, enlisting them as privates in its service. It undertakes to crown no achievement. It

* Address at the first annual banquet of the Honorary Society of Sigma Xi, St. Louis, December 31, 1903.

works through one channel only, that of comradery in research. We are Spudon Xynones—fellow pilgrims in a joyous land—full of glorious scenes, broad outlooks and repaying experiences. But the way we travel is beset with many difficulties both within and without. There are many temptations to turn aside from the main quest, from the large joys to the immediate successes, and the number of those who to the end remain Xynones is far less than the number who first strike out on the trail. These temptations are internal for the most part. The response to them depends on the man, not on anything outside of him. They are the intrinsic factors in his scientific evolution. But there are also extrinsic factors which undermine zeal and discourage enthusiasm. These extrinsic factors are sometimes potent, though relatively few, while the influence of the intrinsic factors decimates our band; wherefore we conclude that the individual in science is more than the environment. Men of research are born more often than made, but those well born may be spoiled or half-spoiled in the making. To prevent this, to keep the ranks firm, it is well for us to stand together, as comrades in zeal, and when necessary, as to-night, we may whistle bravely to keep up our courage.

And in standing together, it is well for men interested in one line of research not to look down on those whose taste or capacity favors some other. So long as it is real, research is the real thing, and one line may come as near the heart of things as another. Whence it is not good for the experimenter to look down on the systematist, the student of exact sciences on the mathematics of the imagination, the physicist on the psychologist, the chemist on the engineer, the engineer on the economist, the biologist who thinks in terms of chemistry only on the biologist who finds vital force a convenient temporary conception while searching for underlying causes, or any class on any other class, each being a loyal follower of the clue which has come into his hands. To be sure, not all is science which takes that name. 'Science falsely so called' is known to all of us as well as to the theologian. Of course, the name of science, even the name of research, is borrowed for purposes utterly at variance with science. Trade-marks which have a value are always imitated. With all that in the long run, there comes to be a science of non-science when even christian science and psychical research will ultimately find a place in the pigeon-holes of investigation.

In general, scientific research may be divided into four or five great classes.

Experiment.—The purpose of experiment is to test laws, to find out how things work. We arrange the conditions, nature does the rest, and our part of the process is to find out what the rest is. In the old days experiment was easy—to let fall an apple, to rub the hair of a cat, to bring a nail near a magnet. Nature would take advantage of the situation and give us a hard answer to an easy question. We have not only to note what she does, but to find out why she does it, or rather why she doesn't do the reverse; for so perverse is nature that she never does any one thing unless she is cut off from doing all other possible things. It never rains when it could possibly do anything else; it is never clear when it could possibly rain. It has been shown that the crab runs sidewise, because such is the perverse nature of the crab, that if it could possibly run in any other way it would do so. The crab is a chip of the great block of Mother Nature. She is so perverse that she never does anything save when she has to. It is no easy thing to say why the limitations we find through experiment are inherent in the very nature of things.

And experimentation is no longer easy. All the obvious questions have been asked. All the obvious answers have been analyzed into infinite difficulties. It takes a master mind to devise a new problem. It takes almost infinite neatness and delicacy of touch to arrange the scenery, and infinite patience to wait for the result. To examine ten thousand minute eggs of a sea-urchin to see if perchance one has been fertilized in some impossible way, so as to eliminate all side conditions from an intricate problem—this requires enthusiasm and patience of a new order, a fanaticism for veracity not rewarded by the ringing of bells nor by scarlet sashes nor a coat with green palms. It can only be encouraged by the comradery of free-spirits, who value the fragment of truth which these methods bring, and who respect the man who gives his time and strength to know a little truth—to know it, not to guess it. Fanaticism for veracity—this is a good word, and those who heed it need all encouragement.

What we wish to encourage is not a specific achievement, but rather a habit of mind. To see clearly, to see deeply, to see with an understanding heart—this is the nature of research. It is not compilation, it is not publication, it is not the formation of curves, nor the giving of new names, nor the stacking up of columns of figures, though each or any of these may lie along the way as necessary accompaniments, as much a part of a piece of research as a walking-stick or a hat band is a part of a journey. 'Fanaticism for veracity' covers the whole matter, and as fanatics of a new order, F. F. V., with a new significance, we rally together under the sign of Sigma Xi.

Comrades in zeal for truth, we care enough for accuracy to sacrifice for it our money, our time, and even, if necessary, some of us give our lives for it. Enough of us have done so to show what the others of the brotherhood would do if placed under like circumstances or if subjected to like demands.

But experiment is not all of science. A large part of the work of scientific research must be simply descriptive, the attempt to record things in the world as they are—just as they are. It is dealing with nature in a static way, the record of experiments of nature herself, so long in trying, that we do not recognize her movement at all. Wherefore descriptive science seems less exhilarating than experimental science. It has less movement to it; for nature does not seem to move, and we need not as we watch her; yet static knowledge lies at the foundation of most discoveries in dynamic nature. We must know the plants and animals of any given region and know them exactly before we can study migrations and movements, the origin of faunas, the distribution of forms. The movements in geologic time are best traced by the shells which the rocks carry with them, and these shells admit of no experiment, have no apparent dynamic significance. Descriptive anatomy precedes physiology and interprets it; embryology interprets anatomy, but to a like degree anatomy interprets embryology. Ecology, the study of life histories, interprets all these and is explained by them. According to Lubbock, the knowledge of the habits of animals, their reaction to stimuli, external and internal, is the final end of zoological science.

It has been a fashion of the *fin du siècle* sort, a fad of the last end of the last century, for workers in other lines to look down on systematic zoology and systematic botany. They would know the general structure and relations of animals and plants in a great large way, but were infinitely bored by the details, and especially by those of the larger forms, those which can not be sliced and imbedded in Canada balsam. This feeling is unworthy of large-minded men. As I said just now, it is not good form in science for one set of workers to look down on another. The varied details of systematic science embody the fanaticism for veracity of the men who have worked them out. It is, after all, the man who does the minute work who advances science. Anybody can devise new groupings of large lines of facts. The man who found out the least true detail about the heart of the lancelet, even the man who found a new kind of lancelet in the sands of the Bahamas, contributed more to science than the men who gave new names to the class of lancelets in their new schemes of vertebrate classification. As if Leptocardii were not good enough, we have these little creatures called Acrania, Pharyngobranchii, Cephalochorda or Cirrostomi. We all know that the lancelet is headless, that it has gill slits around the throat, a nerve cord where its head ought to be, and cirri about its mouth, but we knew that when they were Leptocardii or merely lancelets, and these new names merely cumber the books without adding at all to our knowledge.

Linnæus once said, with the fine sarcasm of the ancients: 'Tyro novit classes, magister fit species.' Any beginner can define classes of plants. It takes a master to work out the species. Any beginner can see things in the large; all the world does that; but only the master can get down to details. He can shut his eyes to all outside, and can make from nature a faithful transcript. It has been said that all advance in knowledge is really quantitative. We must come down to micro-measurements if we are to see more deeply than others have seen, if we are to add to the store of human knowledge.

On the great chart made by the descriptive naturalist the experimenters locate their work. As well try to study geography without maps as to work at the great problems of geographic distribution, without correct faunal lists of species. To study wisely the origin of species, the evolution of forms without knowing species, many species, and knowing them as species, is impossible, as many naturalists have clearly shown by the method of awful example. To fill out the great chart of the descriptive chemists, experiments in chemistry are carried on, and in some degree the same condition holds for physics, astronomy and the other sciences. The word *science* has been defined as knowledge set in order. A large adjunct of research, even if it be not part of research itself, is the work of setting knowledge in order. Very often the man who brings clearness out of confusion has contributed more to science than the discoverer of the facts with which he deals. It takes a high order of mind to sift the evidence, to brush aside the cobwebs, to bring forth the truth. To do this well, one should have large experience with creative work. It was not the least of Darwin's merits that he was able to deal with the records of thousands of men, to bring out clearly what these records showed, though not one of the actual discoverers even dimly suspected the meaning of their work. At the same time Darwin was not once deceived by the errors of other men. Each record he accepted from some one else remains unimpeached to this day. To set knowledge in order requires a master in the value of evidence, and for this reason the authors of index, record, anzeiger and bibliography should be held in esteem in science. To do this work one must know how to do it, and to know how is to have had already a large experience in the kind of work which the index or bibliography is designed to help.

Setting in order the results of research may not demand as high an order of genius as is needed to push forward the line of advance, yet most great investigators have found relating their own work to the work of others a welcome as well as a necessary task. It is the duty of every investigator to enable his successors to start farther along than he was able to do. To enter into the work of others implies that our predecessors have smoothed the path and cleared the way to further advances. Whence the experimenter should not look down on the bibliographer or even the compiler, providing that these do their work with a master's mind and conscience. Good work in the poorest fields is better than bad work in the richest. The progress of science depends not so much on the field actually worked, not even on the method chosen, but rather on the brains, conscience and courage a man puts into his work.

Another line of work is that of invention, the application of the discoveries of science to human needs. It is the fashion to decry science of this sort as commercial, and to speak with scorn of the financial rewards which await those who are successful in its pursuit.

But I am glad that the Sigma Xi finds room for the creative engineer. In its last analysis the ultimate purpose of knowledge is the regulation of human conduct. The end of knowing is doing, and the justification of scientific research is that it makes life more comfortable, saner and richer. It is true that pure science must precede creation, but into some form of creative art all experimental science sooner or later finds its way. We may then welcome the engineer as an inseparable companion in the domain of science, comrade in zeal, diverging in method, but loyal to fanaticism to the truth he can touch and feel.

Highest of all lines of scientific work, most difficult of all, and withal most susceptible of degeneration, is the study of causes and relations. This work is closely connected with all other forms of research; for every fact observed points us to the consideration of its cause.

Each fact must be the resultant of some adequate force. 'The globe is transparent law, not a mass of facts.' So Emerson tells us. Law is the expression of the relation of cause and effect. Nothing would be as it is, could it by any possibility have been something else. Nothing is variable in the universe save the wayward human will, and that only because its stimuli and reactions are too finely balanced to be measured by our instruments of precision.

Each peculiarity of structure, each character or quality of individual or species, has a meaning or a cause. It is the work of the investigator to find this meaning as well as to record the fact. "One of the noblest lessons left to the world by Darwin," Frank Cramer says, "is this, which to him amounted to a profound, almost religious, conviction, that every fact in nature, no matter how insignificant, every stripe of color, every tint of flowers, the length of an orchid's nectary, unusual height in a plant, all the infinite variety of apparently insignificant things, is full of significance." For him it was an historical record, the revelation of a cause, the lurking place of a principle.

For this reason, every line of work leads back to a causal interpretation. Every fact clamors for it. This is the strongest impulse which urges the devotee of science, the comrade in zeal, and his only danger is that he respond to these calls prematurely. The ultimate end of scientific research is found in prophecy, not in proclamations of the mystic order, but in such mastery of the solid ground of the present that we can tread with firm step on the solid ground of the future, 'the action of existing causes.' This interprets all that has been; foretells all that is to be. The value of all facts is found in their relation to such interpretation and such prophecy. It is the function of prophecy, as Dr. Wilhelm Ostwald has shown, which distinguishes the new civilization from the old, 'and the word which expresses this difference is science.' "The height of any civilization," says Dr. Ostwald, "may be directly measured by the thoughtfulness with which the prophets of civilization understand their calling and are able to predict this future. In the struggle for existence the man will be most efficient who can answer these questions: what will happen? and with what certainty, more accurately than his fellow men."

"If we ask," continues Dr. Ostwald: "What is the most general force which has been active in historical times within our knowledge, and is still active, we recognize that it is the *conquest of all intellectual fields by science.* If we imagine the most primitive conditions in the development of mankind, we see that there is no doubt that the individual and the race which is finally successful in the struggle for existence is the one that learns to see most clearly into the conditions of the future and thus learns to influence them. There are conditions in which the war of physical force seems to settle the question; but even here we see skill, that is, the intellectual or scientific factor, offset a large part of the brute strength, and this factor increases as development advances. The greatest leaders of men have been those who saw most clearly into the future.

"Thus every political and moral organization is dependent upon biographical conditions; and these fields are evidently those which are destined to be irresistibly conquered by science."

To us, as 'prophets of civilization,' to use again Dr. Ostwald's illuminating phrase, every line of scientific research has its danger—the danger of inadequacy. In causal interpretation, the impulse is toward superficiality, to premature proclamation of opinions issuing from the heart rather than sanctioned by the head, the tendency toward futile speculation, barren epistemology, or florid sentimentalism. While magister fit species, tyro novit classes, a beginner can frame great generalizations and a great many of them, which it would take a master of masters to define and sustain. 'A flaw in thought an inch long'—this is a Chinese proverb—'may be felt for a thousand miles.' It is the flaw in thought, the flaw in fundamental conception, which distinguishes the sage in science from the speculative philosopher. In this matter we are fortunately not without adequate models. The boldest speculator in biology was also the one of all his century most careful as to his facts. In the twenty-five years of building the hypothesis of the origin of variety in life, Darwin scrutinized each least fact as though it were the center of the whole system. From which it followed that there was no unsound material in the fabric he built. And for this attention to each detail, rather than for the greatness of his final conception, we place Darwin first among the naturalists of all time. Other men had thought of natural selection, had imagined the survival of the fittest, had shown the divergence of forms of life under diverse environment. Only Darwin could show with the demonstration of ten thousand instances that this condition was naturally inevitable, that the origin of species was written in the very nature of things set in the creation of life.

As causal interpretation in weak hands degenerates into speculation, so are all other forms of research subject to deterioration. Experimenters are peculiarly subject to myopia, shortsightedness, narrowness, carelessness as to truth obtained in other ways, and indifference to the outlooks a broader horizon obtains. With all the intensive accuracy of the science of Germany, we have often to look to other countries, notably to England, for the broader view which sets each fact in place.

Systematic or descriptive work often finds its end in pedantry, the accumulation or the ostentation of meaningless knowledge, or in the forming of useless names and the gathering of pointless statistics. The work of setting in order often slides downward through easy stages of copying, compiling and dictionary work, work designed to 'hold the eel of science by the tail,' but which sometimes retains only the slime from that vivacious fish. Ecology too easily falls into sentimental personification of living organisms, not the study of Nature, but the cultivation of our own emotions regarding her. Inventive science degenerates into management of properties and science is lost in the search for salaries for holding down a job. For in engineering there is a subtle line, easily passed, which separates the comrade in zeal from the successful superintendent of a mine or foreman of a machine shop, just as in pure science there is a narrow line which distinguishes advance in knowledge from the simple keeping of what is already in our possession.

We must all rejoice in the steady increase of means for work in America, the multiplication of libraries, laboratories, museums, instruments of precision and facilities for publication, made ready to our hand. These will increase the output in science; they will improve its quality; but they will have little effect on the actual number of investigators.

I am forced to believe that investigators can not be made by opportunity only—merely made better. Not many who would have been investigators have been deterred by scanty means, by burden of work, by lack of encouragement. The impulse of the investigator, as his reward, must be within himself. His results may be incomplete, his product scanty, his outlook narrow, but he will not fail to bring forth after his own kind. A stalk of corn in stony soil may yield but little grain, but what there is will still be corn. You can not starve it down to oats nor feed it till it becomes a banana. I have no faith in the men who might have been productive investigators if they only had a chance. The world is the opportunity of the man who can seize it. All the true naturalist demands is to be born into it.

In like fashion, splendid resources count for nothing till they fall into the right hands. The existence of a microscope or microtome is no guarantee that some one will use it. The presence of a collection is no sign that some one will study it. It requires courage and zeal to lay hold of anything, and these qualities do not always dwell in kings' houses. Generous facilities can not take the place of men, and the best working rooms in the world will not raise mediocrity into genius. Haeckel once said bitterly that the output of laboratories in biology was always in inverse ratio to the completeness of their appointments.

For there are always influences at work, extrinsic and intrinsic forces, as I said just now, which oppose the spirit of investigation. Among these I class all which tend to make investigation perfunctory and all those which crown achievement with worldly reward. I have known men in European museums to say deliberately: It is time to put out another paper. What is the easiest thing I can do? Meanwhile searching for the line of work which will yield the largest number of pages for the amount of energy put forth. Something of this sort results from the pressure of university publication committees. So many pages of original research demanded for each month in the calendar. Better not print at all than to make it a stated function. On the whole, I place the fellowship system as a discouragement to research. The real comrade in zealous learning is a man who can take care of himself. To get his own training where he can do it best, in his own way, at his own cost, is one of the best parts of his scientific training. The free lunch at the university tempts those who are hungry, the pedant, the place-seeker, the second-hand scholar—to the prejudice of the investigator. The kind of man who best passes examinations is not the original, the forceful, the creative scholar. He has something better than examinations to think about. It is not to the credit of the American university system that the number of doctors of philosophy—to borrow a suggestion from Dr. Jacques Loeb—each year corresponds almost exactly to the number of young men hired to study in the particular institution. So many fellowships, so many doctors of philosophy. Very few of these stall-fed scholars have the courage or the conscience to do independent work after the outside stimulus is withdrawn.

Within the walls of the academy the place of the investigator is not sure. Temptations assail him here from within and from without. One of the meanest is the impulse to acquire a reputation cheaply, to conduct his researches under the lime light, making great discoveries while the printer waits. Yet our newspapers are full of grave discussions of the outgivings of these lackeys of science. Almost equally cheap is the temptation to publication for publication's sake, to have something in the market, something to serve at the show-down to show to the advantage of the writer or of his university.

On the other hand, the pressure of university duties often gradually extinguishes the investigator in developing the teacher. The college professor has many students to look after, many committee meetings to attend, many papers to read, many lectures to give, many whist parties to go through—many mouths to feed, while the apparatus rusts, the specimens gather mold or go to feed the *Dermestes,* while the half-begun manuscript is laid away for the season which never comes. Too often the young investigator, transplanted from the German hot-bed, with the easy success of the easy thesis, finds no adequate impulse to continue his work. Nobody cares for his conclusions, nothing depends on them. His place is secure and becomes more so from year to year, and at last instead of fanaticism for veracity, we find a mild form of approval of truth.

Besides all this there are many counterfeit presentments of investigation. Some years ago I had occasion to say:

"I am well aware that there is a cant of investigation, as of religion and all other good things. Germany, for example, is full of young men who set forth to investigate, not because they 'are called to explore truth,' but because research is the popular fad, and inroads into new fields the prerequisite to promotion. And so they burrow into every corner in science, philology, philosophy and history, and produce their petty results in as automatic a fashion as if they were so many excavating machines. Real investigators are born, not made, and this uninspired digging into old roots and 'Urquellen' bears the same relation to the work of the real investigators that the Latin verses of Rugby and Eton bear to Virgil and Horace. Nevertheless, it is true that no second-hand man was ever a great teacher. I very much doubt if any really great investigator was ever a poor teacher. How could he be? The very presence of Asa Gray was an inspiration to students of botany for years after he had left the class-room. Such a man leaves the stamp of his greatness on every student who comes within the range of his influence."

Besides all this, the work of research itself has its difficulties and its limitations. Too often fanaticism for veracity is subtly transformed into fanaticism for an idea—just plain fanaticism—the farthest removed from the open-mindedness which is the sole condition of knowing the proclaiming truth. To proclaim an error in good faith and then to discard it when the real truth appears, is a great strain on human nature. Hence research gives place to partisanship, and there are not many times when a man of science should be a partisan. When such times come, when we have the whole truth lined against all error, there is not much question as to the outcome of the struggle, and the investigator is not needed in the fight. He can afford to let the battle go on to its natural end while he forges new arms for new struggles in new places. There was no need for Darwin to combat the attacks made on the Darwinian theory. It could take care of itself. There were better things for the master to look after. In fact all scientific controversies are essentially unscientific. It is a little more than a century since the great war of the Plutonists and Neptunists was on in geology. The battle was not fought out by the doughty combatants on either side, but by men outside the struggle who brought new truths unknown to the controversialist. Desmarest mapped the volcanoes of Auvergne, and his answer to the question as to the origin of deposits was simply, 'Go and see.' The rocks will tell you. And in London the answer of Sedgwick and Murchison was not different. Let us make a geological map of England; then the rocks will tell us where they came from and the conditions of their deposit.

Yet whatever the discouragements within or without, we have in America two splendid sources of encouragement in scientific research. Ours is a motor country with a democratic people. Every impulse is toward action. Each thought finds its end in doing something. And this makes for zeal in science. It makes for the saving in time. It makes for singleness of heart. For to engage in scientific research is really to do something. It is not talk. It is not meditation. It has an end in view and this end must be reached by activity. Science is positive, aggressive, dynamic. It does not spring from lethargy, and the lands of physical inactivity are lands of scientific ignorance. To be in the forefront of action is a pledge of ultimate leadership in science. This pledge America has given and this she has begun to redeem. It is already true that no other country in the world has done so much as our own in scientific investigation carried on for the benefit of the people and at the people's expense.

The spirit of democracy favors the advance of science. Democracy seems at first to level, because it tears down all artificial props. All men start alike, and all ideas must struggle alike for existence. The tradition of a thousand years to a democracy, is, to borrow Huxley's phrase, 'but as the hearsay of yesterday.' And this should be true of all tradition in the face of truth. A truth is valued for what it is —nothing more. In a democracy truth stands on its own feet, as a man ought to, and it may be assailed from any side. Tradition does not help it, and there is no weight in authority. Democracy at least brings each one to his own. It is not a leveler. It is the great unequalizer, the power which makes each man equal to his own fate, regardless of the fate of all other men. And as no two men deserve the same in life, fair play must end in final inequality.

In the field in which I have worked, that of systematic zoology, it is easy to notice the influence of political conditions on the individual point of view. The American worker applies his rules regardless of whether they affect great men or small. He knows no tradition large enough to check the movement of science. Among the Scandinavians and the Dutch, in nations too small to obscure the democracy of learning, we find much the same feeling. In France, in Germany, even in England, the tradition of great names, the customs of great museums, largely outweigh the testimony of the things themselves. It has taken a long time to bring about in these countries the application of the simple and necessary law of priority in nomenclature. To this law all naturalists have assented in theory, but with the reserve of exceptions in favor of great men or the traditions of great museums. The willingness to adopt new views, to utilize new classifications, to see things in new lights, is, broadly speaking, in proportion to the spirit of democracy by which a worker is surrounded. A perfect democracy means a perfect perspective—each man, each idea, each theory standing for what it is, with all the 'covering of make-believe thrown off.' For the zealous search in which we meet as comrades is the worship of the greatest God known to religion, the God of the things as they are.

And here come the reasons why even the prophets of civilization should cultivate the virtue of modesty. The universe, of which we have explored a few points, is so gigantic in space, so monstrous in duration, that it baffles all our powers of collective thought to conceive of its existence. 'Time is as long as space is wide.' We can not picture the universe as limitless in space or in time, nor can we think of it as having bounds in distance or in duration. And with all its grandeur, it is so finely put together, so delicately adjusted, so eternally interdependent, that the smallest of all its parts is as large as the largest, that if another atom could be brought in from beyond the range of space and added to its infinite side, even if this were done only a moment after time should cease to be, the whole mass of eternity might be thrown from its bearings, its adjustment destroyed and the creation of æons of evolution flung back into primitive chaos. Or again, may be not this, but something else might happen, for likely enough matter is nothing substantial at all, but each molecule merely the vortex of a whirling current of force. Wherefore, bearing on our scientific shoulders the vastness of a universe whose elements are unknowable, unthinkable, 'solid and substantial, vast and unchanging,' we may well, to-night, as Thackeray once said on a similar occasion, say, 'We may well think small beer of ourselves and pass around the bottle.'

THE PREDECESSORS OF COPERNICUS.

By EDWARD S. HOLDEN, Sc.D., LL.D.,

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THE records of the earliest Greek astronomy are very meager. Pythagoras, in the sixth century B. C., held that the heavenly bodies, the earth included, were spheres. Pythagoras is supposed to have known that lunar phases were caused by illumination from the sun; and the curved line separating the bright and dark parts of the moon throughout the month would naturally suggest that it was not a flat disc but a globe. He imagined all the stars to be fixed to a crystal sphere which daily turned round the earth and produced their rising and setting. Each of the seven planets (sun, moon, Mercury, Venus, Mars, Jupiter, Saturn) was attached to a sphere of its own, and their turning made harmonious sound—the music of the spheres. The distances of the several spheres were assigned in accordance with certain laws of music that Pythagoras had himself discovered. The idea of a spherical earth is thus some twenty-five hundred years old.

Philolaus, a Phythagorean of the fifth century B. C., maintained that the earth and all the planets (including the sun) revolved about a central fire. The idea of a moving earth was, therefore, not unfamiliar after his time and Copernicus quotes the Phythagoreans as authorities in the first chapters of his book *De Revolutionibus Orbium Cœlestium* (1543). But the sun was not the central fire in their system, as it is in nature. "This world Pythagoras and his followers asserted to be one of the stars, and they also said that there was another opposite to it, similar to it; and they called that one Antichthona; and he said that both were in one sphere which revolved from east to west, and by this revolution the sun was circled round us; now he was seen, and now he was not seen. And he said that the fire was in the center of these, considering the fire to be a more noble body than the water and than the earth, and giving the noblest center" (Dante, *Convito,* iii., chap. v.). The Pythagoreans took the sun to be about three times the distance of the moon from the earth.

We know too little of the reasons that led Aristarchus of Samos, in the third century B. C., to hold that the sun was motionless at the center of the celestial sphere and that the earth revolved about him, rotating on her axis as she went. He taught also that the fixed stars are at rest, and measured the sun's apparent diameter, fixing it at half a degree. The little that remains of his writings gives the very highest idea of his originality and practical genius.

The views of Aristarchus on the system of the universe are reported by Archimedes. "The World," he says, "is by the greater part of astronomers called a sphere whose center is the center of the earth and whose radius is the distance from the earth to the sun. But Aristarchus of Samos, in quoting this opinion, refutes it. According to him, the world is very much greater; he supposes the sun to be immovable, as also are the stars, and he believes that the earth turns round the sun as a center, and that the magnitude of the sphere of the fixed stars, whose center is that of the sun, is such that the circumference of the circle described by the earth is in proportion to the distance of the fixed stars as the center of a circle is to its surface." Copernicus himself did not announce and describe his system with the magistral completeness and brevity of these few words. It is clear that we have here not only the view of Aristarchus, but also the opinion of Archimedes. We must assume that this announcement was unknown to Copernicus who reports the misty theories of the Pythagoreans, but makes no mention of Aristarchus in this connection.*

Plato (428–347 B. C.) taught that the earth was the center of celestial motions and that the planets and stars revolved about it on eight concentric spheres or circles. He plainly states that the moon shines by the sun's reflected light. Plato was not primarily an astronomer, and in fact held astronomy to be less dignified than the pure geometry that underlaid celestial motions, but his astronomical opinions were always of influence, especially in the orient where he held a high authority. He expressed and enforced the general idea that the heavenly bodies, being perfect in their essence, must necessarily revolve in circles, and with uniform, not variable, motion.

Eudoxus of Cnidus (409–356 B. C.) elaborated the ideas of Plato into a scientific system. By this time the simpler motions of the moon were well known, and to account for them he found three spheres to be necessary. One produced its daily motion of rising and setting, another its monthly motion from west to east, while the third had to do with its motions north and south of the ecliptic. The sun was likewise provided with three spheres, and each of the planets had four (since the planets sometimes appear to 'retrograde' from east to west, though their usual progress is from west to east). The system of Eudoxus thus required twenty-seven spheres; one for the fixed stars, twenty for the planets, six for the sun and moon. It is not probable that Eudoxus and his school regarded these spheres as material crystal shells, but rather as geometrical and abstract vehicles for the resolution of observed mechanical movements into intelligible parts. But the notion of material crystal spheres perpetually recurs in Greek astronomy after his day, and was universally held by the vulgar.

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* Copernicus had access to certain large collections of books and the catalogues of these collections exist to-day. I have had them searched and the works of Archimedes are not there mentioned.

Consider, for an instant, what is involved in the theory of revolving material crystal shells. The stars are at an immense distance, all fixed to a crystal surface, which revolves once in twenty-four hours. The sun is situated on the surface of another shell, but it can not be in one fixed spot on the surface, for we see it rise and set at different points of our horizon at different times of the year. What kind of a crystal shell is it upon which the sun can glide so far and no farther? No wonder that certain medieval writers felt the necessity of imagining two shells for each luminary between which the motion took place with freedom, beyond which there was no passage. What sort of shells are those that correspond to the planets, each of which moves at various rates in varied directions—sometimes eastward, sometimes westward, sometimes north, sometimes south? The details of a scheme like this are literally unthinkable. It must be accepted, if at all, by faith—by a faith founded in phrases.

The ancient astronomers did not, in general, seek knowledge for its own sake. They were either concerned about some practical matter, as the length of the year, the prediction of the seasons and the like; or else sought acquaintance with some aspect of divine or partly divine matter, such as formed the planets and the stars. The science of the middle ages has been summarized in a sentence: 'It was all divination, clairvoyance, unsubjected to our modern exact formulas, seeking in an instant of vision to concentrate a thousand experiences' (Pater). A few of the ancients, Archimedes and Aristarchus, for example, had what we call the modern spirit. Roger Bacon was the first to formulate it. Newton may be taken as its first thorough-going representative, for even Kepler and Galileo were deeply tinged at times with the medieval color.

The *Meteorologica* and the *De Cœlo* of Aristotle (384–322 B. C.) were the text-books of the middle ages. The doctrine of material spheres was frankly adopted in these books and in the writings derived from them. The geometric scheme of Eudoxus was transformed into a clumsy mechanism, and its complexity was further increased by the addition of other spheres, so that fifty-six in all were necessary to explain celestial motions. "The glorious philosopher, to whom nature opened her secrets most freely, proved in the second chapter of his *De Cœlo,* that this world, the earth, is of itself stable and fixed to all eternity. . . . Let it be enough to know, upon his great authority, that this earth is fixed and does not revolve, and that it, with the sea, is the center of the heavens. These heavens revolve round this center continuously even as we see" (Dante, *Convito,* iii., chap. v.). Until we remember that mechanics was an unknown science to the ancients and in the middle ages, it is almost impossible to conceive how professors could teach, or students accept, a system like Aristotle's that was, in essence, unintelligible. While Cremonini was expounding the *De Cœlo* in one lecture-room at the University of Padua in 1592, Galileo was teaching the Euclid's *Elements* in another. It is easier to comprehend how students flocked to listen when a few years later Galileo began his lectures upon astronomy, although by the conditions of his professorship he was only permitted to expound the astronomy of Sacro Bosco.

Aristotle taught that the earth was spherical and gave reasons, good and bad, for his belief. The distance of the sun was fixed by a most ingenious method invented by Aristarchus of Samos (270 B. C.) who concluded that the sun was about 19 times more distant than the moon (it is, in fact, 390 times more distant). Hipparchus determined the moon's distance for himself* and took the sun to be 19 times more distant. He did not leave the earth in the central point of the sun's orbit, but shifted that center towards the sixth degree of *Gemini* by one twenty-fourth of the radius so as to account for observed inequalities in the annual motion. Ptolemy adopted this result without question, and it was accepted by astronomers for twelve centuries. It was not until the time of Kepler that it was proved that the sun must be at least fifty times as far away as the moon. This was one of the consequences of Tycho's accurate observations.

The Chaldeans and Egyptians held the earth to be a flat disc canopied by the sky—the firmament—and this was the view of the Hebrews. A distinctly Christian theory of the figure of the earth and heavens, drawn from scripture, was formulated by the Egyptian monk and traveler Cosmas Indicopleustes. According to this theory, the earth was a flat parallelogram surrounded by the four seas. "We say, therefore, with Isaiah, that the heaven embracing the universe is a vault; with Job, that it is joined to the earth; and with Moses, that the length of the earth is greater than its breadth." This explanation of appearances was very generally accepted as orthodox, and was held by the common people long after the learned had been convinced of the earth's sphericity by the arguments of Ptolemy and Aristotle. Isidore of Seville in the seventh century, and the Venerable Bede in the eighth, declared for the opinion of Aristotle; Dante in the thirteenth century supported it, and Columbus proved it in the fifteenth. In the sixteenth, Magellan's voyage of circumnavigation settled the vexed question once and for all.

There is in the library of the University of Cambridge, so Dr. Whewell reports, a French poem of the time of Edward the Second (1307–27) illustrated with drawings that show men standing upright on all parts of a spherical earth. By way of illustrating the tendency

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* He fixed the greatest distance of the moon at 78, the least at 67, semi-diameters of the earth. The mean distance is, in fact, 60. The distance of the sun, according to Hipparchus, was 1,300 semi-diameters. It is really about 23,000.

of heavy bodies towards the earth's center other men are dropping balls into holes bored entirely through the globe and these balls are falling to the earth's midmost point—

That point to which from every part is dragged all heavy substance,

as Virgil explains to Dante in the thirty-fourth canto of the *Inferno.* The cosmogony of Dante in the *Divina Commedia* was accepted for centuries by Roman Catholics, as Milton's in the *Paradise Lost* has been adopted by protestants. For Dante the globe of the earth was the center of the world. It was surrounded by nine transparent spheres moved by angels. There was a crystal sphere for the moon, and others for Mercury, Venus, the sun, Mars, Jupiter, Saturn and the fixed stars, and beyond them the *Primum Mobile*—nine in all. Beyond the outer sphere was the *Empyrean*—here God sate. Below the earth is hell and here its god—Lucifer—reigned over bad angels. All the discord in the world came from them, even its storms, hail and lightning. The spheres of Eudoxus served as a base to Dante's system, which was adapted, with a poet's license, to a poet's use.*

In the *De Cœlo,* Aristotle lays down certain fundamental principles: The things of which the world is made are all solid bodies, and all have, therefore, three dimensions. The simple elements of nature must also have simple motions. So, indeed, fire and air have their natural motions upwards, water and earth, downwards, both in straight lines. But besides these motions there is also a circular motion, not natural to these elements, although it is a much more complete motion than the rectilinear. For the circle is, in itself, a complete line, which a straight line is not: There must, therefore, be certain things to which complete circular motion is natural: It follows that there must be a certain sort of bodies very different from the four elementary bodies, bodies that are more godlike, that must therefore stand above them: This finer essence was later named by the commentators 'Quinta Essentia'—our quintessence. The heavenly bodies are formed of this; they are spheres endowed with life and activity.

The question of the revolution of the earth in an orbit round the sun is discussed by Aristotle, and he rejects the idea for the reason that such a motion would necessarily produce a corresponding alteration in the place of each and every fixed star. The objection was perfectly valid. If the stars were only a little farther from us than Saturn, as Aristotle believed, a motion of the earth in an orbit would cause each star to move in an apparent parallactic orbit, a miniature copy of that of the earth. No such alteration of place was observable. Hence, said he, the earth did not move. Even the nearest stars are,

* The upper regions of Paradise contained the narrow-minded monks of the middle age as well as the great saints. The wisest and most virtuous heathens, like Virgil, were in *Limbo*—which, it has been remarked, contained the 'best society.' Outcasts from all religions, and sinners of all sorts, were in Hell.

we now know, twenty thousand times as far from us as Saturn, and it is this fact—which was not finally established till 1837—that explains why the miniature apparent orbits of the stars were not seen by the Greeks or by their successors. They were too minute to be discoverable.

All the important writings of Hipparchus, who lived in the second century B. C., are lost, and the doctrines of this 'most truth-loving and labor-loving man' are known to us only through Ptolemy, his expositor and ardent admirer. Hipparchus was an indefatigable observer, a mathematician of tact and insight, an astronomer of original and profound genius. By his own observations, made at Rhodes (188–127 B. C.), he fixed the positions (the celestial longitudes and latitudes) of the principal fixed stars. Comparing their present places with their past positions as determined by Timocharis and Aristillus, he discovered that backward motion of the equinoctial points which causes the epoch of the sun's passage through the equinox to recur earlier and earlier each year—the precession of the equinoxes—and fixed its probable annual amount. Comparing his own determinations of the date of the vernal equinoctial passage of the sun with those of Aristarchus, he determined the length of the year with accuracy.* It is by systematic comparisons of the sort that many of his discoveries were made.

It is very noteworthy that he gives not only his results, but likewise an estimate of their probable errors. His observations of the time of the sun's arriving at a solstice might be erroneous, he says, by about three fourths of a day; at an equinox by about one fourth. Comparisons made in this systematic fashion, and estimates of error of this sort, we are apt to think of as 'modern.' Certainly they are not characteristic of observational astronomy till the eighteenth century, two thousand years after Hipparchus showed the way. Some of his most important researches related to measures of time. What was the length of the year? Were all years of the same length? His observations showed him no difference between one year and another. It is interesting to note how he formulates his conclusions. He does not say that all years are, without doubt, of one and the same length; he asserts simply that the differences, if any, must be very small, so small that his observations are not delicate enough to detect them.

In the year 134 B. C. a new star suddenly appeared in *Scorpio,* and Hipparchus began the formation of a catalogue of stars visible to him. With such a conspectus of the present state of the sky no new appearances could subsequently occur without detection. His catalogue gave the position and magnitude (brightness) of 1,080 stars for the epoch 128 B. C., and arranged them in the constellation figures that have

* Hipparchus fixed the length of the tropical year at 365 days 5 hours 55 minutes. Its true length is 365 days 5 hours 48 minutes 45.51 seconds (1900).

come down to us only slightly changed.* Hipparchus' catalogue stood unique for a thousand years.

An instance of his practical tact as an observer may be quoted. If a straight ruler be held up against the starry sky there will, now and again, be instances where its edge passes through three stars at the same time. Many such cases are recorded by Hipparchus. No one of the three stars can change its situation without detection. A simple observation of the same sort at any subsequent time will at once exhibit any change that may have taken place in the interval between the two observations.

The work of Hipparchus as a theoretical astronomer is as remarkable as his observing skill. The positions of the heavenly bodies are calculated by solving triangles, both plane and spherical. The doctrine of such solutions—trigonometry—was perhaps invented by him; at all events it was greatly developed and improved. Observations give the celestial longitudes and latitudes of planets at the instant of observation. Their positions at past epochs, a month or a year ago, are given by preceding observations of the same sort. Where will Jupiter or Saturn be found in the future—a month or a year hence? It is necessary to invent a geometry of planetary motion that will account for all past and future motions; and this problem was elaborately developed by Hipparchus. We must recollect that his vast activity was exercised under conditions of the most discouraging kind. His best instruments were but rude; all sightings were made with the eye unaided by telescopes; he had only clepsydras (sand or water-clocks) to measure intervals of time; the Greek system of arithmetic in which his calculations were made was cumbrous in the extreme. What he accomplished is little less than astounding.

From his theory of Epicycles Hipparchus was able to construct his tables of the sun and moon. The tables gave the particulars of the motion of these bodies and enabled predictions to be made of coming solar and lunar eclipses. It was sufficient for the purposes of the time to assert that an eclipse would occur on a certain day, about a certain hour of the morning or afternoon, and the tables were adequate to such predictions. His theory was sufficient; it fulfilled all the tests applied to it. The motion of the moon was more complex than that of the sun, but it, too, was reduced to a sufficient order and important discoveries made. The elements of the motions of these bodies were not derived, as we to-day derive them, from continuous observations, but rather from observations made at certain critical times. For the sun the observations were made at the equinoxes and solstices. Six eclipses of the moon sufficed to give him the elements of the lunar orbit and the rate at which they were changing.

* Our constellation figures are those designed by Albrecht Dürer on the star maps of Stoeffler and Heinfogel from the descriptions of Ptolemy.

His theory of the planets was not so complete, for there was no sufficient body of ancient observations to be compared with those which he himself accumulated with so much diligence. Considering the data at his disposition and the use made of them, the work of Hipparchus is of the first order. Astronomers of all ages are agreed that he was 'one of the most extraordinary men of antiquity; the very greatest in the sciences that require a combination of observation with geometry' (Delambre).

His expositor, Ptolemy of Alexandria, was primarily a geometer and made few original observations. The *Almagest* is, in essence, a restatement of the theories of Hipparchus with additions, not all of which are improvements. It begins by laying down certain postulates: The earth is spherical and a mere point in respect of the heavens; its circumference is 180,000 *stadia;* the heavens are likewise spherical and revolve about the earth, which is in the center and has no motion. So far he is in agreement with Aristotle. Where he differs, astronomers who succeeded him followed the *Almagest* while philosophers were more apt to take Aristotle as authority.

Ptolemy's theory of the moon's motion led him to important discoveries, which need not be described here. It is mentioned because it also contained a contradiction of the precise sort that is best suited to lead to further discoveries, and because this contradiction was passed over and entirely neglected by him and by his successors for centuries. His theory gave the position of the moon with satisfactory accuracy. It was, in so far, presumably true. It assumed that at times the moon was twice as far from the earth as at others. If this were true the moon's apparent diameter should sometimes have been twice as great as at other times. But no such variation was observed. The necessary conclusion: Hence the theory can not possibly be true—was not drawn by Ptolemy. The instance is significant; it marks a radical difference between the modern attitude and that of the ancients in matters of physical science. Ptolemy and his successors really held two antagonistic theories of the moon's motion and distance at the same time. Each theory satisfied the conditions of part of the problem. They did not seek for a unique theory. This was not done until the time of Kepler, whose whole life was spent in searching for the physical causes of observed phenomena, and who was not content with mere analytic devices by which the phenomena could be predicted. He sought for these, but he looked deeper and further.

All but a few of the greatest of the ancients regarded a physical problem in the light of a riddle to which an answer was required. Any plausible answer would do. The fixed belief that there was one answer and could be only one did not arise till quite modern times. Modern science is a search for such unique solutions. Most of ancient science was a search for an hypothesis to account for a set of observed facts.

A page from Ptolemy's note-book may be transcribed. He was seeking the position of the bright star *Regulus:* "In the second year of Antoninus, the ninth day of Pharmauthi, the sun being near setting, the last division of *Taurus* being on the meridian (that is 5½ equinoctial hours after noon) the moon was in three degrees of *Pisces* by her distance from the sun (which was 92° 8′); and half an hour after, the sun having set, and the quarter of *Gemini* on the meridian, *Regulus* appeared, by the other circle of the astrolabe, 57½ degrees to the eastward of the moon in longitude." The position of the sun was known from the day of the year by the solar tables; the moon, at 5½ hours, was 92° 8′ east of the sun; the moon's motion in half an hour was also known from the tables, and hence her position at 6 hours was determined; *Regulus* was at that time 57½ degrees east of the moon, and its place was thus fixed with respect to the sun. A modern note-book would give the year and day, and would record that *Regulus* crossed the meridian at a certain hour, minute, second and decimal of a second by the clock. The correction of the clock would be given as so many seconds and hundredths of a second. The sum of the clock-time and the correction is the position of the star. In Ptolemy's case it was known to half a degree (two minutes of time). A modern observation gives it with an error not above one tenth of a second; that is with an accuracy about 1,200 times greater.

Ptolemy's *Almagest* is, in essence, 'modern' in respect of the fact that its theories are designed to give quantitative results and are presented as general bases for special calculations. With a certain set of observations as data the desired results could be worked out in numbers. Tables for calculating future positions of the planets were also given and in Ptolemy's time the actual positions were fairly well represented by the predictions. As time went on, more accurate observations with better instruments, were made. The observed places of the planets did not agree with the predictions. The ingenuity of his disciples in the middle ages was taxed to improve the theory, and the tables of Ptolemy were supplanted in turn by the Hakemite tables of Ibn Yunus (about A. D. 1000), the Toledan tables of Arzachel (1080), the Alphonsine tables of Alphonso the Wise (1252) and others. Finally, in the first half of the sixteenth century it became evident that Ptolemy's theory was itself gravely at fault. It was the fortune of Copernicus to open a new way to scientific thought—to lay down a new theory of the world.

The details of the long history thus sketched out are only interesting to astronomers.* We are here concerned with the main outlines alone.

* They are given in clear form in various encyclopedias and other books of reference. Perhaps Berry's *Short History of Astronomy* (1899) will best serve the purpose of the general reader. Gyldén's *Die Grundlehren der Astronomie* (1877) develops the mathematical bases of ancient astronomy in an elementary form. Delambre's *Histoire de l'Astronomie* is still the best general history.

The Arabian school of astronomers added nothing to the theory of Ptolemy. They transmitted the text of the *Almagest* to the west accompanied by intelligent comment and almost without criticism except in the cases of Alpetragius and Geber. The Arab observations were very numerous, and resulted in fixing new and much more accurate values of the constant of precession, the length of the year, the obliquity of the ecliptic, the eccentricity of the sun's orbit and the motion of its apogee. Their arithmetic was the clumsy sexagesimal arithmetic of the Greeks, until in the eleventh century the Hindu decimal system began to make its way in Egypt, Spain and Europe. Geometry is not indebted to the Arabs for any marked advances. On the other hand, trigonometry was greatly improved.

As observers the astronomers of the Arab school had great merit. They grasped the need for continuous observations, whereas the Greeks in general had contented themselves with making observations at certain critical times only—at the solstices and equinoxes, for instance. The Arabs were the first to assign the exact time at which any phenomenon occurred—a fundamental datum. They measured the altitude of the sun at the beginning and ending of solar eclipses, for example, in order that the time might be known. The calculation of a spherical triangle enabled the instants of beginning and ending to be accurately assigned. The Greeks never employed this device and the times of phenomena recorded by them are seldom known with any accuracy. Indeed Ptolemy has no formula by which to calculate the time when the sun's altitude is given, and it is noteworthy that the Arab device was not known in Europe until 1457, when Purbach used it for the first time. Yet it was employed at Bagdad at the solar eclipse of A. D. 829, six hundred years earlier. Even the times of phenomena recorded by Tycho Brahe in 1600 are seldom known so close as a quarter of an hour. Short intervals of time were measured by the Arabs by counting the beats of pendulums.

A few of the greatest Arabians are named in what follows. Albategnius was an Arab prince of Syria who flourished at the end of the ninth century of our era. His observations were made at Aracte (Rachah) in Mesopotamia and at Antioch, between the years 878 and 918. After studying the *Syntaxis* of Ptolemy he set himself to correct the errors of its catalogue of stars by observations of his own, made with apparatus fashioned after Ptolemy's descriptions. It appears that some of his instruments could be read to single minutes (1′) and were divided possibly to 2′ (or it may be to 6′). He detected the change of position of the sun's apogee, determined the obliquity of the ecliptic, the length of the year, the precession-constant (54″), observed and calculated solar and lunar eclipses and computed new tables of the planetary motions, although he did not seek to improve Ptolemy's planetary theory. He was original and inventive as an observer; a sound mathematician; an expert and careful computer; and he introduced marked improvements in the methods of calculation. He holds the very first rank in the Arabian school. In his trigonometry he substituted sines for chords; reduced the calculation of spherical right triangles to four cases; and possessed a general rule for the solution of oblique spherical triangles in the cases (I.) given a, b, c, required A; (II.) given a, b, C, required c; was acquainted with the doctrine of tangents and cotangents, though he made no useful application of it; and seems to have known something of secants and cosecants. To understand his exact merits as an observer, it would be necessary to go into details that have no place here.

Ibn Yunus, the scion of a noble family, was the astronomer-royal of the Fatimite Caliphs of Cairo, where he constructed the Hakemite tables, in 1008, from his own observations. Comparing his own observations with those determined by Hipparchus or Ptolemy, he obtained accurate values of the changes that had supervened. They were accurate for two reasons: In the first place, the modern observation was very near to the truth; and in the second, the annual change was better determined the greater the interval of elapsed years. Albategnius and Ibn Yunus were 800 years after Ptolemy, while Ptolemy was but 263 years after Hipparchus, and Hipparchus but two centuries after Timocharis. The divisors increased with the lapse of time.*

"At Nishapur lived and died (early in the twelfth century) Omar Khayyam busied in winning knowledge of every kind, and especially in astronomy, wherein he attained to high preeminence. When Malik Shah determined to reform the calendar, Omar was one of the eight learned men required to do it; the result was the Jalili era, 'a computation of time,' says Gibbon, 'which surpasses the Julian and approaches the accuracy of the Gregorian style.' He is also the author of astronomical tables, and of a treatise on algebra" (Fitzgerald).

It is interesting to note that the Bagdad astronomers observed an eclipse of the sun by its reflection in water. The obliquity of the ecliptic for the year 1000 Ibn Yunus found to be 23° 33′ (the true value is 23° 34′ 16″). The latitude of Cairo he determined to be

* It may be remarked, in passing, that the foregoing explains how it is that Copernicus and Kepler had such accurate values of the periods of revolution of the different planets. Hipparchus noted, for example, that Mars was in conjunction with a certain star—Sirius for instance, on a certain day. Tycho, 1700 years later, observed that Mars was again in conjunction with Sirius on a certain day, at a certain hour. In the seventeen centuries that had elapsed, Mars had made about 860 revolutions. The interval of time between the two epochs, divided by the number of revolutions, gave the time of revolution with great exactness. On the other hand, the distance of Mars from the sun was only roughly known, even to Kepler. Of the dimensions of the planets nothing was known until their apparent angular diameters had been measured with the telescope. Anaxagoras held that the sun was about the same size as the Peloponesus.

30° (the true value is 30° 2′). Like all the Arabs he adopted the theories of the *Almagest* without change;* but his observations were materially better than Ptolemy's and his numerical results were, consequently, much more accurate. What is said of Ibn Yunus is, in general, true of the whole school of Arab and Moorish astronomers.

Ibn Yunus was acquainted with the Indian numerals 1, 2, 3, 4, 5, 6, 7, 8, 9, and used them occasionally in place of the clumsy Greek system, and he also introduced tangents and secants into trigonometry, as well as auxiliary angles (which latter were not used in Europe till the eighteenth century), but he continued to calculate triangles by formulæ involving sines only. Abul-Wafa of Bagdad (940–948) gave the formulæ relating to tangents and cotangents, and also to secants and cosecants, and even calculated tables of tangents; though he also stopped short of useful applications that were well within his reach. The science of trigonometry was, however, built up by Arabs, and the way was prepared for Vieta, who is the founder of the accepted doctrine. Abul-Wafa is the discoverer of the third inequality of the moon—the variation. Observing at a time when the first and second inequalities (discovered by Hipparchus and Ptolemy) had no effect, he noticed that the moon was a degree and a quarter from her calculated place. "Hence," he says, "I perceived that this inequality exists independently of the two first." This discovery remained unknown in Europe for six centuries until Tycho Brahe independently came to the same result.

Alhazen was an Arabian mathematician and astronomer of the eleventh century who is noteworthy for his treatment of physical problems, especially that of refraction. Ptolemy had experimented on the refraction of glass and of water and had made out the law that the angle of refraction is a fixed submultiple of the angle of incidence ($r = 1/m \cdot i$). This was denied by Alhazen, but the true law was not discovered till the time of Willebrod Snell in 1621, who found the relation $\text{sine}\, r = 1/m \cdot \text{sine}\, i$, where m has a different value for each different substance. Alhazen's 'Optics' treats of the anatomy of the eye, and of vision, and has several propositions relating to the physiology of seeing, and it remained the standard work until the time of Roger Bacon and Vitello (thirteenth century).

The astronomical instruments of the Arabs were greatly superior to those of the Greeks. The caliphs of Bagdad and of Cairo founded observatories and supplied them generously. The grandson of Jhenghiz-Khan maintained a splendid establishment of the sort at Meraga on

* It is to be noted, however, that the theories of Ptolemy, as understood by the Arabs, made some of the crystal spheres of the planets clash; and that Ptolemy's place for Mercury was consequently changed arbitrarily to allow room for its motion! This is not a change of *theory;* but it illustrates how slavishly the doctrine of spheres was followed by some of its votaries.

the northwest frontier of Persia under Nasr-ed-Din as chief astronomer. Here the Ilkhanic tables were prepared. Ulugh-Beg, prince of Samarkand, a grandson of Tamerlane, founded a great observatory in 1420, on the hill of Kolik, where a hundred observers and calculators were employed. Albategnius, another Arab prince, possessed admirable instruments, as we have seen. Astronomy was in favor with princes and caliphs, and flourished accordingly. We have seen that some of the instruments of Albategnius read to one minute of arc (1′) and were very likely divided to 2′. The observatory of Nisapur, in Khorassan, had in A. D. 851 a huge *armilla* reading to 1′. In 992 Al Chogandi set up at Bagdad a sextant of sixty feet radius. In 1260 the observatory of Meraga possessed, among many other instruments, a mural quadrant of twelve feet radius. Ulugh-Beg had a quadrant (perhaps a species of sun-dial) that had a radius of 180 feet. Colossal instruments of the sort permitted accurate readings of angles because the space corresponding to an arc of one minute was correspondingly large. Until the invention of the telescope accuracy was only to be attained by the use of large circles, and the Arabian school anticipated Tycho Brahe in the use of such instruments by several centuries. Some of the Arabian observers employed free-swinging pendulums to measure short intervals of time; and the science of gnomonics—the theory of sun-dialing—was extensively developed by them.

This is the place to describe the system by which Ptolemy explained the world. It will be sufficient to explain the two main problems that any system of astronomy was bound to consider, and to leave details to one side. These two chief problems were: (1) How to account for the rising and setting of the sun, moon, stars and planets —how to explain the general diurnal motion of all celestial bodies; (2) how to explain the motions of the planets among the stars. These motions are, in general, towards the east—but are varied by occasional westward motions, and interrupted by periods of no motion at the 'stations.' As we have seen, Ptolemy declared the earth to be a sphere fixed in the center of the heavens. The sphere of the fixed stars was at an immense distance, so that the earth was a mere point in respect of the distance of the stars and the stars revolved about the earth. All the observed phenomena of the rising and setting of the stars are satisfactorily explained in this way. Ptolemy perfectly understood that they could also be explained by the hypothesis of a rotating earth, but he concluded that it was easier to attribute motion to bodies like the stars which seem to be of the nature of fire, than to the solid earth. The sun, moon and planets share in the diurnal motion of the stars. It will be seen that no mechanical conception of the diurnal motion is attainable in this way without the assumption of crystal spheres. Ptolemy sought an analytic device by which calculations of phenomena could be made, not a physical explanation based on mechanical laws.

The problems relating to the motions of the heavenly bodies are more complex and must be considered somewhat in detail. It is necessary to describe the observed phenomena for each body separately, and to adopt a system which will explain every phenomenon and appearance in turn.

The Moon.—The facts of observation, familiar to us all, are that the new moon sets in the west about sunset, and that on every succeeding night the moon sets at a later hour. It, therefore, moves to the east among the stars from night to night, which can readily be verified by observation. If the moon is near the stars of *Orion* on one night, it will be found many degrees to the east of them on the night following. It sets later and later every night throughout the month. If it is in the same longitude as the stars of *Orion* on any one day, it will be again in that longitude about a month (27 days) later (more exactly, $27^d\ 7^h\ 43^m\ 11^s.5$). It has moved through the whole circuit of the heavens, 360°, in 27 days. Ptolemy explained the phenomena, as we explain them to-day, by asserting that the moon revolves in an orbit, about the earth as a center, making a complete revolution among the stars (from one star back to the same star again) in 27 days. Its motion among the stars is always forward—always from west to east.

The Sun.—The observed phenomena with regard to the sun are of the same nature. If the sun rises at the same time as the bright star *Sirius* on a particular day of the year, on the next day it will rise later than *Sirius.* It has, therefore, moved a certain distance (about one degree) eastwardly during that day. On the next following day it will have moved about two degrees east of *Sirius* and will rise correspondingly later; and so on for each succeeding day. After 180 days (six months) the sun will have moved about 180 degrees to the east of *Sirius.* *Sirius* will be visible on the meridian at midnight, (when the sun is 180° away from the meridian). At the end of 365 days (more exactly, 365.2564 days) the sun will have moved eastward through 360° and will again rise at the same moment as *Sirius.* The sun, then, appears to move eastwardly among the stars (from one star back to the same star again) once in 365¼ days. At different times of the year it is among different groups of stars, and it is for this reason, therefore, that we see different groups of stars at different seasons of the year. *Orion* is visible in the winter skies, *Scorpio* in the summer, because *Orion* and *Scorpio* are 180 degrees apart in longitude. Ptolemy's explanation of all these phenomena is that the sun moves about the earth in a circular orbit at such a rate as to make a complete revolution in 365¼ days. The explanation of Copernicus is that the earth revolves about the sun in the same period.

It is to be noted that either of these explanations will completely account for all the observed phenomena.

New moon occurs when the earth, moon and sun are in a straight line. At sunset the new moon is seen in the west. After 27 days the moon has made one circuit among the stars, moving from west to east. But in those 27 days the sun has likewise moved eastwardly, about 27 degrees. The moon, then, has to make one circuit and a little more in order to be again in the line joining the earth and sun, in order to be again 'new.' The time from one new moon to the next—the lunar month—is about 29½ days (more exactly $29^d\ 12^h\ 55^m\ 2^s.9$) for this reason. Just as there is a difference between the moon's sidereal and synodic period, so there is a corresponding difference between the sidereal and tropical year, because the equinoctial points are in motion relatively to the stars.

The Superior Planets.—In the system of Ptolemy, Mars, Jupiter and Saturn were supposed to be further from the earth than the sun—to be above it—and they were, therefore, called superior planets; while Mercury and Venus were called inferior planets. The facts of observations for one of the superior planets, for Mars, for example, are as follows. If on any day Mars rises at the same time as *Sirius,* on the next day it will rise a little later, and so on. The planet, therefore, moves eastwardly among the stars. It continues its motion so that at the end of 687 days (1.88 years) the planet again rises at the same time as *Sirius.* It has therefore made a complete circuit of the sky (from one star back to the same star again) in a little less than two years. Its orbit was supposed by Ptolemy to be a circle (the deferent) about the earth like the sun's orbit. In like manner Jupiter makes a revolution in 4,332 days (11.86 years), and Saturn in 10,759 days (29.46 years). Such are the general motions of the three superior planets; but there are irregularities in their motions that must be accounted for.

For example, the actual motion of the planet Jupiter among the stars for the year 1897 is as follows: Beginning on October 28, 1897, the planet's motion is eastwards until January 22, 1898; here it turns and moves westwards until May 28; here, again, it turns and moves eastwards and its direct motion continues for the rest of its period of nearly twelve years. Ptolemy accounted for the irregularities of motion just described by supposing that Jupiter revolved in a small circular orbit—the epicycle—once in 365 days, while, at the same time, the center of the epicycle moved along the circumference of the deferent circle, making a complete revolution in about twelve years.

As time elapses the center of Jupiter's epicycle will move onwards on the deferent while Jupiter will move onwards in its epicycle. The combination of these two motions will produce a direct motion of the planet. After Jupiter has moved through a quarter of a circumference on its epicycle the planet will appear to the observer on the earth to move in a retrograde direction, because it will move to the right or left on its epicycle faster than the center of the epicycle moves to the left or right. Hence the planet will appear to an observer to be moving in a retrograde direction—east to west. The epicyclic motion combined with the motion of the epicycle forwards along the deferent will produce first the retrograde and (in the last quadrant of the epicycle) again the direct motion of the planet in the sky. By taking the diameter of the epicycle of an appropriate size all the circumstances of the apparent motion of Jupiter can be represented. The explanation given by Ptolemy is complete and satisfactory. The general motion of the planet around the sky in twelve years is explained by the motion along the deferent. Its retrogradations and stations are explained by the combination of its epicyclic motion with its general motion. A like explanation serves for the other superior planets, Mars and Saturn.

The Inferior Planets.—The inferior planets, Mercury and Venus, appear sometimes east of the sun, sometimes west of it, but are never very far distant from the sun. We see them at sunset and sunrise as the morning and evening stars, Hesperus and Phosphorus, always in the sun's vicinity. Ptolemy explained their apparent motions completely and accurately by supposing that the centers of their epicycles revolved round the circumferences of their deferents in 365¼ days; and that Mercury revolved round the circumference of its epicycle in 88 days, Venus round the circumference of its epicycle in 225 days. The sizes of the epicycles were chosen to correspond to the amount of each planet's greatest elongation from the sun. In the foregoing summary explanation only the main phenomena are described and explained. Irregularities in the moon's motion were explained by supposing that the earth did not lie at the center of the moon's orbit, but to one side; and other irregularities in the motions of the sun and planets were explained in a similar way. All motions took place in circles; the circle was the only 'perfect' curve. But the circles were eccentrics; the earth did not lie at their centers.

The periods of revolution of the planets were known to Ptolemy, but he knew little of their distances and nothing of their actual dimensions. The moon, he knew, shone by reflected light from the sun and he explained the lunar phases in this way, as is done to-day. The planets he supposed to shine by their own light, just as the fixed stars do. Astronomy to-day asserts that the planets, like the moon, shine by reflected light, and that the fixed stars are suns situated at immense distances.

Ptolemy solved the problem of the universe by solving the problem of the motion of each planet separately and by annexing each solution to the others. He never sought, it seems, for a single law governing all the cases. But such a law is patent. The radii of the epicycles of the superior planets are always parallel to the line joining the earth and the sun. The deferents of Mercury and Venus were really identical with the sun's orbit. It would seem that these very obvious laws could not escape a geometer of the caliber of Ptolemy. It appears that he never attempted the generalization; nor did his successors till the time of Copernicus. Each case was treated separately. When each was solved the explanation was complete. It required fourteen hundred years to make a generalization which is, in reality, simple, almost obvious.

Ptolemy's explanation of the system of the world accounted for all the facts known to him. As time went on, those assiduous observers, the Arabians, discovered other irregularities in the lunar and planetary motions unknown to Ptolemy. Every new irregularity required a new epicycle to explain it and in time the commentators of Ptolemy had added cycle on cycle, orb on orb until more than sixty spheres were necessary. The system lost its simplicity as more and more facts had to be explained and became a tangle of single instances, a web of particularities. It was never refuted. It broke of its own weight. The heliocentric hypothesis of Copernicus explained all these matters so simply, so convincingly, that it was soon adopted by all competent persons who examined it. The simplicity of a hypothesis is, of course, no evidence of its truth. Many modern theories are complex to a degree, but this is no proof that they are not true.

A layman seldom understands the attitude of a man of science towards 'theories,' as they are often half-contemptuously termed. Theory is popularly used as a synonym of opinion. 'His theory' is thought of as merely 'his opinion.' When, let us ask, is a science perfect? It is perfect when the circumstances of a phenomenon that is to occur in the future can be as accurately predicted now, as they can subsequently be observed when the actual phenomenon occurs. The 'theory' of transits of Venus over the sun's disc is practically perfect. We can predict the conditions of the next transit in A. D. 2004 almost as well as the astronomers of that day can observe it. The theory of Neptune's motion is so well known that the position of the planet in 1999 can be now predicted almost as accurately as it can be observed in that year. The theory of the circulation of the sap in plants is, on the other hand, far from perfect. We understand its general laws very well, but it is quite impossible to predict the circumstances for any particular plant in any particular season. The theories of hail, of lightning, of auroras and many others are in the same state.

It is obvious that if our own methods and instruments of observation are greatly improved at any particular epoch the science to which they belong will cease to be perfect even if it were a perfect science in the first instance. Tycho Brahe observed the longitudes of the stars by the naked eye. It is impossible, as we now know, to fix a longitude by such observations within one minute of arc (1′). This depends on the very constitution of the eye. When the telescope was invented and provided with a micrometer it became possible to fix star-places to within about one second of arc (1″). Tycho's observing science, perfect in his day—incapable of further improvement—was no more than a rude approximation to Bradley, Astronomer-Royal of England in 1750. Bradley's tests were at least sixty times more delicate (1′ = 60″). Examples of this sort show how theories are held. Certain tests are now available—tests of a certain delicacy. When phenomena can be predicted beforehand as well as they can be subsequently observed, science is perfect up to that point. Increase the delicacy of the tests and a new standard is set up. Wave-motion was pretty well understood at the end of the nineteenth century until the X-rays came and refused, at first, to be reflected, refracted or polarized.

We in our day have learned a patient tolerance of opinion; wait, these theories that seem so baseless may, perhaps, come to something, as others have done in the past. To what especial and peculiar merit do we owe this acquired virtue of tolerant patience? It is owed solely to the experience of centuries. We have so often seen the impossible become the plausible, and at last the proved and the practical. Can we justly expect that our frame of mind—the strict result of centuries of experience—should have been the attitude of the doctors of the middle ages? Galileo was a great physicist: would not even he require time to accept our modern cobweb theory of the constitution of matter with its ether, molecules, atoms, electrified and non-electrified half-atoms, ions, dissociation, radio-activity and the like? Centuries of experience have taught us to hold theories lightly even while we are using them for present interpretations of phenomena. What physicist doubts that our present theory of electricity needs a thorough-going revision? And yet, who fails to use it where it can serve even a temporary purpose, foreseeing all the while new interpretations in the future?

The fundamental necessity in studies like the present is to *realize* the state of mind of our heroes and of the communities in which they lived. The only data are the words of the books they have left us.

How to interpret their words *in their sense* is the central difficulty; it is often most misleading to interpret them in our own. 'Do unto others as you would that they should do to you' is a golden rule that has been given in nearly the same words by Aristotle, by Christ and by Confucius; yet by 'others' Christ meant all men; Aristotle meant all the free born men of Greece, not their slaves; and Confucius meant the virtuous among his countrymen and excluded all wicked men and all foreign barbarians. If we consider what was meant by the words 'citizen,' 'honor,' 'duty,' in ancient Rome; in the later Roman Empire; in Constantinople; in the free towns of Italy; in the England of the middle ages; we shall understand the snares that lie latent in words which at first glance seem obvious in meaning.

In comparing the view-point of different ages with our own we continually meet with surprises. The uncritical attitude of the men of the thirteenth century towards miracles and wonders is little less than astounding to us. Our thought seems to be ages in advance of theirs. On the other hand, we often meet with an insight that has what we call the distinctly modern note. An instance from literature will illustrate:

A man's character is his fate

is a sentence that one would assign to Taine or to Stendhal in the nineteenth century, if one did not know it to have been written by Heracleitus in the fifth century before Christ. In like manner, some of the scientific processes of Hipparchus, Archimedes and Roger Bacon are so 'modern' as to bring a glow of delighted wonder when they are met with. Their failure to draw certain conclusions that seem almost obvious to us is equally astonishing. A formal explanation of the differences and of the resemblances of ancient ages with our own may be had somewhat as follows. We may suppose that a completely developed man of our day has educated his sympathies and intelligence to have outlets in a certain large number of directions—let us say, in the directions

A, B, C, D, E, F, G, H, I, J, K, L, M, N, O, P, Q, R, S, T, U, V, W, X, Y, Z.

It is possible, however, that some few of these outlets are absent, or nearly closed, E and O for instance. The men of the eighteenth century may be supposed to have had fewer outlets, and those of the thirteenth still fewer; but the intensity and refinement of their sympathies in certain directions may not have been less but greater than ours. The feeling of the thirteenth century for religion, and of the sixteenth for art, for example, were not only different in intensity, but very different in quality from our own. When we make a formal comparison of our age with that of St. Thomas Aquinas and of Newton the table might stand thus:

A, B, C, D, –, F, G, H, I, J, K, L, M, N, –, P, Q, R, X, Y, Z..twentieth century
a, b, c, d, e, f, g, h, i, –, –, –, m, n........................thirteenth century
a, *b*, –, –, –, –, *g*, *h*, *i*, *j*, *k*, *l*, *m*, *n*, *o*, *p*, *q*, *r*................eighteenth century

If in a comparison of the thirteenth century with our own the discourse is upon the matters A, B, C and D we may find their insights, a, b, c, d, singularly like our own. The case may be the same for the matters G, H, I compared with g, h, i. But if, by chance, we are comparing their insight e with our absence of insight or our X, Y, Z, with the blanks in their experience, we are astonished at the difference of outlook. This formal and unimaginative illustration may not be quite useless in clarifying one's thought upon a matter easy to describe in words and exceedingly difficult to realize. It is essential to admit the presence of blanks in the experience of past centuries; and also the presence of insights upon fundamental matters astonishingly different in intensity and in quality from our own. The experience of the thirteenth century was handed onwards to succeeding ages; it could be understood by the ages near to it; words continued to mean in the fourteenth very nearly what they meant in the preceding century. But as ideas changed, the signs for ideas changed with them; and we must be constantly on our guard lest we unthinkingly admit an old form as if it had the new meaning.

Consider, for example, what astrology meant to Roger Bacon and what it means to us. He had no difficulty in reconciling the fateful influence of the stars with a scheme of salvation for men possessed of free-will. Words had different meanings to him and to us. His mind was conscious of no conflict between his religion and his science. His religion—that of the thirteenth century—is in absolute conflict with our science—that of the twentieth. Let his one example stand as a type of many that might be brought forward.

In what follows we shall study the words of Roger Bacon, the highest product of the thirteenth century.* His *Opus Majus* has recently (1897) been admirably edited by Bridges. Bacon has there expressed himself fully; and his century can be understood by implications. For this reason—to recreate, as it were, the background upon which the figure of Copernicus is projected, I have set down a few sentences. The paragraphs chosen relate chiefly to science, in which Bacon was far advanced, but enough is given of his views of philosophy, theology and morals to assist our judgment of his time. These extracts show what was possible to a man of the thirteenth century; and Bacon did not stand alone. He is the representative of a spirit that was active and widespread. It was creative; and it formed the scientific thought of succeeding centuries. Extracts from the summary of Bridges follow:

Opus Majus.—The four general causes of human ignorance—(1) subjection to unworthy authority; (2) habit; (3) popular prejudice; (4) false conceit of our own wisdom. Popular prejudice is a potent cause of error—pearls should not be cast before swine. Aristotle, wisest of philosophers, was not perfect. Avicenna sees where Aristotle erred; Averroes corrects Avicenna. Errors are found among the fathers of the church. By the habit of discussing received opinion we cease to be its slaves. The best Greek thought was not known to the Latin fathers. The early church made no use of Greek science, and the same is true of Bacon's own day, though without a good excuse.

The Connection of Philosophy with Theology.—Reason comes from God, therefore philosophy is divine. It is not an invention of heathen nations. The business of philosophy is to furnish a criterion of knowledge. All speculative philosophy has moral philosophy for its end and aim.

* See a paper on Roger Bacon in The Popular Science Monthly, January, 1902.

The Study of Language.—The quality of one language can never be perfectly reproduced in another; Latin altogether lacks many necessary words; a translator must not only be perfectly acquainted with his subject, but also with the two languages with which he deals; the translators of Aristotle have not fulfilled this condition; errors remain in the Vulgate; Hebrew, Chaldean, Latin, Greek (and Arabic) should be studied.

Mathematical Science is the key to all sciences; astronomy depends on mathematics; things terrestrial no less, since they are governed by things celestial.

Rays issuing in infinite number from a point in every direction find their termination on the hollow surface of a sphere. Light and other forces propagate themselves in this way. By the foregoing principles and others akin to them all natural actions are to be explained—as, for example, eclipses. (The moon and planets are self-luminous.) Refraction is discussed. The varying heat of different regions of the earth at different seasons is explained.

The emanations from the stars affect not merely climate but character; implanting in the new-born child dispositions to good and evil: though free-will, God's grace, temptations of the devil, or education may modify these innate tendencies. (Temperament is itself a result of the influence of the stars.)

The theory of (radiations of force) may be applied to the tides. These evidently depend on the moon. It is still unexplained why tides occur in the hemisphere averted from the moon.

On geometrical grounds the shape of the universe may be inferred to be spherical. The water, air and the fire surrounding the earth concentrically are of similar form (the sphere of fire is neither luminous nor visible).

In a body falling towards the earth's center a strain is involved; from this strain, heat results; experiment shows this to be a fact.

The Application of Mathematics to Sacred Subjects.—Astronomy shows the insignificance of the earth as compared with the heavens. The smallest of the stars is larger than the earth. Chronology is dependent upon astronomy. The lunar periods are discussed.

The rainbow is produced by the solar rays striking on the raindrops and being refracted or reflected thence.

One degree of latitude is 56 miles. The semi-diameter of the earth is 3,250 miles. The distance of the starry sphere (according to Alfraganus) is 130,-715,000 miles. The distances of the planets are given—Saturn's as 65,357,500 miles (it is in fact 886,000,000) and the moon's 208,541 (it is in fact 238,840).

There are 1,022 fixed stars catalogued, The largest are 107 times as large as the earth; the smallest 18 times. Besides these there are infinite numbers of other stars.

Astrology as it relates to church government is discussed. Christianity is associated with the conjunctions of the planets Jupiter and Mercury; the extinction of religions is related to the conjunctions of Jupiter and Saturn with the moon.

The correction of the *Church Calendar* is discussed. At the present time its errors are so great as to attract the ridicule of Jewish and Arab astronomers.

Geography is discussed at length. The space of ocean separating Spain and India is inconsiderable; the seven climates of Ptolemy.

Astrology.—The sun may be said to beget no less than the parent. Each planet has an influence. Special parts of the body are affected by different constellations. The bearing of this on medical art is obvious. The comet of 1264 was due to Mars, and it was related to the European wars of that year.

Optics.—The organs of vision, psychical and cerebral; the organs of the sensitive soul are in the brain; threefold division of the brain; the heart is the seat of life; the brain first receives impressions; the nerves; the anatomy of the eye; its humors; the function of vision; vision is the result of radiation; vision is not completed in the eye but in the brain; matter is infinitely divisible; as many divisions can be made in a grain of millet as in the diameter of the world; theory of color; conditions of vision; time is required for the propagation of light; double images; radiations from the object and from the eye; perception; the Milky Way is a multitude of small stars clustered; shooting stars are probably bodies of small magnitudes seen by (persistent vision); phases of the moon; the surface of the heavens is spherical; illusions respecting relative motion; twinkling of stars; animals pass through a train of mental processes akin to syllogistic reasoning, though they can not put it into a logical figure; they have a storehouse of mental impressions; can generalize and draw conclusions.

On Reflected Vision.—The angles of incidence and reflection are equal whether the mirror be plane or spherical; mirrors; illusions; color; refraction; by refraction great wonders may be wrought; small things may be made to seem great, distant things near.

Moral Philosophy.—Civic morality; personal morality; we must pursue our steady course, not diverted from it by the varying blasts of opinion; proof of the truth of the Christian religion; revelation is necessary; it is not enough for the reason to be convinced in this matter—the heart must be stirred. If we are made one with God and Christ, to what greater good can we aspire?

The thirteenth century is memorable by the appearance of three great men, Roger Bacon, Albertus Magnus and St. Thomas Aquinas. Albert was born in Suabia in 1193, the descendant of a celebrated and powerful family. He may be reckoned as the best product of the middle ages. He studied in Padua and Bologna, taught at Cologne and Paris (1245) and returned to Cologne. He became provincial of the Dominicans in Germany in 1254, and was Bishop of Ratisbon (in 1260) till he resigned about 1263. He was the friend of kings and popes. His great service to the church was a systematic presentation of the philosophy of Aristotle with a full accompaniment of Arab commentary. Among his contemporaries he was known as *Doctor Universalis,* and, in the history of the world, is especially famous for his works on physical science. Like all the learned men of his time he was supposed by the vulgar to practise magic and, as a matter of course, he sought the philosopher's stone. It was even currently believed that he paid the large debt of his bishopric of Ratisbon with transmuted gold. The flowers that he grew in the winter time, which the wondering townsfolk called magical, were in all likelihood the product of the first hot-house constructed in Europe. An edition of his works in twenty-one volumes was first published in 1651. This complete collection shows, in the first place, that he was thoroughly familiar with all the learning of the Arabs up to his own time. He was to the west what Avicenna was to the east, an encyclopedia of all knowledge. His philosophy is, of course, Aristotle's, elucidated by the schools of Arabia and Spain. His works on physical science are, in a large degree, mere reproductions of Greek treatises, but they are nearly everywhere enriched by original observations. In his treatise *De Animalibus* (Vol. VI. of his works) he begins by a study of the spinal column, calls the sponges the lowest forms of animal life, improves on the zoological classification of his forerunners, and includes good descriptions of the fauna of the Arctic, and at the same time admits the legendary monsters of the Bestiaires of the tenth century, the barnacle-goose, *anser arboreus,* for example.

His botany is said to be full of errors. He quotes Pliny's facts relating to the fecundation of the date-palm, and correctly explains them, it is believed for the first time. The term *affinity* is first used in his chemical writings. There was no branch of knowledge that he did not treat, from mineralogy to magnetism, and it is noteworthy that he describes the magnet as in use by navigators in his time.*

It is not necesary in this place to speak of the achievement of St. Thomas Aquinas, the pupil of Albertus. His work does not lie in the field of physics, but in the universe of man. His *Summa* treats more than five hundred questions, but only one section refers to the phenomena of the material world. One remark may be made on the activity of the thirteenth century. Every one of the distinctly 'modern' problems was propounded in that age. Few were solved; but substantially all of them were stated. When a problem is clearly stated it is at least half solved.

The most noted figure in the generation preceding Copernicus was Regiomontanus, who is always thought of in company with his colleagues Purbach and Walther. They formed part of a group of German and Italian astronomers, calculators and teachers, no one of whom made any signal advance, but all of whom were well instructed in the fashion of the time. There are many names of men forgotten to-day among this group; but, on the other hand, the faint beginnings of a critical spirit are here and there to be noted. The *Almagest* was not always taken as infallible; observation began to be accepted as a test of theory. Dominicus of Bologna, the teacher of Copernicus, is a marked example of the new spirit.

George Purbach (or Beurbach, from his native village), professor of astronomy in the University of Vienna, was born in 1423 (died 1461), and studied at Vienna and in Italy. He was a votary of the old astronomy, and his chief work, *Theoricæ Novæ Planetarum* (1460), is a development of the doctrine of crystalline spheres. At the same time he was an ardent student of Ptolemy. The epicycles of Ptolemy were a geometrical conception; the crystalline spheres of Eudoxus and Purbach a crude cosmological idea; they could not be reconciled with nature. In so far Purbach was on the wrong road. He saw, however, the necessity for further observations of the planets and for

* It was introduced into Europe by Flavio Gioja, according to common report, about 1302.

accurate tables to replace those constructed for Alphonso the Wise, which no longer served to predict eclipses or to account for the configurations of the planets.* Errors of a couple of hours in the predicted time of a lunar eclipse were noted, and Mars was two degrees away from its calculated place.

In the work of observation and calculation he gained an invaluable coadjutor in Johann Müller, of Königsberg, a village of Franconia, one of his pupils. Müller called himself, after the fashion of the time, Johannes de Monteregio, but is known to us as Regiomontanus. Together they studied the works of Ptolemy, and together they observed the planets with the best instruments they could construct, though their apparatus was much inferior to that of the Arabs. Like all men of their time they were believers in judicial astrology, and their tables were arranged to meet the wants of this pseudo-science. At the same time astronomy benefited by their investigations, which began to be based on actual observation of the sky.

The Papal Nuncio in Vienna was then Cardinal Bessarion, once Bishop of Nicaea in the Greek, now high in power in the Latin Church and a friend of learning. Purbach's enthusiasm for the works of Ptolemy was shared by the cardinal, and they planned a new edition of his writings. For such an edition it was necessary to collect Greek manuscripts. After the death of Purbach (1461) Regiomontanus went to Italy in the cardinal's suite for this purpose (1462). Here he remained some seven years, collecting manuscripts, mastering the Greek language, studying the sciences, and writing his treatise on trigonometry. His text of Ptolemy was printed at Basel in 1538 and was used by Copernicus.

In 1471 he was settled in Nuremberg near the printing presses that had been installed a few years earlier. Here he had the fortune to meet a wealthy amateur, Bernhard Walther (1430–1504), who built an observatory for their joint use, and aided him in his publication of various writings, his own and Purbach's. The *Ephemerides* of Regiomontanus made him famous. They were the nautical almanacs of those days, and were used by Columbus and Vasco da Gama in their voyages of discovery. He is also the inventor of the method of lunar distances for determining the longitude at sea. He was invited to Rome by the Pope in 1475 to reform the calendar and there died in 1476.

There is a legend that Regiomontanus was assassinated by the sons of George of Trebizond, the first translator of the *Almagest* of Ptolemy from the Greek, because of strictures passed upon it. The legend

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* This great collection of tables was calculated in the middle of the thirteenth century by Arabian and Jewish astronomers, under the patronage of the king, on the system of Ptolemy with some changes. The *Libros del Saber* were an encyclopedia of all the astronomical knowledge of the time and are invaluable to the historian.

is probably not true, but it is, perhaps, worth repeating, as it was credited at the time and casts a light on the age. During his short life Regiomontanus accomplished much, and gave promise of more. In particular he greatly improved the doctrine of trigonometry. Purbach and himself were the very first Europeans to utilize the discoveries of the Arabs in this science. As every astronomical calculation depends upon the solution of spherical triangles, the tables of sines and tangents computed by Regiomontanus were of fundamental importance, since they gave numerical values of these trigonometric functions calculated once for all, and saved the computer endless special reckonings.

It is difficult for us to conceive the state of science in those days. The school-boy problem: given *a, b, c,* in a spherical triangle, to find *A, B, C,* was considered operose by Regiomontanus and his friends, although the solution had been reached long before, by Albategnius. Blanchini, a contemporary of note, sends him the following equations for solution:

$$x:y = 5:8;\ x + y = xy.$$

A star rises at Venice at $3^h\,25^m$, and transits at $7^h\,38^m$, after midnight; required its longitude and latitude: is a problem addressed to Blanchini, in return. The Arabs five centuries earlier would have found these questions easy. Regiomontanus was, nevertheless, the most accomplished man of science in Europe. The ancients determined the longitude of a planet somewhat as follows: The difference of longitude between the planet and the moon was measured (*A*) and next the difference of longitude between the moon and the sun (*B*). The longitude of the sun was calculated from the solar tables (*C*). The sum of *A, B* and *C* gave the planet's longitude. In Walther's observatory the angular distances of the planet from known stars were measured and the required longitude and latitude of the planet were calculated, by the formulæ of spherical trigonometry, from the known longitudes and latitudes of the stars. The gain in precision was considerable, and the observations could be made on any clear night, whether the moon was or was not above the horizon.

Walther survived his friend for many years and carried on the observations which they had begun together. It was in their observatory that clocks (not pendulum-clocks) were first employed to measure short intervals of time and that observations were first corrected for terrestrial refraction. A star seen through the atmosphere appears higher above the horizon than if the atmosphere were absent. Its apparent position must then be corrected for refraction in order to obtain its true place. At an altitude greater than 45° the correction is less than 1′, which was inappreciable before the day of the telescope; but near the horizon the correction is large (the line of sight passing through the deepest layer of atmosphere there) and must be taken account of, even with rude observing apparatus. Refraction had been studied by Ptolemy and more deeply by Alhazen and Roger Bacon. Twilight, the scattering of the rays of the sun from the particles of dust and the like in the upper atmosphere, was investigated by Peter Nonius (1492–1577) a voluminous writer on astronomical matters.

All that was known in astronomy was familiar to Regiomontanus, and during his seven years' residence in Italy his relations were with the best instructed *savants* of Rome, who were then concerned with projects for improving and correcting the calendar. When Copernicus went to Italy in 1496 the best traditions of all Europe had spread throughout its universities and he was, therefore, familiar with all that his predecessors had accomplished.

A passage from the 'Principles of Astronomy' of Gemma Frisius (died 1558) is worth translation, since it fixes an important date and describes methods of determining longitudes and latitudes which are used to-day. He says: "People are beginning to make use of little clocks that are called watches. They are not too heavy to be carried about; they will run nearly twenty-four hours, and even longer if you aid them a bit; they afford a very easy method of determining longitude. Before starting on a journey, set your watch carefully to the local time of the country you are leaving; take pains that the watch doesn't stop on the road; when you have gone twenty leagues, for instance, determine the local time of the place where you are, with an astrolabe; compare this with the time by your watch, and you will have the difference of longitude." The latitude of the place can be had by measuring the altitude of the pole-star. Watches, which were invented about 1525, varied several minutes a day, and the portable astrolabes of the time could hardly give the altitude so close as 10′; but the methods were correct, and are those to-day employed in using the chronometer and the sextant.

Mention must be made of Peter Bienewitz, otherwise Peter Apianus (born 1495, died 1552), who expounded the Ptolemaic system in a great volume—*Astronomicum Cæsareum* (1540). Apianus was the first to observe the sun through colored glasses. The astronomers of Bagdad had observed an eclipse, when the sun was low, by its reflection in water, and Reinhold had proposed to project the solar image on a card in a camera obscura, a method which was used by the astronomers of Galileo's time. His best contribution to astronomy was the discovery that the tails of comets are generally directed away from the sun, a remark independently made by Fracastor.

Comets in his day were usually supposed to be atmospheric phenomena. Why this connection between them and the sun? Why should the sun, and not the earth, control their forms? The comet of 1472 had been studied by Regiomontanus and its course among the stars traced. This was the very first occasion upon which a comet had been treated as a celestial body like another. How could an object of the sort circulate among material crystal spheres? Questions of this kind were in men's minds; the observations upon which their solutions must depend were a-making; sufficient progress in mathematics had already been made; the time for a recasting of the accepted theory of the world was at hand.

Crystalline spheres were the basis of the theory of Fracastor. To explain the motions of the heavenly bodies he employed sixty-three spheres whose motions were linked one with another like wheel-work. His doctrine is that: All motions take place in circles; uniform motions are the most probable; each planet always remains at a constant distance from the earth; the changes in their observed brilliancy depend not on changes of distance, but on differences in the earth's atmosphere, or in the density of the crystal spheres; the *Primum Mobile* moves uniformly and always will do so unless God the Creator intervenes by a special act; spheres are of various kinds—conductors, anticonductors, circling, anticircling, countervailing; sixty-three of them will explain the world; ten orbs belong to Saturn, eleven to Jupiter, nine to Mars, four to the sun, eleven to Venus, eleven to Mercury, seven to the moon. The system of Fracastor is not only complex, but mechanically impossible. It represents the worst aspect of the doctrine which Copernicus was to overthrow and it is interesting as almost the last exposition of its sort, and especially because Fracastor was a contemporary of Copernicus and died in the same year (1543).

THE CONSERVATION OF ENERGY IN THOSE OF ADVANCING YEARS.

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THE study of the conditions and changes in the tissues of human beings as they pass beyond middle age would seem at first sight to be of wide-spread interest. Upon the very simplest presentation of the matter it will be universally admitted to be of the greatest importance. The first principle of economics is not so much what we win in any line of industry as what we save; this is the essence of the conservation of values. What matters it how well the child is provided with opportunities for growth and how excellently the young adult is developed in the fullness of such strength as is compatible with individual opportunity; how high a degree of efficiency, mental or physical, can be attained, if all this is to last but for a few brief years of practical utility? Again, allowing ourselves to indulge in a more selfish view, what does it profit us if we shall acquire place and power and the means by which we may be able to enjoy life, as we have learned to live it through years of experience and the exercise of careful choice, if we are to become speedily cut off from the continuance of the enjoyment of those privileges the product of matured judgment and the full energizing of our powers? It is to me a remarkable, indeed an astonishing, fact in searching for data on the subject of senility which one would naturally assume to have grown up in the enormous field of medical literature, that so little is to be found bearing on this subject. There are here and there references to old age and the phenomena of senility in a few of the standard works on physiology, far fewer than the subject would seem to warrant. The subject does not seem to have aroused much interest in the great authorities on medicine, although there are some crisp and vigorous articles which are valuable and interesting.

My own studies have been most largely in the line of growth and development of children and yet interest by no means ends there, and my attention has been drawn to this matter through a constant study based upon part medical research and part individual interest in the whole question of bodily development and the possibilities which lie in this direction for the advance of individual efficiency in all periods of life. It has seemed that the phenomena of degeneration are present in most disturbances referable to those of the nerves and their centers where the analogue of senile changes constantly appears.

Old age has been tritely described as a purely relative term; senility is to be recognized in many persons young in years and is often absent in those of late middle, or even of advanced age. There is no time in the life of a human being when this can be said definitely to begin. It is possible that if the undivided attention and energy of able thinkers were directed toward the means of combating these changes great gains could be made. Indeed notable progress has already been initiated and is being demonstrated with increasing rapidity in prolonging the age of the race through the one avenue of research which is really a development of the last decade. In laying the foundations of constitutional vigor by giving the chief attention to the disorders of children, their proper feeding and hygiene during the first few months of life, the foundation of longevity is capable of being firmly laid. Already there are abundant statistics to prove that the possibilities of retaining vigor to late age in civilized countries is being hopefully revolutionized. Too great praise can not be given to the researches of those men who, with insistent and prophetic voice, have demanded that the infant life shall have better opportunity afforded for prolongation by the regulation of diet and hygiene. If the foundations be well laid the problem of the superstructure can be made a matter of exact procedures. Not only are we of the medical profession becoming keenly alive to this great truth, but the gospel has filtered down and is being rapidly accepted by the great mass of thinkers. It matters little what is done, or what opportunities for growth and development are offered for the nation, if the infant child is neglected, even relatively, in the first three to six months of its life. No skill consistent with modern medicine is able to repair, except in the smallest degree, the irretrievable damage upon that human constitution which has not acquired a fair start in life. Two items of knowledge have been added to the subject of child growth by the clear teachings of such men as Jacobi and Rotch in insisting upon thorough attention to the details of food and nursery life during the period of babyhood. It is possible to find among the histories of those who have attained great age and retained their vigor beyond the ordinary span of life few instances of bottle-fed babies. In the future this will not be so, although at no time can we assume that the same degree of physical integrity can be acquired by artificial feeding as could have been by the natural methods of infant nourishment. Another fact comes up in the histories of very old people that they nearly all spent the earlier months and years of their lives outside of large centers of population.

It is a fact abundantly well known, and yet not of popular knowledge, that constitutional vigor is practically impossible except in the first generation in those who live in large centers without change. Statistics go to show, for London at least, that the fourth generation of the town dweller is unknown. But enough is currently reported to make the conclusion inevitable that the *sine qua non* of longevity is a certain amount of time spent in the country. The city child is subject to a number of disturbing conditions other than mere absence of creature comforts, which undermine the constitution by throwing too heavy a burden upon the sense organs, through which exhaustion of the central neurons follow; these conditions are such as noises, a perpetual round of hurry, unending sequences of incident exhausting the attention, to which are superadded the physical discomforts of vitiated air and effluvia from human beings and waste organic products, besides offensive gases and infection-laded dust, etc. All these and others more than offset the civic improvements which have their value, of well paved streets and shelter from winds, better housing and many conditions furnished in cities and not in country places. What has been said does not obtain in respect to well conditioned villages and suburbs; at least to the same degree. All this makes for an alteration in the character and quality of symmetrical development. When adult age is reached, these conditions are merely exaggerated. The rush and hurry of competition still interferes with the acquirement of full organic vigor, which demands for its fruition, adequate time and leisure, so that cellular stability may be safely secured. To those of comfortable means, who can from time to time withdraw from the agitating circumstances of city life and enjoy periods of rest and quietude elsewhere, there is less left to be desired. For those who can choose their manner of living, the natural instinct may be trusted to secure selection of those opportunities in the life of most persons which will make for better conditions for continuance of life. To those who have reached middle age, and to whom the desire comes of conserving their powers to the utmost, it is distinctly possible to gain excellent success. So far as the general circumstances of life are concerned, there should be no difficulty in intelligent persons determining for themselves what had best be done. This of course will consist in relieving themselves from worry, strains and anxieties, and in the periodic withdrawal from the hurly-burly of effortful existence; in modifying their diet, in omitting the use of stimulants and narcotics and in spending long periods of time under pleasant conditions, in practical retirement. Above all, amusements should be simplified and accepted rather than sought after. There is enough, Heaven knows, of happiness to be had in keeping the eye, mind and heart open to the enjoyment of those opportunities which lie in the pathways of every one.

It has been my experience to know a number of men and some women who, when the occasion came to them out of the fullness of opportunities for choice, instead of contenting themselves with enjoying life, rushed after such sports as were popular or fashionable, thought to be amusement, and the following of these exhausting pleasures cut short their career. There will be no difficulty in any one of us searching about in our experience and calling to mind instances of people who had acquired wealth and position, in the enjoyment of good health and relative youth, who yet strove so fiercely to keep themselves (or it may be their thought was for their friends chiefly), supplied with amusements that they fell into the fatal error of doing more than their health would warrant or their constitution sustain.

Perhaps the most important quality, mental or physical, which conditions the attainment and enjoyment of advanced years, is a serene mental view; a capacity for deliberate enjoyment of whatsoever betide. In short a cheerful temperament is as good as an insurance policy; indeed far better. Much might be said along this line of prevention of death by the prolongation of life, but it has been presented to every one of us many times in endless guises and from divers sources. The difficulties are that we fail to realize the practical applicability of oft-reiterated truths which become trite and wearisome and yet are of golden quality and unspeakable value. It is my purpose to offer a few useful hints how one may definitely set about to earn a postponement of the evil days which come upon all, it may be not of ill health, but of a lessening capacity for enjoyment. Heaven has been most cleverly described as being the condition of one who knows what he wants and is able to enjoy it when he gets it, and the reverse of this, Hell, is clearly the atmosphere of that individual who does not know what he wants and could not enjoy it even if he did get it.

Touching the question of self-education in serenity which is admittedly one of the most important accomplishments which any one can acquire, it will be found by each that ever so little attention in this direction will be followed by prompt reward. For instance take the ever present subject of diet. As the effects of age become obstrusive, it is the part of wisdom to omit the use of those stimulating articles of diet to which we accustom ourselves throughout our youth and adult life. It may not be so plain to all, as it is to a man even of my age, how easy and pleasant a thing it is to put aside this or that item of food or drink and substitute for it either less or something different and more suited to our present needs. It is almost a working axiom in the achievement of long life that the less we eat and the less variety of objects eaten, the better. Exceptions will arise; sometimes follies may be committed by carrying these thoughts too far. But in the main it can not be gainsaid, and a great array of conspicuous illustrative instances can be pointed out, that as a working equation, the least should be eaten compatible with existence, to secure the greatest amount of continued health. As will be shown more specifically later, the paramount condition of buoyant youthfulness, whose loss is known to characterize the beginning of old age, is elasticity of the tissues. To preserve flexibility, it may readily be possible, as has been claimed by some, that this can be done by choice of foods. The use of some articles of diet tends to encourage the deposit of lime salts or to discourage elimination. It may be that by a careful review of the experiences of certain aged folk, we might find a guide to the line of diet by which these good effects can be secured. Old age may not be altogether due to accident in the choice, nor selection of conditions, in the avoidance of accidental damage or trauma. Time will not permit enlargement on this subject now, but there is interesting and instructive reading to be found here and there for those who desire to know. The most notable book devoted to this subject is the 'Autobiography of Louis Cornaro,' whose life was prolonged far beyond that age which is ordinarily thought to be possible, by extreme care chiefly as to choice of diet, and he has set it forth in a most entertaining volume. It is only a partial guide, because temperamental differences must be considered, in the light of the experience of each person, race and community. Families and individuals and nations have different habits of diet. That which might suit one group of cases would not be an exact guide for another, but in the main the principles are the same.

These principles in brief consist in a choice of vegetable and semi-animal foods in preference to red meats. I took a course in physical training long ago under a man who possessed phenomenal vigor, much older than he looked, and he declared that bread, by this is meant leavened bread chiefly, was the most pernicious agent in producing the stiffness of the tissues. This is merely instanced to show how strong convictions are at times, and how they differ from customary beliefs. I do not know how much truth is in this thought, but am of the opinion it is worth attention. Again, the question of the use or non-use of alcohol must be settled for each one. For myself I believe alcohol to be almost altogether bad, although prepared to admit that there may be instances where its use is to be recommended. Some years since there was a popular agitation on the subject of the use of opium. The outgrowth of the opium traffic sanctioned by the British government gave rise to much discussion, which if I have been rightly informed was carried on both by the government in India and by exportation to China. The contention waxed hot and almost all the testimony was against the traffic and encouragement of the use of this baneful drug. In the midst of this, however, Sir Joseph Fayrar, at that time the one chief in authority in medical politics in the government of India, wrote a most powerful and able defence of the use of opium, particularly its habitual use, in which he showed that among certain races, especially those of the Orient, opium was not followed by the destruction of mind and body which it is our custom to consider inevitable. He gave instances, numerous and convincing, that by the use of this drug or food, as it might possibly be called, a large number of intelligent, indeed most wise and capable Hindoos, had acquired great length of days without impairment to their best powers.

All such matters must be discussed with due deliberation and full knowledge of all attainable facts. The topic at the time interested me exceedingly, and in the course of a research which I made upon the causation of mental impairment, imbecility and idiocy, I became convinced that the use of opium by the individual was of relatively little harm in some exceptional instances. It certainly does not seem to be as hurtful as the habitual use of alcohol. So far as the effect of these poisons, for poisons they are, upon the second generation, it was shown that alcohol produced infinitely worse results upon the second and third generation of those that used it than followed the use of opium.

Close to the realm of deliberate thought and rational conclusions comes the debatable ground of varying opinion. The study of the life history of aged people would furnish much of value if it could be undertaken judiciously and thoroughly studied. The opinion of these or those old persons as to what article of diet, the use or omission of which aided them to acquire their age, comes close up to the realm of conjecture. As an instance of my study may be cited that of a certain lady, famous in my city for wit and wisdom, and who attained a ripe old age with apparently no diminution of her powers. She was on one occasion presiding in a distant city over a meeting of Colonial Dames, and was regarded as almost a prophetess by many, both friends and strangers. She told me that a certain lady approached her with much deference one morning and asked with bated breath if she would be so good as to tell her to what she attributed her great age and elasticity of mind and body. In the way of a joke she told her that it had always been her custom to eat great quantities of salt; and in relating the story to me, this lady said that she had no doubt that by this time that stranger was thoroughly well pickled in endeavoring to follow her lead.

It must always be borne in mind that old age is an inexact term. During the middle ages, statistics would seem to show that the recognized span of life was much shorter than it is now. As an instance of this, Old John of Gaunt, who was a byword, throughout many troublesome years, of age and wisdom, yet died before he was sixty. Warwick, the King Maker, whose history lapsed over that of many sovereigns, is said to have died at the age of fifty-four. In our own time great improvements have been wrought, more particularly within the last quarter of a century, in the matter of increasing the tenure of life, and the average of age has been brought up in a most satisfactory fashion to that which we could not have expected, although optimists have hoped for.

Again, mere existence beyond the ordinary bounds set by nature is of little value unless accompanied by many characteristics and qualities which make life worth living. It certainly should not be a desirable fate to remain alive and yet lose the capacity of enjoyment or, what is even more important, the capacity of being enjoyed. If it be not an integral part of the personality of an old man or woman to present qualities of attractiveness to others, the fullness of life has not been attained. The factors which go to make up the quality of desirable and admirable old age are above all, first and foremost, self respect, an interest in the affairs of others, a dignity and kindliness, a patient and uncomplaining endurance and a capacity constantly exercised to be of use in the world. A woman, for instance, can if she give her undivided attention to it, grow old so charmingly that she may at great age attain more grace and fascination than she had in her youth or middle life. We all know instances of this truth though some are thus more blessed than others. A man again may become a greater power for good even when well past the age of so-called usefulness than at any previous time. Nor do these qualifications depend necessarily so much upon the original structure of mind or body as the maintenance of a faithful vigilance and conscious desire to be, and do, that which shall furnish forth these good attributes.

The principles of action upon which the effects of advancing years may be postponed are simple, clear and practicable. The difficulties are chiefly the indifference or indolence which age begets. Wherever a person has acquired an active desire to retain the freshness of youth and is moderately diligent in pursuing whatever means should be adopted, the results are successful often beyond expectation. The conditions of success are an original soundness of constitution and fairly healthy organs. It might be added reasonably comfortable circumstances, but I know several cases where the environment was far from satisfactory, and daily labor onerous, yet these people were not discouraged. One other condition might be mentioned as needed often, but not constantly, viz., the counsel of a wise physician. Medical advice ought to be more frankly and constantly sought for the lesser infirmities of age than during middle life for reasons obvious. As the internal resistances lessen small disorders more readily throw the actions of the organism out of balance, and fatal results follow seemingly small causes. Another prerequisite is consistency and persistence in the measures employed. The balance of power in the old is not easily retained, and regained with far greater difficulty. It is an axiom among horsemen that an old horse can be kept fit if used carefully and constantly, but once allowed to get into poor condition through disuse it can never be reinstated.

The potentiality of cellular cleanliness, and lymph activity, on the mechanism of life is paramount, and is not yet duly appreciated by men in or out of the profession of medicine.

Diet has been alluded to already and all that it is needful to say here is to repeat that temperance in food and drink is an essential condition of the best results. Regularity of conduct is important both in bodily habits and the daily routine of labor or pleasure.

Certain organic defects bear heavily upon the integrity of the ageing organism unless corrected. What miseries have followed unrelieved disturbances of the ears, nose, throat, digestion and eyes in many important lives, can never be fully known. George M. Gould has furnished an amazing lesson in the need for exactitude in correcting refractive errors in the eyes in his analysis of the causes of ill health in later life of epoch making men, among whom are Wagner, Beethoven, Spencer, Huxley, Darwin, Carlyle, Browning, Parkman, DeQuincey (who was thus driven to use opium) and Whittier. The continued usefulness of these men was thus cut short in mid career, let alone the agonies they were compelled to suffer unrelieved.

Open air life is a *sine qua non*. Many old people become hypersensitive to the cold and exposure to the extremes of temperature can become easily fatal. To spend much time in the open air is a guarantee of health, over and above that which was aforetime enjoyed if one has been in the habit of remaining much indoors. It is wise for old people to follow the sun by early rising and going early to bed. To utilize the young morning hours is best for all, but for the aged it is essential. Much sleep is not needed for them, unless they especially crave it as some do and most do toward the end. Dozing during the day is pleasant and salutary, but long night sleep is not necessary as a rule.

The suitability of clothing is deserving of careful study for each. As a rule old people crave much heavy underwear and they are disinclined to expose the skin to the air, and especially to drafts. This is due partly to the lessened activity of the cutaneous capillary circulation, to lowered cellular resistance and blood making power, but also habits and prejudices exert a most potent influence. The readiness with which old people catch cold has more to do with their habits than their age. It is a matter of common knowledge that the products of waste must be more carefully removed in the old than the middle aged. In this the skin must be reckoned as perhaps the greatest eliminating organ and the one most neglected. It is easy to drink lithia water or use other medicines. It is no effort to swallow a pill at night; but unless equipped by a valet or body servant the care of the skin involves personal effort, but one which will amply well repay. Finally, an enormous field of possibilities is opened by studiously striving to retain the fullest elasticity of all the tissues; and to this I desire to call particular attention with some detail and emphasis in the later sections of this article.

The constantly forming poisons invading the nobler tissues require to be removed. If the organic activities can not be relied on, a judicious use of laxatives, diuretics and special baths must be resorted to.

THE GEOGRAPHICAL DISTRIBUTION OF METEORITES.

BY DR. OLIVER C. FARRINGTON,
FIELD COLUMBIAN MUSEUM.

SPEAKING broadly, we know as yet of no fundamental reason why meteorite falls should be any more numerous upon one part of the earth's surface than upon another.

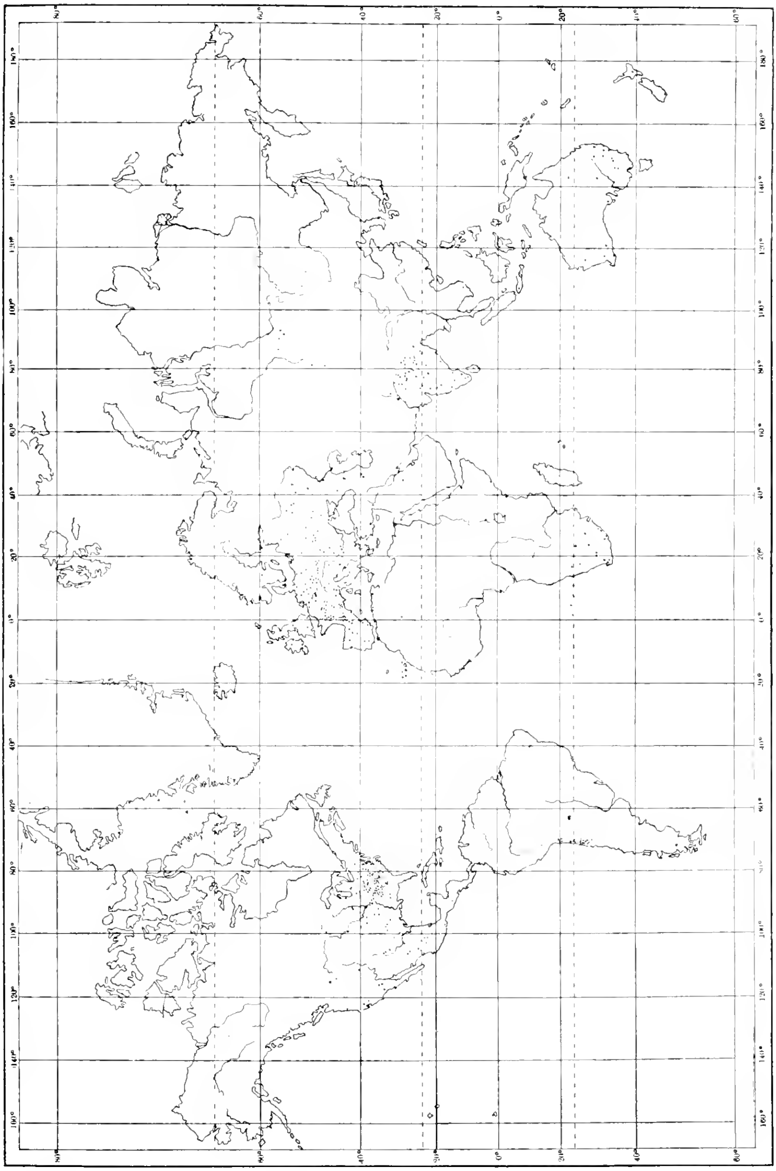
Compared with the vast area of space in which meteorites wander, our earth is but a point, which draws into itself from time to time one of these masses. Moreover, it is a rotating and wabbling point, ever presenting new surfaces to the portions of space in which it is traveling. The marksman who displays his skill by shooting glass balls thrown into the air would have the difficulty of his task enormously increased if he should endeavor to strike successively the same point upon the ball, especially if it had in addition to its forward motion one of rapid rotation about a wabbling axis. It is true that there is some prospect of our being able after much study and comparison of data to locate a few meteorite swarms with sufficient accuracy to warrant a conclusion as to what point upon the earth stones from them will strike, but this possibility seems at present quite remote. At present we can only presume that a gentle rain of meteorites has fallen regularly and impartially upon the earth since the morning stars first sang together.

The latest and best calculations, which are by Professor Berwerth, of Vienna, have shown that the number of meteorites actually falling upon the earth at the present time each year, not including of course shooting stars or meteors, is about nine hundred. Two or three of these bodies fall, then, somewhere upon the earth every twenty-four hours. But about three fourths of the earth's surface is covered with water, and the missiles impinging upon this area are lost. Upon the remaining one fourth, however, 225 falls should take place, accompanied by phenomena such as to make the occurrence noteworthy. A large part of the land is, however, unpopulated and our figure of 225 may, therefore, be cut in half in order to take account of this factor. Again, falls taking place in the night would, in many cases, not be observed, and as a last concession we may halve our figure on this account. It would finally seem then that about 55 meteorite falls capable of record might be expected to take place each year, and in a century the total should be 5,500. As a matter of fact, the total number of recorded meteorite falls, including some from as far back as the fifteenth century, is only about 350.

The first conclusion one is likely to draw from results so contradictory is that the original premise is entirely at fault. Yet within the small area of France 50 well-authenticated meteorite falls have taken place within the last one hundred years. We have no reason to suppose France especially favored of the gods in regard to the number of meteorites which it receives and, as it covers only about one one-thousandth part of the earth's surface, we shall find by reversing the calculations made above that our original figure of 900 a year is fully substantiated. The difficulty will be somewhat explained by a glance at the accompanying map. Tracing upon this the locations of known meteorite falls, we see at once that they are largely confined to the civilized nations, or, with the exception of the Semites of Africa and Arabia, to regions inhabited by the Caucasian race. Of a total of 634 known meteorites, 256 are located in Europe and 177 in the United States. In other words, more than two thirds of the whole number known belong to countries which occupy but about one eighth of the land surface.

We reach then the rather curious conclusion that the ability to observe and record meteorite falls is a mark of civilization, and that the relative civilization of regions equally populated may be judged by the numbers of meteorites known from each. The superiority of civilized peoples in this regard comes probably not so much from their greater ability to observe the fall of a meteorite as from their better facilities for recording such an occurrence and for preserving the stone which has fallen. To an unorganized community, the fall of a meteorite is an isolated occurrence, impressive enough at the time, but so infrequent that in the absence of records or means of communication with other communities, it is lost sight of. Civilized communities with their means of records and museums are able to correlate such occurrences, and in time accumulate important knowledge regarding them. So upon the accompanying map there are depicted not only the places where meteorites have fallen, but the isolation of China, the bleakness of Canada, the impenetrability of South America, the hollowness of Australia and the darkness of Africa. Meteorites known from uncivilized countries should for the most part be credited to travelers from civilized nations.

It would be quite superficial, however, to suppose that the distribution of Caucasian peoples is the only important factor affecting the location of known meteorite falls. There are evidences that other factors, the nature of which can hardly be even suggested as yet, affect the place of fall of meteorites. Thus, there appears upon the accompanying map a tendency of these bodies to flock toward mountainous regions. This is indicated by the large numbers of them occurring in India near the Himalayas, in Europe in the vicinity of the Alps, in the United States about the southern Appalachians, and in the Americas up and down the great western mountain range. It is possible that investigation will show that greater gravitational force is exerted at these points, and that thus the number of meteorites drawn in is there



MAP OF KNOWN METEORITE FALLS AND FINDS UP TO 1903.

increased, or, again, mountains may present actual mechanical obstacles which stop and accumulate meteorites. Whether either of these hypotheses has any foundation in fact, however, is not known as yet.

There are again remarkable differences in the kinds of meteorites found in the two hemispheres. Thus, taking falls and finds together, of the 256 meteorites known from the western hemisphere, 182 are irons and only 74 stones; while from the eastern hemisphere, of 378 known, 299 are stones and only 79 are irons. Professor Berwerth has sought to account for the excess of irons in the new world by the suggestion that the dry air of the desert areas which abound in this hemisphere has preserved meteorites fallen in long distant periods, while those of a similar age in the other hemisphere have been exposed to a moist climate and have for the most part been decomposed. It is true that many of the iron meteorites known from the western hemisphere occur upon the Mexican and Chilean deserts, but quite as many come from the southern Appalachians, where a comparatively moist climate prevails. There are also numerous desert areas in the old world perhaps as fully explored as those of the new, so that on the whole the above explanation seems inadequate.

Other remarkable groupings of meteorites with regard to their geographical distribution may be noted when areas smaller than hemispheres are compared. Thus of a total of nine meteorites belonging to the peculiar class called howardites, five have fallen in Russia. Of the nine meteorites known belonging to the still more remarkable class of carbonaceous meteorites, three have fallen in France and two in Russia.

Again small areas of equal extent and equally well populated vary curiously in their number of meteorite falls. Within the state of Illinois, for instance, no meteorite is known ever to have fallen, while in the state of Iowa, which has about the same area, but a smaller population, four falls have been noted, and from the state of Kansas, which has a larger area than Illinois, but a smaller and less uniformly distributed population, twelve meteorites are known.

It is usual to dismiss inquiries regarding the meaning of such groupings with the remark that they are mere coincidences. But it is the mission of science to investigate coincidences, and however long the task may be of determining the laws which bring about the particular occurrences here referred to, there can be no doubt that they are the result of law and of law which will some day be discerned by the human mind.

WASHINGTON UNIVERSITY.

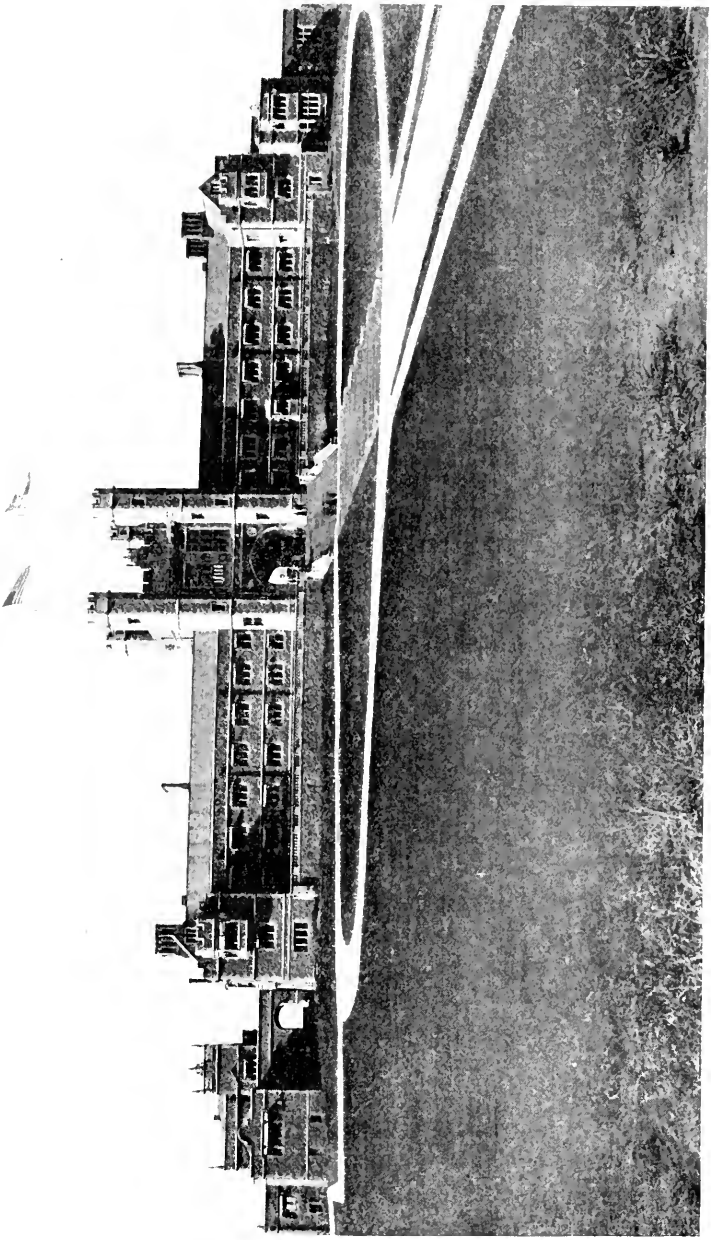
BY CHARLES P. PETTUS.

THE organization and establishment of universities, colleges and institutes of learning in the middle west during the half century just past, has been a striking feature in the growth of that section of the country. The act of congress of 1861 to assist state universities by the grant of lands opened the way for the foundation of a number of colleges and universities under state control which have since become great institutions covering all branches of learning, notably the universities of Michigan, Minnesota, Illinois, Wisconsin and Missouri. How well these excellent institutions of higher education have covered the field and supplied the demand for higher learning is shown by the fact that but two important non-sectarian universities, not under state control, have developed in this part of the country, namely, the University of Chicago and Washington University of St. Louis.

Numerous small colleges are to be found throughout all the states, usually under denominational control, and in many instances but little more than high schools, these nevertheless have supplied a certain demand which could not be filled otherwise and have occupied a not unimportant part in the educational system of the country; but the natural location both of Chicago and St. Louis, with a large and populous territory tributary to each of them, demanded university education of the highest type. And the advantages that a great city affords to the student in the many libraries, artistic and scientific museums, hospitals and dispensaries, law courts, manufacturing plants and machinery of all kinds, are such as can not be found outside of a large town.

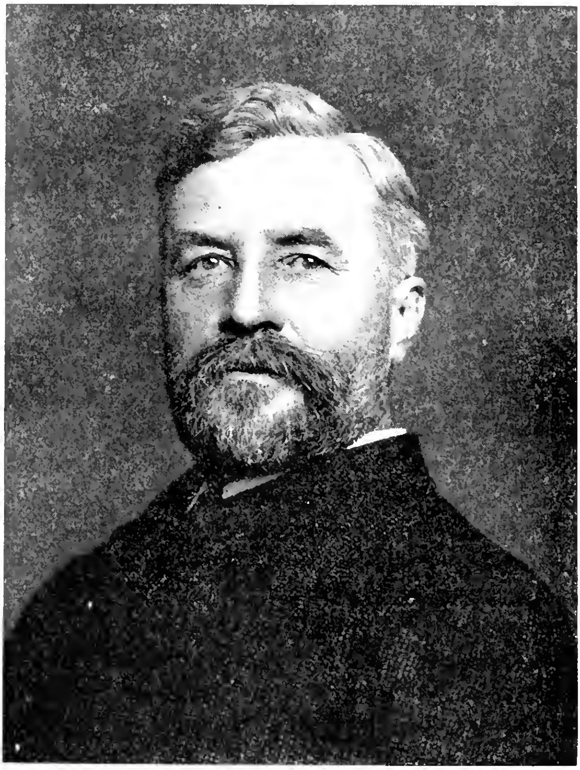
In 1853 Mr. Wayman Crow, then a member of the Missouri state senate, secured the passage of an act of incorporation, approved February 22, 1853, by which a charter was granted to an educational institution to be known as the Eliot Seminary.

This charter, one of the broadest and most liberal upon which any institution is founded, is a perpetual one, and all property belonging to the university is exempt from taxation, city, county and state; and no limitations of any sort are imposed, except those which forbid any sectarian or partisan teaching. So desirous were the founders to avoid any accusation whatever of political or religious bias, that at their first meeting, this eighth article of the constitution was adopted:



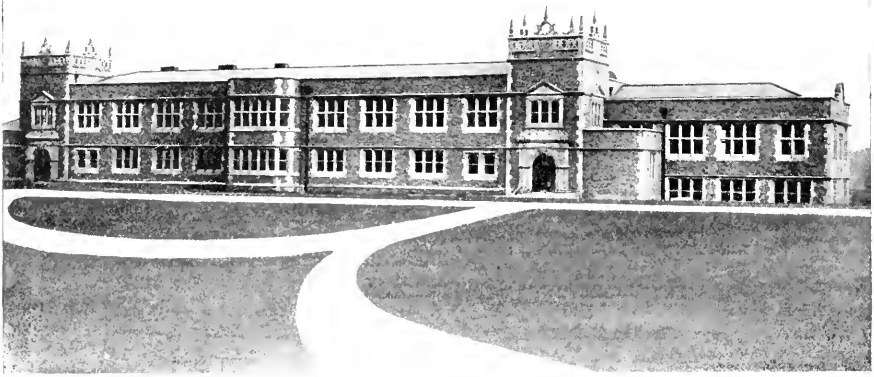
University Hall.

No instruction either sectarian in religion or partisan in politics shall be allowed in any department of the university, and no sectarian or partisan test, shall be used in the election of professors, teachers or other officers of the university, for any purpose whatever. This article shall be understood as the fundamental condition upon which all endowments of whatever kind are received. Any violation whatever of this article is punishable through the courts.



WINFIELD SCOTT CHAPLIN, A.M., LL.D.,
Chancellor of Washington University.

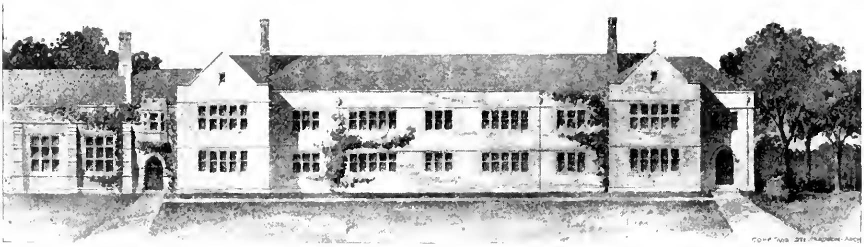
After the lapse of a year, on the twenty-second of February, a meeting of the incorporators was held, the charter accepted and the institution organized under the name of Washington Institute, which name was further changed in 1857 to Washington University. The name was chosen because of its national significance, having also been suggested by the day, February 22, on which the charter was given. The first building was erected in 1853–4, and since that time the university has had a steady and substantial growth, a new department being added when the circumstances warranted it, until to-day Washington University comprehends six departments and has three preparatory schools organized under its charter and, embracing the whole range of university studies except theology, affords complete preparation for every sphere of practical and scientific life.



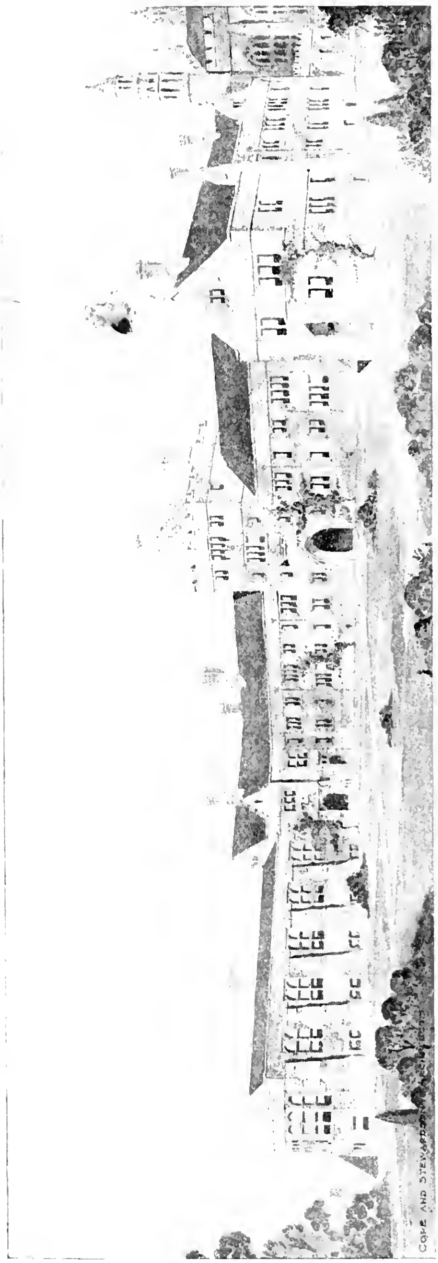
Busch Hall—Chemical Laboratory.

The first board of directors was composed of seventeen well-known influential citizens of St. Louis, who were named in the charter and who were given the power to fill vacancies in their number caused by death or resignation. To this board made up of many of the most prominent and successful professional and business men of St. Louis much of the success of the university is due. Not only have they at all times been most generous in their gifts, but by their careful and broad-minded administration of the affairs of the institution, they have carried it through several financial crises and brought it to its present prosperous condition and to its place of commanding influence in the educational world.

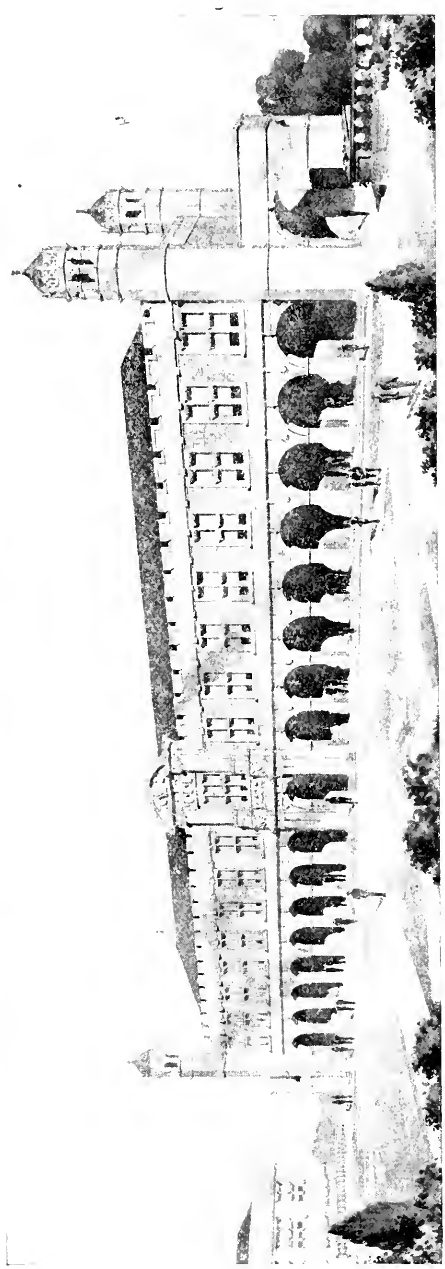
The beginnings, like those of most of the educational institutions of the country that have not had a munificent gift from some philan-



Physical Laboratory.



New Dormitories.



Library.

thropic millionaire with which to build and equip an entire institution at the start, were necessarily small, and the growth slow, until the public should recognize the worth and value of such an organization and assist it with substantial gifts.

The first building erected by the university was the south wing of the old university group on Seventeenth Street, near Washington Avenue, in which a school was opened in 1856. During the first year 108 scholars were entered in this school, which afterwards became the preparatory department of the university, the name being subsequently changed to its present title of Smith Academy.

On the twenty-second of April, 1857, the formal inauguration of the Washington University took place, with appropriate exercises in Academic Hall and an oration delivered by the Honorable Edward Everett, as well as addresses by the president of the board and several of the directors. This same year, 1857, saw also the erection of a building for a chemical laboratory and the appointment of Dr. Abram Litton to the chair of chemistry. Dr. Litton, 'the first thoroughly trained chemist west of the Mississippi River,'* held this position until 1892.

The chair of mechanics and engineering was filled by the appointment of Joseph J. Reynolds, a graduate of West Point, and afterwards Brevet Major-General in the United States Army. The chair of physics and civil engineering was filled by the appointment of John M. Schofield, also a graduate of the United States Military Academy, of the class of 1853, who, after a brilliant record during the civil war, finally reached the rank of Lieutenant-General commanding the United States Army.

Dr. George Engelmann, 'the leading scientist of the west,' was called to the chair of botany; Dr. Charles A. Pope, the celebrated surgeon at the head of the St. Louis Medical College, was made professor of comparative anatomy and physiology, and the Rev. Truman M. Post accepted the professorship of ancient and modern history. With such distinguished men on its first faculty, the influence of the university in the community was at once felt, and the future seemed assured.

During 1858 a college building was erected on the corner of Washington Avenue and Seventeenth Street, and on December 17 of that year Joseph G. Hoyt was elected the first chancellor of the university. Chancellor Hoyt was a native of New Hampshire and a graduate of Yale College, of the class of 1840, and for many years had been professor of mathematics at Phillips Academy, Exeter, N. H. He was a man of scholarship and learning, and of great tact and affability, than whom no one could be better fitted for the young institution.

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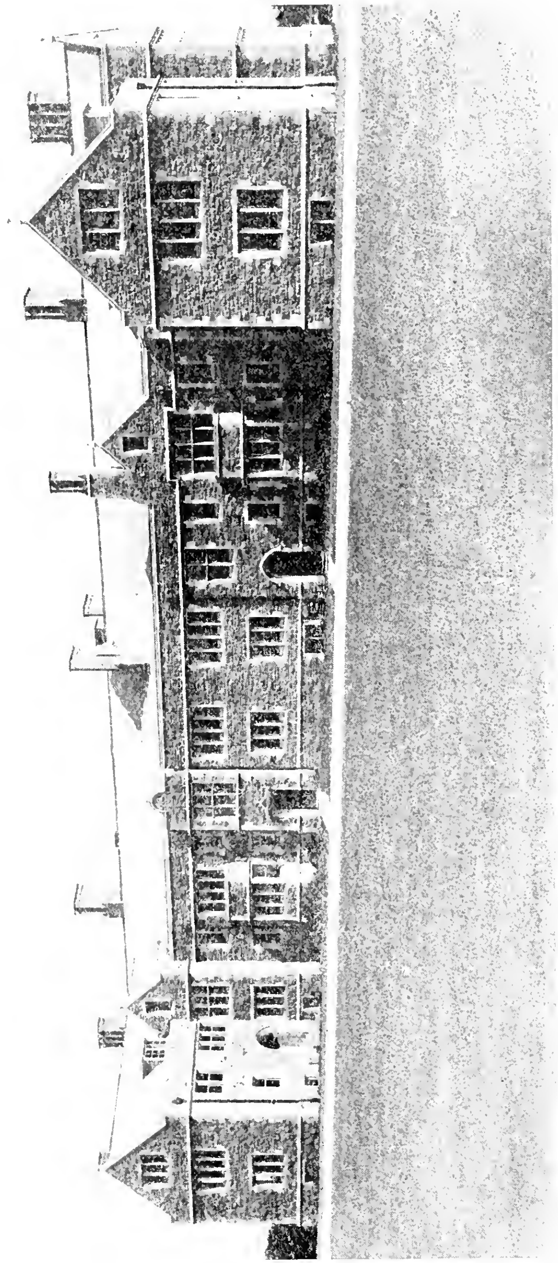
* The Popular Science Monthly, December, 1903, p. 122, footnote.



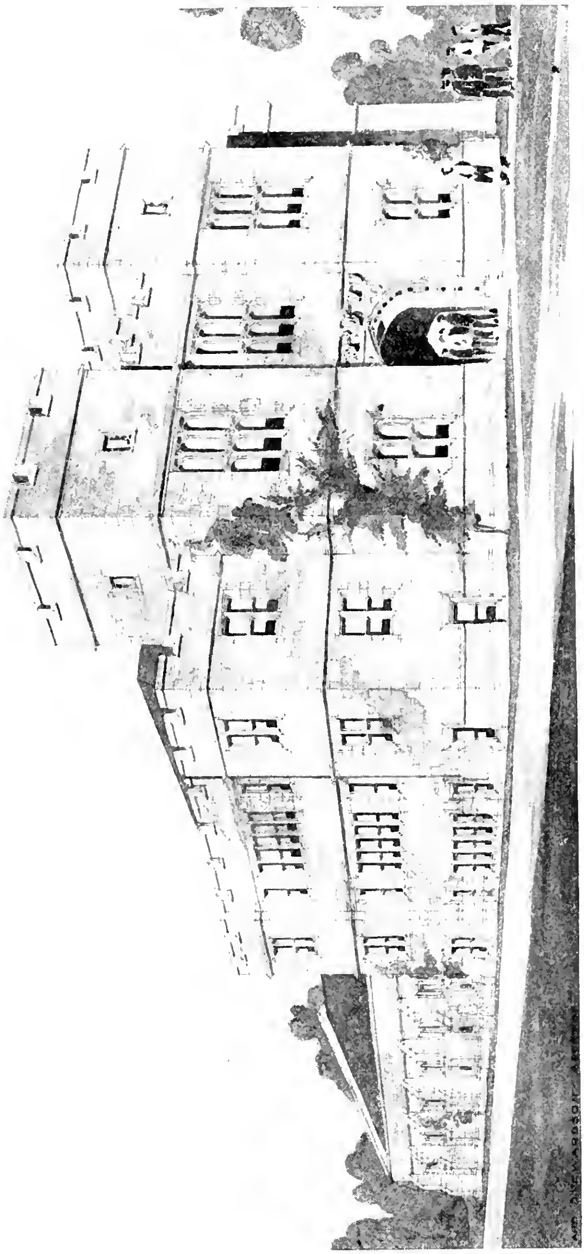
Liggett Hall Dormitory.

Hardly had he taken up his work when the civil war broke out, and for four trying years the university had a hard struggle, handicapped as it was by loss of professors and students, but with reduced resources it braved the storm and continued the work of the institution in all departments. In 1862 the first class was graduated from the college, and in November of the same year, after four years of successful labor, spent in organizing the work of the university, Chancellor Hoyt died. He was succeeded in 1863 by William Chauvenet, who, a year or so before, had been appointed professor of mathematics and astronomy. Chancellor Chauvenet was a classmate of his predecessor at Yale College and a mathematician of national and even of international reputation. He was for some years professor of mathematics at the United States Naval Academy, both at Philadelphia and at Annapolis, and great credit is due to him for his part in organizing that institution, which has always enjoyed such a high scientific position. His textbook on trigonometry is still the standard work in most colleges of this country. For seven years he held the chancellorship, and during his administration a steady growth was maintained. On his death he was succeeded, in 1872, by the Rev. Wm. G. Eliot, the president of the board of directors since the incorporation, both of which positions he continued to hold until his death in 1887.

In 1867 the law school was organized and equipped, and some of the ablest lawyers and judges of the city became members of the faculty. Two years later, in reorganizing the scientific department, courses of study leading to degrees in civil and mechanical engineering and in chemistry were established in this department; in 1870 these courses were lengthened from three to four years, and in 1871 a course of study in mining and metallurgy was added.

And so, finally, we find the work of the scientific department carried on in conjunction with the work of the college, and these two departments soon became grouped together, as the undergraduate department. This union gave final form to the general scheme of the university—a department offering work in arts and science, around which center preparatory and professional schools. Thus, in but a little more than a decade, the university had been organized and the various departments brought into due coordination, leaving the way clear for rapid expansion in the directions which were best adapted to the demands of the times.

In 1878 a new building was provided for the academy, thus separating it completely from the college, and in 1880 the Manual Training School was organized as a third preparatory department. It was the first school of its kind in the country, and its organization is due to Professor Calvin M. Woodward, who was, and still is, professor of mathematics and applied science in the university.

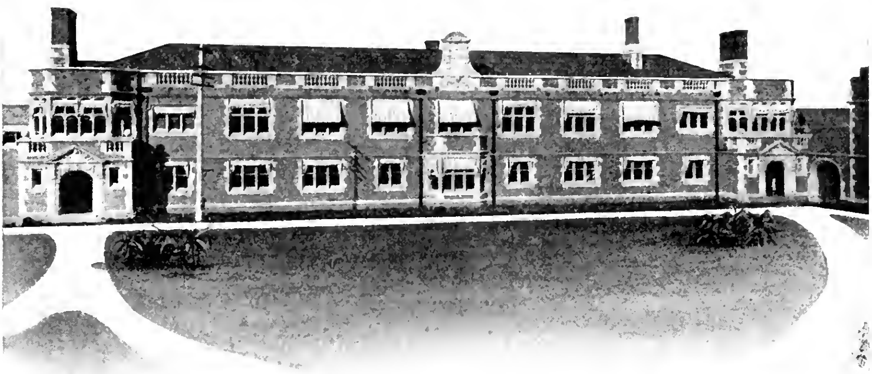


GYMNASIUM.

In 1880 the School of Fine Arts was established and the Museum of Fine Arts was erected and presented to the university by the Hon. Wayman Crow.

In 1885 the Shaw School of Botany was founded and endowed by Mr. Henry Shaw, as a department of the university, in close connection with the Missouri Botanical Garden,* with rare opportunities for advanced botanical research.

In 1892 the Missouri Dental College was made a department of the university, and in 1895 the St. Louis Medical College, organized in 1841, was made the medical department of the university. Two years



CUPPLES HALL NO. 1.
Department of Civil Engineering and Architecture.

later the medical course was lengthened to four years, and in 1898 the Missouri Medical College, founded in 1840, was united with this department, forming one of the strongest departments of the university. As it has at its disposal the combined resources of two institutions of such high standing, it is now one of the best schools of medicine in the country.

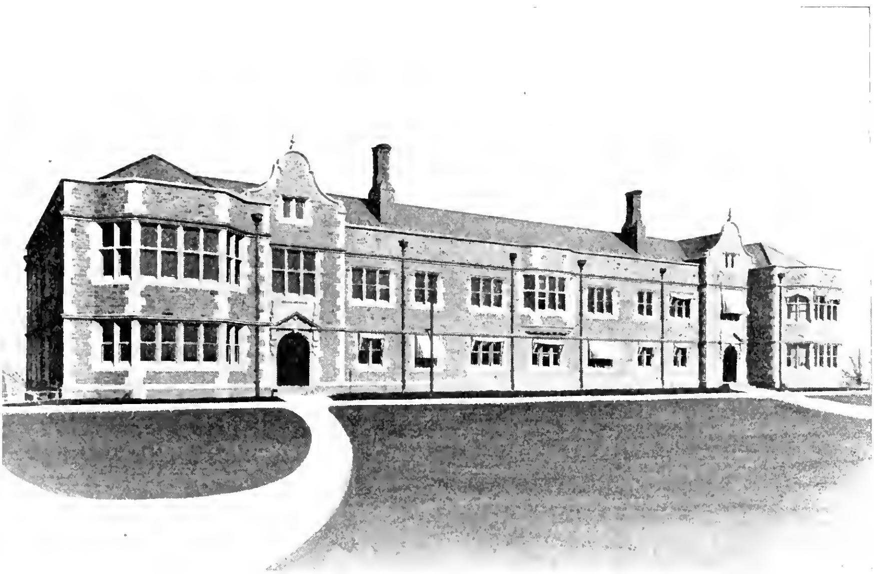
On the death of Chancellor Eliot, in 1887, there was an interregnum of four years, during which Professor Marshall S. Snow, dean of the college, acted as chancellor. He was succeeded in 1891 by Winfield S. Chaplin, the present chancellor, a graduate of West Point, in the class of 1870, who had been successively a professor in Maine State College, in the Imperial University of Tokio, Japan, in Union College

* See THE POPULAR SCIENCE MONTHLY, 1903, for account of Missouri Botanical Garden.

of Schenectady and in Harvard University, where he was also dean of the Lawrence Scientific School.

A high standard of scholarship has at all times been maintained, though often with the loss of students, who could obtain their degrees elsewhere with less labor. That this standard is fully recognized is shown by the fact that a degree from the undergraduate department of the university will admit its holder to the best professional and graduate schools in the eastern institutions.

Until 1892 a regular prescribed course leading to each degree was required, but in the fall of that year the elective system of studies was



CUPPLES HALL No. 2.
Laboratories of Mechanical and Electrical Engineering.

adopted, and at the same time the scientific department was reorganized and the name changed to the School of Engineering, so that now eight courses of study are offered in the undergraduate department, all requiring four years' work.

COLLEGE.

Elective Course in Arts.

SCHOOL OF ENGINEERING.

1. Civil Engineering.
2. Mechanical Engineering.
3. Electrical Engineering.
4. Chemistry and Chemical Engineering.
5. Architecture.
6. Architectural Engineering.
7. Science and Literature.

The undergraduate department of the university has always recognized that its field of usefulness lay in the city of St. Louis, and no attempt has been made to draw students from a distance. In the early catalogues of the university is found this notice: "Washington University has the advantage of not being incumbered with the dormitory system, which has been proved by experiment to be both expensive and troublesome—a great part of the disturbances so common in collegiate institutions and most of the temptations to which young men in college are exposed, arise from their monastic mode of life, and the consequent removal from the social influence of home."

But in the last fifty years conditions have changed. St. Louis is no longer a small western town of 78,000, but a metropolis of 700,000 inhabitants and the great commercial center of a vast and rapidly growing territory, especially to the south and southwest, and preparations had to be made to receive the increasing number of students coming to St. Louis for university training. Then the westward growth of the city had left the group of university buildings in the midst of factories and other objectionable surroundings. The noise was uncongenial to classic teaching, the passing cars and heavy traffic prevented delicate scientific observations and the dirt and smoke made the situation almost unbearable.

In 1896 a tract of land containing 110 acres on the western border of the city, adjoining Forest Park, was purchased with the intention of moving the undergraduate department to this high and commanding situation. The purchase price of $296,000 was subscribed by citizens of St. Louis, largely through the efforts of the president of the board of directors, Mr. Robert S. Brookings, to whom also belongs the credit of raising an endowment fund of $500,000, of which he gave one fifth, as well as the gift of the Cupples Station, a large group of wholesale business buildings with splendid railroad facilities, valued at $3,000,000, the joint gift of Mr. Brookings and Mr. Samuel Cupples.

An architectural competition was held to select a design for a group of buildings for the undergraduate department on the new site. Plans were submitted by the best architects of the country, and after careful deliberation by an impartial committee those of Messrs. Cope and Stewardson, of Philadelphia, were selected.

The style of architecture is that of the Tudor-Gothic period, and the buildings are constructed of the best red Missouri granite in the most substantial manner, and are thoroughly fireproof; they are all two stories high, thereby avoiding tedious climbing, the lecture rooms and numerous laboratories are large, well-lighted and ventilated, and all the latest improvements in scientific education are included, making them equal, if not superior, to any group of college buildings in the country.

Eleven buildings are now occupied and ready for occupancy by the university at the expiration of the Louisiana Purchase Exposition which has leased them for the World's Fair period.

University Hall, facing the main approach to the group of new buildings, the gift of Mr. Robert S. Brookings, was erected at a cost of $220,000. The building is 325 feet long, with wings on each end 119 feet long, and the towers 85 feet high. This building will contain the administrative offices of the university, and the offices and lecture rooms of twelve professors, besides study rooms, reception and faculty rooms.

Cupples Hall, No. 1, erected by Mr. Samuel Cupples, at an expenditure of about $110,000, is to be used by the department of civil engineering and architecture. The building is 232 feet long and the width 52 feet. It is two stories high on the quadrangle and three on the north side. The first floor will be used by the department of architecture and the second floor will be devoted to civil engineering.

Busch Hall, the laboratory of chemistry, was presented by Mr. Adolphus Busch and cost $110,000. The building is 291 feet long and about 60 feet wide, two stories high on the north side and three on the south side, and contains laboratories for all branches of chemical instruction and research work.

The library finishes out the first quadrangle and occupies a central position in regard to the group of buildings. It was erected at a cost of $250,000. The eastern front is 257 feet long and the depth is 46 feet, with a reading room one story high in the rear of the center of the building, about 100 feet long and 41 feet wide. The building will contain stacks with room for over 400,000 volumes.

Cupples, No. 2, and the Cupples Engineering Laboratory, directly behind it, were also presented by Mr. Samuel Cupples, and cost together about $165,000. The hall is 207 feet long, the first floor of which is to be devoted to mechanical engineering, and the second floor to electrical engineering. The laboratory adjoining is only one story, but is built in a style uniform with the other buildings, and of the same grade of granite and will contain the engines, pumps, dynamos and motors, etc., as are necessary for instruction in those departments. The university power house close by is provided with a splendid equipment of boilers, engines and dynamos, to furnish light, power and heat for the entire plant.

Eads Hall, the laboratory of physics, the gift of Mrs. Eliza How in memory of her father, Captain Jas. B. Eads, the well-known engineer, adjoins the library on the west.

Farther to the west are two large dormitories both of the same style and construction of the other buildings. Liggett Hall, erected by Mrs. Elizabeth J. Liggett in memory of her husband, the late Mr. John E. Liggett, at a cost of $100,000, will accommodate 75 students, and the other, built by the university at an expenditure of $190,000, containing a large dining hall, will accommodate 80 students.

At the western end of the university tract is the gymnasium adjoining the athletic field. This building, costing $150,000, is of the bold gothic type, with two square towers facing the east. It contains eight large dressing rooms with showers and lavatories attached, and will accommodate 2,000 men. The gymnasium hall is 75 feet by 108 feet, with overhead running track.

The large athletic field is provided with a grand stand of solid concrete 704 feet long, extending the entire length of the south side of the field, and will seat 7,300 people.

The Washington University Club, on the corner of Twenty-ninth and Locust Streets, is a splendidly appointed club-house belonging to the university and managed by a committee composed of the dean, one alumnus and one student of each department. Membership is open to all officers, to all male professors and instructors of the university, and to all male students and graduates of the college, the schools of engineering and law and the medical and dental departments. The building is admirably constructed and contains dining-rooms, library, smoking and reading-rooms, billiard-room and bowling alleys. The dues are only $5.00 a year, and meals are furnished to students at $3.50 a week. The club has proved of great value in the social life of the university, by bringing together on a common ground the students of all departments, so keeping all the students in touch and helping to create a true university spirit.

With a large and productive endowment, with an efficient faculty, with buildings that will compare favorably with any in the country and with a large enrollment of students in all departments the future growth and usefulness of the university seem to be assured.

WHAT IS GROUP THEORY?

BY PROFESSOR G. A. MILLER,
LELAND STANFORD JUNIOR UNIVERSITY.

IN the recent International Catalogue of Scientific Literature, group theory is classed among the fundamental notions of mathematics. The two other subjects which are classed under this heading are 'foundations of arithmetic' and 'universal algebra.' While it might be futile to attempt to popularize those recent advances in mathematics which are based upon a long series of abstract concepts, it does not appear so hopeless to give a popular exposition of fundamental notions. In what follows we shall aim to give such an exposition of some of the notions involved in the theory of groups.

This theory seems to have a special claim on popular appreciation in our country because it is one of the very few subjects of pure mathematics in whose development America has taken a prominent part. The activity of American mathematicians along this line is mainly due to the teachings of Klein and Lie at the universities of Göttingen and Leipzig respectively. During the Chicago exposition, the former held a colloquium at Evanston, in which the fundamental importance of the subject was emphasized and thus brought still more prominently before the American mathematicians.

There is probably no other modern field of mathematics of which so many prominent mathematicians have spoken in such high terms during the last decade. In support of this strong statement we quote the following:

> There are two subjects which have become especially important for the latest development of algebra; that is, on the one hand, the ever more dominating theory of groups whose systematizing and clarifying influence can be felt everywhere, and then the deep penetrations of number theory.* The theory of groups, which is making itself felt in nearly every part of higher mathematics, occupies the foremost place among the auxiliary theories which are employed in the most recent function theory.†
>
> In fine, the principal foundation of Euclid's demonstrations is really the existence of the group and its properties. Unquestionably he appeals to other axioms which it is more difficult to refer to the notion of group. An axiom of this kind is that which some geometers employ when they define a straight line as the shortest distance between two points. But it is precisely such axioms that Euclid enunciates. The others, which are more directly associated with the idea of displacement and with the idea of groups, are the very ones

* Weber, 'Lehrbuch der Algebra,' vol. 1, 1898, preface.

† Fricke und Klein, 'Automorphe Functionen,' vol. 1, 1897, p. 1.

which he implicitly admits and which he does not deem even necessary to enunciate. This is tantamount to saying that the former are the fruit of later experience, that the others were first assimilated by us, and that consequently the notion of group existed prior to all others. . . . What we call geometry is nothing but the study of formal properties of a certain continuous group, so that we may say space is a group.*

From these words of Poincaré it follows that the group concept is implicitly involved in some of the earliest mathematical developments. In an explicit form it first appears in the writings of Lagrange and Vandermonde in 1770. These men inaugurated a classic period in the theory of algebraic equations by considering the number of values which a rational integral function assumes when its elements are permuted in every possible manner. For instance, if the elements of the expression $ab + cd$ are permuted in every possible manner, it will always assume one of the following three values: $ab + cd$, $ac + bd$, $ad + bc$.

The eight different permutations which do not change the value of one of these expressions are said to form a *permutation group* and the expression is said to belong to this group. There is always an infinite number of distinct expressions which belong to the same permutation group. Hence it is convenient for many purposes to deal with the permutation group rather than with the expressions themselves. This fact was recognized very early and led to the study of permutation groups, especially in connection with the theory of algebraic equations. The most fundamental work along this line was done by Galois, who influenced the later development most powerfully, although he died when only twenty years old.

Galois first proved (about 1830) that the solution of any given algebraic equation depends upon the structure of the permutation group to which the equation belongs. As the algebraic solution of equations occupies such a prominent place in the history of mathematics this discovery of Galois furnished a powerful incentive for the study of permutation groups. Before Galois an Italian named Ruffini and a Norwegian named Abel had employed permutation groups to prove that the general equation of the fifth degree can not be solved by successive extraction of roots. In doing this the former studied a number of properties of permutation groups and is therefore generally regarded as the founder of this theory.

The definition of a permutation group is very simple. It is merely the totality of distinct permutations which do not change the formal value of a given expression. Such a totality of permutations has many remarkable properties. One of the most important of these is the fact that any two of them are equivalent to some one. That is, if

* Poincaré, *The Monist*, vol. 9, 1898, pp. 34 and 41.

any one of these permutations is repeated, or is followed by some other permutation in the totality, the result is equivalent to a single permutation in the totality. This property is characteristic; for if any set of distinct permutations possesses this property they form a permutation group and it is possible to construct an infinite number of expressions such that they are unchanged by these permutations but by no others.

Soon after the fundamental properties of permutation groups became known, it was observed that many other operations possess the same properties. This gradually led to more abstract definitions of the term group. According to the earliest of these any set of distinct operations such that no additional operation is obtained by repeating one of them or combining any two of them was called a group. All the later definitions included this property, but they generally add other conditions. These additional conditions are frequently satisfied by the nature of the operations which are under consideration and hence do not always require attention. This may account for the fact that the oldest definition is still very commonly met in text-books, notwithstanding the fact that the ablest writers on the subject abandoned it a long time ago.

The three additional conditions which a set of distinct operations must satisfy in order that it becomes a group when the operations are combined are: (1) The associative law must be satisfied; *i. e.*, if r, s, t represent any three operations of the set, then the three successive operations rst must give the same result independently of the fact whether we replace rs or st by a single operation. The operations are, however, not generally commutative, that is, rs may be different from sr. (2) From each of the two equations $rs = ts$, $sr = st$ it follows that $r = t$. (3) If the equation $xy = z$ involves two operations of the set the third element of the equation must also represent an operation in the set. It may be observed that the totality of integers combined by multiplication obey all these conditions except the last. Hence this totality does not form a group with respect to multiplication, although the contrary has frequently been affirmed.*

One of the simplest instances of a group of operations is furnished by the n different numbers which satisfy the equation $x^n = 1$. It is very easy to see that these numbers obey each of the four given conditions when they are combined by multiplication. Hence we say that the n roots of the equation $x^n = 1$ form a group with respect to multiplication. Since all these roots are powers of a single one of them

* Among other places this error is found in the first edition of Weber's classic work on algebra, vol. 2, p. 54. It has been corrected in the second edition of this work. Somewhat simpler definitions of the term group have recently been given by Huntington and Moore, *Bulletin of the American Mathematical Society*, vol. 8, p. 388.

this group is said to be cyclic. Cyclic groups are the simplest possible groups and they are the only ones whose operations can be completely represented by complex numbers.

Another very simple category of groups of operations is furnished by the totality of movements which leave a regular polygon unchanged. For instance, a regular triangle is transformed into itself when its plane is rotated around its center through 120° or through 240°. Moreover, its plane may be rotated through 180° around any of its three perpendiculars without affecting the triangle as a whole. These five rotations together with the one which leaves everything unchanged (known as the identity) are all the possible movements of the plane which transform the given triangle into itself. Hence these six movements form a group, which happens to be identical with the group formed by the six possible permutations of three things.

It is not difficult to see that a plane can have just eight movements which do not affect the location of a given square in it. These consist of the three movements around the center of the square through 90°, 180° and 270° respectively; the four movements through 180° around the diagonals and the lines joining the middle points of opposite sides; and the identity. This group of eight operations has exactly the same properties as the permutation group on four letters which transforms $ab + cd$ into itself. Hence these two groups are said to be simply isomorphic. From the standpoint of abstract groups, such groups are said to be identical.

In general, a regular polygon of n sides is left unchanged as a whole by just $2n$ movements of its plane, viz., $n-1$ movements around its center and n rotations through 180° around its lines of symmetry, in addition to the identity. The first $n-1$ movements together with the identity clearly form a group by themselves. Such a group within a group is known as a *subgroup*. This category of groups of $2n$ operations is known as the system of dihedral rotation groups or the system of the regular polygon groups. It is not difficult to prove that each of them is generated by some two non-commutative rotations through 180° and that no other groups have this property.

Among the non-regular polygons the rectangle with unequal sides has perhaps the most important group. There are clearly just three movements of the plane (besides the identity) which transform such a rectangle into itself, viz., the rotation through 180° around the center and the rotation around its two lines of symmetry through the same angle. These four operations form a group which presents itself in very many problems and is known by a number of different names. Among these are the following: four-group, anharmonic ratio group, axial group, quadratic group, rectangle group, etc. Since we arrive at the identity by repeating any one of its operations, it is entirely different from the group formed by the four roots of the equation $x^4 = 1$. It is easy to prove that these two groups represent all the possible types of groups of four operations; that is, there are only two abstract groups of four operations. In general, the number of groups which can be formed with n operations increases very rapidly with the number of factors of n. When $n = 8$ or 12 the number of possible abstract groups is 5.

Similarly, all the movements of space which transform a given solid into itself form a group. For instance, the cube is transformed into itself by twenty-four distinct movements. Nine around the lines which join the middle points of opposite faces, six around those which join the middle points of opposite edges, eight around the diagonals, and the identity. The group formed by these twenty-four movements is simply isomorphic with the one formed by the total number of permutations of four things. The regular octahedron has the same group, while the group of the regular tetrahedron is a subgroup of this group. The icosahedron and the duodecahedron have a common group of sixty operations. The groups of the regular solids play an important rôle in the theory of transformations of space. They are treated at considerable length in Klein's 'Ikosaeder' as well as in many other works.

All the preceding examples relate to groups of a finite number of operations, or of a finite order. During recent years the applications of groups of infinite order have been studied very extensively. As the theory of groups of finite order had its origin in the theory of algebraic equations, so the theory of groups of an infinite order might be said to have had its origin in the theory of differential equations. The rapid development of both of these theories is, however, due to the fact that much wider applications soon presented themselves. This is especially true of the latter. In fact, the earliest developments of the groups of infinite order were made without any view to their application to differential equations.

One of the simplest examples of groups of infinite order is furnished by the integral numbers when they are combined with respect to addition. The totality of the rational numbers clearly becomes a group when they are combined with respect to either of the operations addition or multiplication. The same remark applies evidently to all the real numbers as well as to all the complex numbers. These additive groups of infinite order are frequently represented by the equation $x = x' + a$, where a may assume all the values of one of the given groups. If a may assume all real values the group is said to be continuous. When a is restricted to rational values the group is said to be discontinuous, notwithstanding the fact that it transforms every finite point into a point which is indefinitely close to it.

While these examples exhibit a very close relation between continuous and discontinuous groups of infinite order, yet the methods employed to investigate problems belonging to these groups are generally quite different. The theory of the former is mainly due to Sophus Lie and has been developed principally with a view to the solution of differential equations. The theory of the latter has been developed largely in connection with questions in function theory and owes its rapid growth to the influence of Klein. A large part of Lie's results are contained in his 'Transformationsgruppen,' consisting of three large volumes, while the 'Modulfunctionen' and 'Automorphe Functionen' of Klein and Fricke are the best works on the discontinuous groups of infinite order.

Although the notion of group is one of the most fundamental ones in mathematics, yet it is one which is more useful to arrive at reasons for certain results and at connections between apparently widely separated developments than to furnish methods for attaining these results or developments. Its greatest service so far has been its unifying influence and its usefulness in proving the possibility or the impossibility of certain operations. In fact, it is generally conceded that group theory had its origin in the use which Ruffini and Abel made of it to prove that the general equation of the fifth degree can not be solved by radicals.

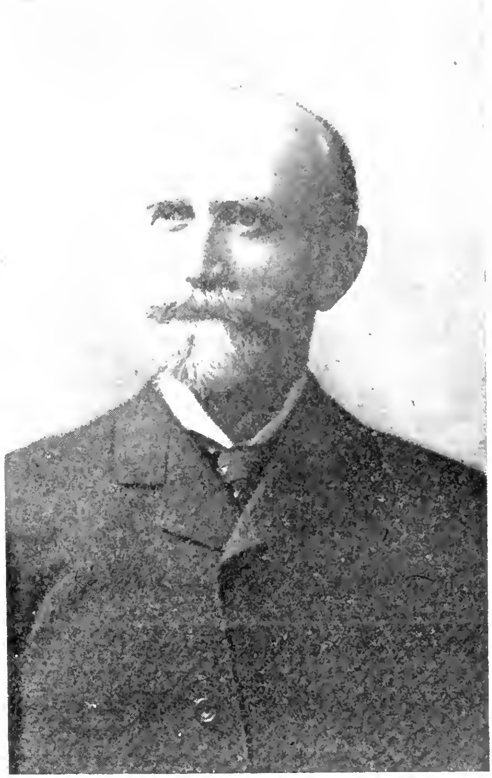
While it may be said to have 'shown its dominating influence in nearly all parts of mathematics, not only in recent theories, but also far towards the foundation of the subject, so that this theory can no longer be omitted in the elementary text-books,'* yet this influence is largely a guiding influence. The bulk of mathematics is not group theory and the main part of the work must always be accomplished by methods to which this notion is foreign. On the other hand, it seems safe to say that this theory is not a fad which will pass into oblivion as rapidly as it rose into prominence. Its applications are so extensive and useful that it must always receive considerable attention. Moreover, it presents so many difficulties that it will doubtless offer rich results to the investigator for a long time.

* Pund, 'Algebra mit Einschluss der elementaren Zahlentheorie,' 1899, preface.

THE PROGRESS OF SCIENCE.

CONVOCATION WEEK MEETINGS OF SCIENTIFIC SOCIETIES.

There is an accounting of scientific stock at the close of each year when the national scientific societies hold their annual meetings. There does not, however, exist either for this or any other country a census of scientific work and scientific men. As a rough guess, it may be suggested that there were perhaps 100 men in the United States professionally engaged in scientific work in 1850, 200 in 1860, 400 in 1870, 800 in 1880, 1,600 in 1890, 3,200 in 1900; and that we may expect to find as many as 6,400 in 1910. Certainly the increase in endowments, in opportunities and in men appears to follow a geometrical rather than an arithmetical progression. The American Association for the Advancement of Science held its first meeting in 1848, but the first meeting for which the record of attendance has been pre-



Otto H. Tittmann, Superintendent of the U. S. Coast and Geodetic Survey, Vice-president for Mathematics and Astronomy.

served was that of 1851, when 87 members were present. The National Academy of Sciences was incorporated in 1863, and its fifty members included a large proportion of the scientific men of the country. There was no national society for a separate science until the American Chemical Society was established in 1874. Now the American Association is divided into ten sections, and about twenty different societies met Society of College Teachers of Education.

A Society for Vertebrate Paleontology held its first meeting at Philadelphia and a Political Science Association was organized at New Orleans.

There were about 500 members of the American Association and affiliated societies at St. Louis, about 200 naturalists at Philadelphia and about 50 philosophers at Princeton. Last year the

Edwin H. Hall, Professor of Physics, Harvard University, Vice-president for Physics.

in affiliation with it in St. Louis, six societies devoted to the biological sciences met simultaneously at Philadelphia, the Historical and Economic Associations met at New Orleans and the Philosophical Association at Princeton. Nearly every year new national associations are established, which are rarely if ever abandoned. Thus there became this year affiliated with the American Association two new societies—The Society for Horticultural Science and the American Association and affiliated societies held two meetings—one at Pittsburg in the summer with an attendance of about 600, and one at Washington during convocation week with an attendance of about 1,400. The attendance at the winter meeting was consequently this year only half as large as last year, and the attendance of the year only about one third as large. Yet the number of scientific workers increases continually, and the membership of the association rose during the year from 3,600 to 4,000. The falling off in attendance due to the abandonment of the summer meeting appears to be a definite loss with no compensating advantages. Many members unable to attend in midwinter want a summer meeting, and those who can not travel as far as a thousand miles should be given an opportunity to attend a meeting within reach, and this requires two meetings annually. The summer meeting can also be given certain distinctive features of out-of-door life and scientific excursions, which are out of the question in midwinter. The American Association must be national in scope, but meetings in the central states are always smaller than those on the Atlantic seaboard. The scientific centers in the east are more concentrated, and it is also true that it is psychologically further from the east to the west than from the west to the east. Many scientific men would rather travel 1,000 or 1,500 miles to an eastern meeting than a much shorter distance to a meeting in the central states.

Under the circumstances the St. Louis and Philadelphia meetings may be regarded as successful. They were working meetings of scientific men with nearly as many papers on the programs as members in attendance. In both cities excellent local arrangements were made for the meetings of the societies and sections and for the entertainment of visitors.

WILDER D. BANCROFT, Professor of Physical Chemistry, Cornell University, Vice-president for Chemistry.

We publish above the address of President Ira Remsen, the retiring president of the American Association, and the address of President David Starr Jordan before the Sigma Xi Society. Other addresses of interest were given before the sections of the associations and the special societies, and the public lecture on radium by Professor Rutherford was on a particularly timely topic. The American Association, and it may be hoped all the societies that were affiliated last year in Washington, will meet next year at Philadelphia. New Orleans is recommended as the place of meeting two

Section of Mathematics and Astronomy—Professor Alexander Ziwet, University of Michigan.

Section of Physics—Professor William F. Magie, Princeton University.

Section of Chemistry—Professor Leonard P. Kinnicutt, Worcester Polytechnic Institute.

Section of Mechanical Science and Engineering — Professor David S. Jacobus, Stevens Institute of Technology.

CALVIN M. WOODWARD, Professor of Mathematics and Applied Mechanics, Washington University, Vice-president for Mechanical Science and Engineering.

years hence. Professor W. G. Farlow, the eminent botanist, was elected president of the association. His portrait is given as a frontispiece, and we reproduce here the photograph of the vice-presidents who presided over the sections. Presiding officers for the sections and for the special societies were elected as follows:

Section of Geology and Geography—Professor Eugene A. Smith, University of Alabama.

Section of Zoology—Dr. C. Hart Merriam, U. S. Biological Survey.

Section of Botany—Professor B. L. Robinson, Harvard University.

Section of Anthropology—Walter Hough, Bureau of American Ethnology.

Section of Social and Economic Science—Martin A. Knapp, Washington, D. C.

Section of Physiology and Experimental Medicine—The present vice-president, Professor H. P. Bowditch, Harvard University, will serve another year.

The American Society of Naturalists—Professor E. L. Mark, Harvard University.

The Astronomical and Astrophysical Society of America—Simon Newcomb, Washington.

Physiology—Dr. G. T. Moore, Washington.

American Physiological Society—Professor Russell H. Chittenden, Yale University.

American Society of Zoologists, Eastern Branch—Professor E. A. Andrews, Johns Hopkins University.

American Society of Vertebrate Paleontologists—Professor Henry F. Osborn, Columbia University.

EDWARD L. MARK, Professor of Anatomy, Harvard University, Vice-president for Zoology and President of the American Society of Naturalists.

The Geological Society of America—Professor J. C. Branner, Stanford University.

The American Philosophical Association—Professor G. T. Ladd, Yale University.

The American Psychological Association—Professor William James, Harvard University.

Association of American Anatomists—Professor Charles S. Minot, Harvard University.

Society of American Bacteriologists—Dr. F. G. Novy, the University of Michigan;

Society for Plant Morphology and

THE ST. LOUIS EXPOSITION AND ITS CONGRESS OF ARTS AND SCIENCE.

It is quite possible that the attendance at the St. Louis meeting of the American Association was somewhat decreased by the fact that many members propose visiting the Louisiana Purchase Exposition and were unable to make the journey to St. Louis twice within a year. Those in attendance at the meeting had, however, the privilege of visiting the grounds of the exposition and witnessing the extraordinary magnitude of the undertaking. We are told that the approximate cost is $50,000,000, the size of the grounds 1,240 acres, and the area of the buildings 200 acres. It is consequently planned on a scale much surpassing the expositions of Philadelphia, Chicago and Paris. The making of expositions is becoming a sort of applied science, each showing progress over its predecessors. A large proportion of the chiefs of departments and others in charge of the work at St. Louis have been trained at previous expositions.

An exposition is both interesting and tiring, whereas a description is likely to be tiring without being interesting. The subjoined plan gives some idea of the arrangement of the buildings, their number and their size. An enumeration of the buildings shows clearly that the whole undertaking is an apotheosis of applied science, extending even to the shows along 'The Pike.' Education has been given a central place, both in the position of the building, the first to form part of an exposition, and in the classification of the exhibits. The exposition and education are also fortunate in the fact that the new buildings of Washington University are on the grounds. We are glad to be able to publish elsewhere in this number a description of the university which is rapidly becoming one of the great universities of the country. The art gallery is also a permanent building, erected with its temporary annexes at the cost of over a million dollars.

THOMAS H. MACBRIDE, Professor of Botany, State University of Iowa, Vice-president for Botany.

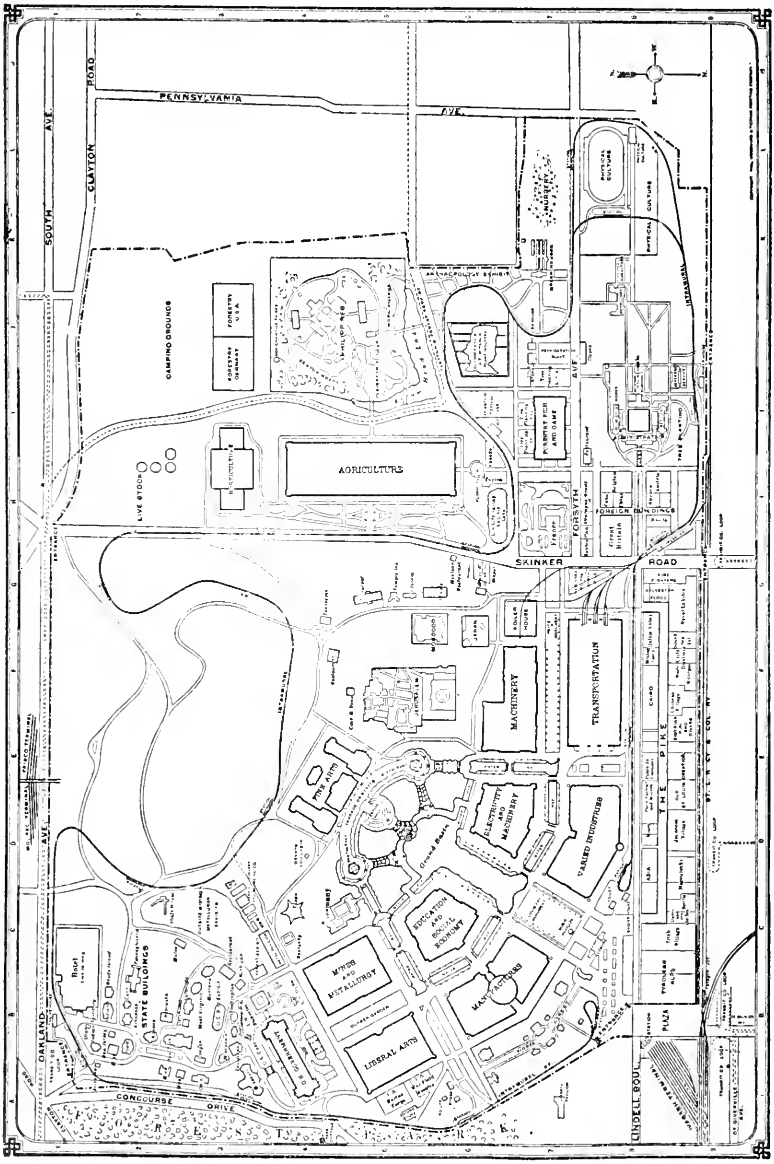
Several of the features of the exposition—such as the exhibit of aerial navigation—for which prizes of the value of $200,000 have been set aside—

are of direct scientific interest. Far surpassing all the rest in this respect is, however, the Congress of Arts and Science, to which we have already called attention. Instead of congresses devoted to each special science, such as have met in connection with other expositions, one great congress has been planned to represent the total accomplishment and unity of science. It is can speakers to be invited was completed. About 125 of the most eminent foreign men of science and scholars have accepted the invitation, and there will doubtless be an equally cordial response from Americans. Professor Münsterberg in an article on the congress in *The Journal of Philosophy* says: "Almost every one of these European scholars has in his own field

SIMEON E. BALDWIN, Judge of the Supreme Court of Errors, New Haven, Conn., Vice-president for Social and Economic Science.

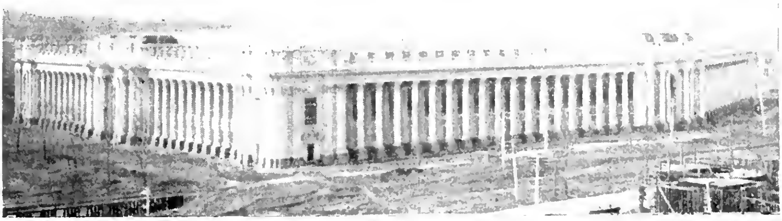
easy to object to certain details of classification and method; but it is evident that a large idea has been conceived and is likely to be successfully realized. The original plan is due to Professor Hugo Münsterberg. The members of the committee visited Europe during the summer to extend invitations to foreign men of science, and at St. Louis during the meeting of the American Association the list of Ameri-

brought about a certain synthesis of widely separated elements of thought, and has devoted not the smallest part of his work to the fundamental conceptions and methods of his science. The addresses which they will deliver thus lie essentially in the line of their own best thought, and yet it is most probable that the greater part of these addresses would never have been written had not the outer occasion of our invitation stimulated them to undertake the task. Such work is too easily postponed. And thus the congress may hope to create in these hundreds of ad-



PLAN OF THE ST. LOUIS EXPOSITION GROUNDS.

dresses a connected and consistent work which no chance group of individuals would have produced, which demanded a unified program and the enthusiasm of the leading thinkers of the world. But we hope that still more important than the set addresses will be the living influence of this gathering, in which the four or five hundred invited official speakers and chairmen, together with the thousand who may make shorter communications, will form merely the nucleus of the international meeting. That such a unique fusion of scholarship will be productive in itself no one can doubt; but that these scholars are brought together and are doing their work under the control of the demand for unity in knowledge, for interrelation and synthesis—this thought will be the living force, the most powerful factor of the congress, and a tremendous influence in overcoming the pedantic and unphilosophic narrowness of specialists in every corner of the realm of science."



PALACE OF EDUCATION AND SOCIAL ECONOMY.

THE SCIENTIFIC BASIS OF CHEESE MAKING.

THE processes involved in the making and curing of cheese have been the subject of some of the most noteworthy dairy investigations which have been made. While the subject had been studied in a fragmentary way in this country and in Europe for some time, little real progress was made until several of the American experiment stations undertook a systematic investigation of the nature and causes of the changes involved and the chemical character of the products formed. This has gone on steadily for eight or ten years, and has resulted in the working out of the scientific principles underlying this very ancient art. The largest amount of work has been done by the experiment stations in Wisconsin, New York and Canada, and the names of Babcock, Russell, Van Slyke and Hart are especially prominent. The reports of progress have appeared in a series of bulletins from these stations, several particularly important ones having been issued during the past few months.

In the course of the chemical studies the product formed by the action of rennet on milk, about which there had previously been considerable doubt, was identified as paracasein. This was found to combine with acids to form mono- and di-acid salts, quite different in character and in their effect upon the appearance of the curd. In normal cheese making the mono-acid salt is formed, the paracasein uniting in that proportion with the lactic acid produced in the curd by lactic-acid bacteria. These bacteria have invariably been found in the milk and green cheese in predominating numbers, but their true function has remained until now a mystery. They are indispensable to the formation of paracasein monolactate in cheese curd, and this compound is found to be the starting point of the ripening or curing process.

The first step in this appears to be a peptic digestion of the monolactate, the rennet ferment being the active agent. Rennet, which was formerly supposed to contain two enzyms, is found to be in reality a peptic ferment and to act in all essentials like commercial pepsin in forming soluble nitrogen compounds. In fact, normal cheese has been made by the substitution of commercial scale pepsin for rennet extract. The chemical changes produced by both rennet and pepsin are confined mainly to the formation of paranuclein, caseoses and peptones, only small amounts of amids and no ammonia being formed. The action of these enzyms does not appear to extend to the formation of the compounds that give the flavor to cheese. In normal cheese tyrosin, oxyphenylethylamin, arginin, histidin, lysin, guanidin, putrescin and ammonia were found as end products of the proteolysis. The investigations indicate that the formation of secondary amido compounds and ammonia are due to the action of a biological factor, not yet determined.

The conditions affecting the chemical changes in the ripening process have been worked out in detail, and among these the favorable effect of low temperatures has been demonstrated. The latter is entirely opposed to the views heretofore held by practical cheese makers, who have avoided too great cold, believing it to result in a bitter, inferior product. The advantages of cold curing are shown by an extensive experiment recently concluded by the National Department of Agriculture in cooperation with the experiment stations in Wisconsin and New York. About 500 cheeses representing a great variety of makes were cured at temperatures of 40°, 50° and 60° F., whereas the temperature of ordinary curing rooms runs up to 70° and often higher in summer. The improvement in quality of the cold-cured product was evident in the flavor and texture and in its higher market value. The loss of moisture in cold curing was very much less, resulting in diminished loss from shrinkage; moreover, the cheese can be held a long time at low temperatures without impairment of quality. These investigations will tend to revolutionize cheese making in several respects, by furnishing a scientific basis for it in place of the purely empirical rules and traditions which formerly prevailed, and will simplify the process, rendering possible a more uniform product of improved quality.

SCIENTIFIC ITEMS.

We regret to record the death of Professor Karl Alfred von Zittel, the eminent paleontologist of the University of Munich; of M. Proust, professor of hygiene of the University of Paris and inspector general of the Sanitary Service; of Dr. Eugene Askenasy, honorary professor of plant physiology at the University of Heidelberg; and of Mr. Gurdon Trumbull, the artist and ornithologist, of Hartford, Conn.

Mr. John Morley will deliver the principal address at the opening of the Technical Institution, founded at Pittsburg by Mr. Carnegie, in the autumn of 1904.—Sir William Ramsay, of London, will give a course of lectures during the summer session at the University of California on 'The Constituents of the Atmosphere and the Emanations from Radium.'

Dr. G. W. Hill, of Nyack, N. Y., has been elected a corresponding member in the section of astronomy of the Paris Academy of Sciences.—Professor George W. Hough, of Northwestern University, has been elected an associate member of the Royal Astronomical Society.—The sixtieth birthday of Dr. Robert Koch was celebrated on December 11. A portrait bust was unveiled in the Institute for Infectious Diseases, Berlin, a museum for bacteriology was established and a *Festschrift* is in press.

Mr. Shyamaji Krishnavarma, of India, has offered $5,000 to Oxford University to establish a lectureship in honor of Herbert Spencer to be known as the Spencer Lectureship.

The Nobel prizes, each of the value of about $40,000, were awarded in Christiania, on December 10. The prize in physics was divided between M. Becquerel and M. and Mme. Curie, of Paris. The prize in chemistry was awarded to Professor Arrhenius, of Stockholm; the prize in medicine to Dr. Finsen, of Copenhagen, and the prize in literature to Dr. Björnstjerne Björnsen, of Christiania.—The prize for French contributions to science given by M. Osiris through the Paris Press Association has been divided between Mme. Curie and M. Branly. Mme. Curie receives 60,000 francs for her work on radium and M. Branly 40,000 francs for his work in connection with wireless telegraphy.

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AERIAL NAVIGATION.*

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THERE are now dawnings of two possible solutions of the problem of aerial navigation; a problem which has impassioned men for perhaps 4,000 or 5,000 years. Navigable balloons have recently been developed to what is believed to be nearly the limit of their efficiency, and after three intelligent but unfortunate attempts by others, a successful dynamic flying machine seems to have been produced by the Messrs. Wright.

It is therefore interesting to review the present status of the question, the prospects of its solution and the probable uses of the hoped-for air-ships.

Balloons.

As to balloons, we may pass over the early gropings and failures to make them navigable. It was recognized very soon that the spherical balloon was the sport of the wind, that it was necessary to elongate it in order to evade the resistance of the air, and that, inasmuch as aerial currents are much more rapid than aqueous currents, it was necessary to obtain considerable speeds in order to have a useful air-ship. This means that there must be great driving power, and that this power shall weigh as little as possible; for in any case the balloon itself with its adjuncts and passengers will absorb the greater part of its lifting power.

Giffard was the first to apply in 1852 an artificial motor to an elongated balloon. This motor consisted in a steam-engine of three horse power, which weighed with its appurtenances 462 pounds, and

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Giffard obtained only 6.71 miles per hour, although his balloon was 144 feet long and 39 feet in diameter, or about the size of a tramp steamer.

Dupuy de Lome in 1872 went up with a balloon 118 feet long and 49 feet in diameter, but, having a wholesome dread of the contiguity of fire and inflammable gas, he employed man power (weighing about 2,000 pounds to the horse power) to drive his screws, and he obtained less speed than Giffard. The accidents to Wölfert and to DeBradsky have since shown the soundness of his fears.

Next came Tissandier in 1884, who employed an electric motor of 1½ horse power, weighing some 616 pounds, with which he attained 7.82 miles per hour.

Meanwhile the French war department took up the problem. It availed itself of the labors of the previous experimenters and made careful and costly investigations of the best modes of construction, of the best shapes to cleave the air and of the weight and efficiency of motors. This culminated in 1885 when Messrs. Renard and Krebs, of the Aeronautical Section, brought out the war balloon 'La France' which attained about 14 miles an hour (or half the speed of a trotting horse) and returned to its shed five times out of the seven occasions on which it was publicly taken out.

This air ship was 165 feet long, 27½ feet in diameter and was provided with an electric motor of 9 horse power, weighing with its apurtenances some 1,174 pounds. The longitudinal section was parabolic, somewhat like a cigar rolled to a sharp point at both ends, the largest cross-section being one fourth of the distance from the front, and it was driven, blunt end foremost, by a screw attached at the front of the car. No better shape and arrangement have yet been devised and subsequent experimenters who have wandered away therefrom have achieved inferior results, so far as the coefficient of resistance is concerned.

In 1893 the French War Department built the 'General Meusnier,' named after an aeronautical officer of extraordinary merit of the first French Republic. This war balloon is said to be 230 feet long, 30 feet in diameter, 120,000 cubic feet in capacity and to have been originally provided with a gasoline motor of 45 horse power. It is said by all the writers on the subject that it was *never taken out*. Possibly the French were waiting for a war which fortunately never came; but, be this as it may, it is probable that with the reduction which has since taken place in gasoline motors this balloon could carry an engine of some 70 horse power, and attain a speed of about 30 miles an hour, which is greater than that of transatlantic steamers.

Some unsuccessful experiments were carried on in Germany in 1897. First by Dr. Wölfert, whose balloon was set on fire by his gasoline motor and exploded in the air, killing both himself and his engineer, and later by Schwarz, whose aluminum balloon proved unmanageable and was smashed in landing. The most ambitious attempt, however, was that of Count Zeppelin, who built in 1900 a monster air-ship 420 feet long and 39 feet in diameter. It was a cylinder with paraboloid ends, but the shape was inferior and almost all the lifting power was frittered away on a internal frame of aluminum, so that the gasoline motor could be of only 32 horse power, and the speed attained has variously been stated at 8 to 18 miles per hour. Nevertheless the design of Count Zeppelin contained many excellent features, and a movement is now on foot in Germany to enable him to try again, through means of a popular subscription. The mere size, if he builds again as large, is a great element of success, for as the cubic contents and lift increase as the cube of the dimensions, while the weights increase in a far smaller ratio, a balloon of this great size ought to be able to lift a very powerful motor, and to attain a speed of 30 or more miles per hour. He has shown that the size is not beyond the possibility of control.

Meanwhile gasoline motors had been increasing in efficiency and diminishing in weight. The French war department gave no sign and it was reserved for a Brazilian, Mr. Santos Dumont, to show to the Parisians what could be accomplished by equipping an air-ship with a gasoline motor. The history of his triumphs is so present to all minds that it need only be alluded to, but it may be interesting to give some details of the sizes and arrangements of his various balloons. His first idea seems to have been that, in order to make it manageable, a balloon should be made as small as possible, and that it was practicable to disencumber it of many adjuncts hitherto considered indispensable. Neglecting to study carefully what had been found out by his predecessors, he had to learn by experience, and he built five balloons, all navigables, before he produced in 1901 his No 6, with which he won the Deutsch Prize, by sailing 3½ miles and return in half an hour. This balloon was 108 feet long, 20 feet in diameter and was provided with a gasoline motor of 16 horse power which might be driven up to 18 or 20 horse power. While the speed over the ground was 14 miles an hour, retarded as it was by a light wind, the speed through the air was about 19 miles an hour, a small but marked advance over any previous performance; but the result would have been still better if the shape had been that of Colonel Renard's balloon.

Since then Mr. Santos Dumont has built four new navigable balloons. His No. 7, with which he expects to compete at St. Louis in 1904, is 160 feet long and 23 feet in diameter and is to be provided with a motor of 60 horse power. His No. 8, which was sold to parties in New York last year. His No. 9, which is his visiting balloon, being only 50 feet long and 18 feet in diameter and provided with a 3 horse power motor. Its speed is only 10 miles an hour, but it is handy to ride around to breakfast or afternoon teas. He is now finishing his No. 10, the omnibus, which is 157 feet long and 28 feet in diameter, with a motor of 46 horse power. Fares are to be charged for by the pound of passenger when it comes out next spring.

Emulators of Santos Dumont there have been that have come to grief. Mr. Roze built in 1901 a catamaran consisting of two twin balloons, which, although 148 feet long, failed to raise their own weight serviceably. Mr. Severo built in 1902 a navigable balloon which was so injudiciously constructed that the car broke away in the air, and the inventor was killed as well as his engineer. Later in the same year DeBradsky built a navigable balloon equipped with a gasoline motor located so near the vent for the gas that the latter took fire, exploded the balloon, and the inventor and his engineer were killed, thus for the second time verifying the fears of the experts who discountenanced this combination.

Some meritorious projects have been published but not yet carried out. Among these may be mentioned that of Mr. Yon, now deceased, and that of Mr. Louis Godard. The latter project was for a balloon 180 feet long and 36 feet in diameter, with two steam motors of 50 horse power each. It was expected to attain a speed of 30 miles per hour.

One navigable balloon which was built this year, that of the Lebaudy brothers, has achieved a great success. It is 185 feet long, 32 feet in diameter, and is equipped with a gasoline motor of 40 horse power. It has beaten the speed of Santos Dumont, having on many occasions, it is said, attained 24 miles an hour.

There is also a navigable balloon being built in Paris by Mr. Tatin for Mr. Deutsch, the donor of the famous prize. This is 183 feet long, 27 feet in diameter and is equipped with a gasoline motor of 60 horse power.

Besides these there are said to be a number of navigable balloons either being built or proposed in France. They are those of the Marquis de Dion, of Pillet & Robert, of Girardot, of Boisset and of Bourgoin, but there is no telling how many of them will materialize.

These are all French balloons, while there are in England the balloon of Mr. Spencer, 93 feet by 24 feet with nominally 24 horse power; of Mr. Beedle, 93 feet by 24 feet with 12 horse power, and that of Dr. Barton, now in construction, with dimensions of 170 feet in length, 40 feet in diameter, and equipped with a number of aeroplanes and three gasoline motors of 50 horse power each. It is a question whether the weight of the aeroplanes will leave sufficient margin to lift 150 horse power.

The ultimate practicable size for balloons is not yet known, but the mathematics of the subject are now tolerably well understood. The larger the balloon the more speed it can attain, and it is possible to design it so that the results shall not be disappointing. Those inventors who expect to attain 70 to 100 miles an hour by some happy combination do not know what they are talking about.

It is interesting to speculate which of the above-mentioned navigable balloons would, if competing, stand a chance of winning the $100,000 prize which has been offered by the St. Louis Exposition of 1904. So far as can now be discerned, the only vessels which are likely to develop the required minimum speed of 20 miles an hour over the ground, which speed really requires about 25 miles an hour through the air as there will almost invariably be some wind, will be the Santos Dumont No. 7, the Lebaudy and the Deutsch air-ships, all of them French. The English vessels of Spencer and of Beedle are too small to lift sufficient power to drive them at 25 miles an hour. The balloon of Dr. Barton might gain this speed if it were not 40 feet in diameter, besides being loaded down with aeroplanes, and it remains to be seen what will be the effect of this combination. The American air-ships all seem to be too small to lift enough power to give them the required speed save the Stanley air-ship, 228 feet by 56 feet in diameter, begun in San Francisco. Should this be completed in time, and should the weights be kept approximately near those stated in the circulars, it might have a chance to obtain 25 miles an hour, but it would need more than three times the 50 horse power contemplated in order to do so, and the weight of the aluminum shell and framing would probably absorb much of the lifting power.

Flying Machines.

If the aeronautical contest at St. Louis were scheduled to take place a few years later, thus giving time to consummate recent success, it is not improbable that the main prize would be carried off by a flying machine. This yet lacks the safe flotation in the air which appertains to balloons, but it promises to be eventually very much faster.

The writer found, somewhat to his surprise, when on a visit to Paris last April, that a decided reaction has set in among the French against balloons. It seemed to be realized that the limit of speed had been nearly reached for the present, and that but small utility was to be expected from navigable balloons. They must be large, costly and require expensive housing, while they are slow and frail and carry very small loads. As commercial carriers they are not to be thought of, but they may be useful in war and in exploration.

Hence the French are turning their thoughts towards aviation and propose to repeat some of the experiments with gliding machines which have taken place in America. Even Colonel Renard, the celebrated pioneer of the modern navigable balloon, is now said to have become a convert to aviation and to say that the time has come to try the system of combined aeroplanes and lifting screws for flying apparatus.

A good deal of experimenting has been done with power-driven flying models. The more recent types have been actuated by twisted rubber threads, by compressed air and by steam, and the most notable experiments in order of date are those of Penaud, Tatin, Hargrave, Phillips, Langley and Tatin and Richet. The data for these (except the first) will be found by searchers in such matters in the London *Times* edition of the 'Encyclopædia Britannica,' in the article on aeronautics. The most successful experiment was that of Professor Langley, who obtained in 1896 three flights of about three fourths of a mile each with steam-driven models, the apparatus alighting safely each time and being in condition to be flown again.

The one great fact which appears from all these various model experiments is that it requires a relatively enormous power to obtain support on the air. Omitting the cases in which the power was probably overestimated, the weights sustained were but 30 to 55 pounds to the horse power expended, thus comparing most unfavorably with the weights transported by land or by water; for a locomotive can haul about 4,000 pounds to the horse power upon a level track, and a steamer can propel a displacement of 4,000 pounds per horse power on the water at a speed of 14 miles an hour.

But models are, to a certain extent, misleading. They seldom fly twice alike and they do not unfold the vicissitudes of their flight. Moreover, the design for a small model is sometimes quite unsuited for a large machine, just as the design for a bridge of ten feet opening is unsuited for a span of one hundred feet.

After experimenting with models three celebrated inventors have passed on to full-sized machines, to carry a man. They are Maxim, Ader and Langley, and all three have been unsuccessful, simply because their apparatus did not possess the required stability. They might have flown had the required equilibrium and strength been duly provided.

At a cost of about $100,000, Sir Hiram Maxim built and tested in 1894 an enormous flying machine, to carry three men. It consisted in a combination of superposed aeroplanes, portions of which bagged under air pressure, and it was driven by two screws 17 feet 10 inches in diameter, actuated by a steam engine of 363 horse power with steam at 275 pounds pressure. The supporting surface was about 4,000 square feet, and the weight 8,000 pounds. The machine ran on a track of 8-feet gauge, and was prevented from unduly rising by a track above it of 30-feet gauge. At a speed of 36 miles per hour all the weight was sustained by the air, and on the last test the lifting effect became so great that the rear axle trees were doubled up and finally one of the front wheels tore up about 100 feet of the upper track; when steam was shut off and the machine dropped to the ground and was broken. Its short flight disclosed that its stability was imperfect and Sir Hiram Maxim has not yet undertaken the construction of the improved machine which he is understood to have had under contemplation.

Having already built in 1872 and 1891 two full-sized flying machines with doubtful results, Mr. Ader, a French electrical inventor, built in 1897 a third machine at a cost of about $100,000 furnished by the French War Department. It was like a great bird, with 270 feet supporting surface and 1,100 pounds weight, being driven by a pair of screws actuated by a steam engine of 40 horse power which weighed about 7 pounds per horse power. Upon being tested under the supervision of the French army officers, the equilibrium was found so defective that further advance of funds was refused. The amount lifted per horse power was 27 pounds.

The data for the full-sized flying machine of Professor Langley, tested October 7 and December 8, 1903, have not yet been published. From newspaper photographs it appears to be an amplification of the models which flew successfully in 1896, and this, necessarily, would make it very frail. The failures, however, seem to have been caused by the launching gear and do not prove that this machine is worthless. Like the failures of Maxim and of Ader, it does indicate that a better design must be sought for, and that the first requisites are that the machine shall be stable in the air, shall be quite under the control of its operator, and that he, paradoxical as it may appear, shall have acquired thorough experience in managing it before he attempts to fly with it.

This was the kind of practical efficiency acquired by the Wright Brothers, whose flying machine was successfully tested on the seventeenth of December. For three years they experimented with gliding machines, as will be described farther on, and it was only after they had obtained thorough command of their movements in the air that they ventured to add a motor. How they accomplished this must be reserved for them to explain, as they are not yet ready to make known the construction of their machine nor its mode of operation. Too much praise can not be awarded to these gentlemen. Being accomplished mechanics, they designed and built the apparatus, applying thereto a new and effective mode of control of their own. They learned its use at considerable personal risk of accident. They planned and built the motor, having found none in the market deemed suitable. They evolved a novel and superior form of propeller; and all this was done with their own hands, without financial help from anybody.

Meantime it is interesting to trace the evolution which has led to this result and the successive steps which have been taken by others.

It is not enough to design and build an adequate flying machine; one must know how to use it. There is a bit of tuition which most of us have seen, that of the parent birds teaching their young to fly, which demonstrates this proposition. Even with thousands of years' evolution and heredity, with adequate flying organs, the birdlings need instruction and experience.

Safety is the all-important requisite. It is indispensable to have a flying machine which shall be stable in the air, and to learn to master its management. Nothing but practise, practise, practise, will gain the latter, and upon this the school of Lilienthal and his followers is founded.

Otto Lilienthal was a German engineer of great originality and talent, who after making very valuable researches, assisted by his brother, published a book in 1889, 'Der Vogelflug als Grundlage der Fliegekunst,' which it is very desirable to have translated and published for the benefit of English investigators. Then, putting his theories to the test of practise, he built from 1891 to 1896 a number of aeroplane machines with which he diligently trained himself in gliding flight, using gravity for a motive power, by starting from hillsides. He grew exceedingly expert, and made, it is said, more than 2,000 flights, until one rueful day (August 9, 1896) he was upset and killed by a wind gust, probably in consequence of having allowed his apparatus to get out of order.

He was followed by Mr. Pilcher, an English marine engineer, who slightly improved the apparatus, but who, after making many hundred glides, was also upset and killed in October, 1899, through structural weakness of his machine.

The basis for the equilibrium of an apparatus gliding upon the air being that the center of gravity shall be on the same vertical line as the center of air pressure, both Lilienthal and Pilcher reestablished this condition by moving their bodily weight to the same extent that the center of pressure varied through the turmoils of the wind. The writer ventured to think this method erroneous, and proposed to reverse it by causing the surfaces themselves to alter their position, so as to bring the center of pressure back vertically over the center of gravity. He began experimentally with man-carrying gliding machines in June, 1896, and has since built six machines of five different types, with three of which several thousand glides have been effected without any accidents. The first was a Lilienthal machine, in order to test the known before passing to the unknown, and this was discarded some six weeks before Lilienthal's sad accident.

With three of the other machines favorable results were obtained. The best were with the 'two-surface' machine, equipped with an elastic rudder attachment designed by Mr. Herring, and this was described and figured in the 'Aeronautical Annual' for 1897.

Three years later Messrs. Wilbur and Orville Wright took up the problem afresh and have worked independently. These gentlemen have placed the rudder in front, where it proves more effective than in the rear, and have placed the operator horizontally on the machine, thus diminishing by four fifths the resistance of the man's body from that which obtained with their predecessors. In 1900, 1901, 1902 and 1903 they made thousands of glides without accidents and even succeeded in hovering in the air for a minute and more at a time. They had obtained almost complete mastery over their apparatus before they ventured to add the motor and propeller. This, in the judgment of the present writer, is the only course of training by which others may hope to accomplish success. It is a mistake to undertake too much at once and to design and build a full-sized flying machine *ab initio,* for the motor and propeller introduce complications which had best be avoided until in the vicissitudes of the winds bird-craft has been learned with gravity as a motive power.

Now that an initial success has been achieved with a flying machine, we can discern some of the uses of such apparatus, and also some of its limitations. It doubtless will require some time and a good deal of experimenting, not devoid of danger, to develop the machine to practical utility. Its first application will probably be military. We can conceive how useful it might be in surveying a field of battle, or in patrolling mountains and jungles over which ordinary means of conveyance are difficult. In reaching otherwise inaccessible places such as cliffs, in conveying messages, perhaps in carrying life lines to wrecked vessels, the flying machine may prove preferable to existing methods, and it may even carry mails in special cases, but the useful loads carried will be very small. The machines will eventually be fast, they will be used in sport, but they are not to be thought of as commercial carriers. To say nothing of the danger, the sizes must remain small and the passengers few, because the weight will, for the same design, increase as the cube of the dimensions, while the supporting surfaces will only increase as the square. It is true that when higher speeds become safe it will require fewer square feet of surface to carry a man, and that dimensions will actually decrease, but this will not be enough to carry much greater extraneous loads, such as a store of explosives or big guns to shoot them. The power required will always be great, say something like one horse power to every hundred pounds of weight, and hence fuel can not be carried for long single journeys. The north pole and the interior of Sahara may preserve their secrets a while longer.

Upon the whole, navigable balloons and flying machines will constitute a great mechanical triumph for man, but they will not materially upset existing conditions as has sometimes been predicted. Their design and performance will doubtless be improved from time to time, and they will probably develop new uses of their own which have not yet been thought of.

THE METRIC SYSTEM: SHALL IT BE COMPULSORY?

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NO tribe of savages has ever been found that did not present some evidence of the existence of individual property among them. By force of character and personal prowess the chief acquires possessions of increasing variety. Where compulsion can not be directly applied resort is had to exchange, and this at once develops the need for measurement of values. Local convenience suggests conventional standards for the measurement of quantity, and custom tends to fix such standards. When a number of tribes have become aggregated into an embryonic nation, the different standards are soon found to need revision. From a group of temporary standards some fall into disuse and the most convenient are retained. The readiest standard of length is some part of the human body, such as the forearm or hand. The cubit is thus one of the most ancient of units. The foot, the pace, the palm, the digit, the inch as the length of the last bone of the thumb, the yard as arm length from mouth to finger tip, all of these are units of unknown antiquity, and accurate enough for the common needs of many who are moderately civilized to-day.

The unit of length is the primary unit to which finally all others are referred. To derive from it units of surface and volume would appear most natural, and it seems but a short step farther to derive a unit of mass from the unit volume of some selected kind of matter, such as water or earth. But it is safe to say that such a process of derivation was unknown until within the last few centuries or even less. For the comparison of masses scales were early developed, and with the advance of civilization linear units derived from human bodies of variable size gave place to metallic standards prepared and kept by some central authority. From the buried city of Pompeii have been taken steelyards carrying inscriptions which showed that they had been 'proved' by comparison with the standards kept in the Temple of Jupiter at Rome.

In England the standard of length during the last eight or nine centuries has been the yard, traditionally derived from the length of the arm of King Henry I. about the year 1101. A rod or bar of this length was kept in London, and copies of it, of various grades of crudeness, received the royal stamp which made them legal measures. One third of this length was called a foot, although about one fifth longer than the average masculine foot. Both in England and on the continent legislation relating to standards of measurement was exceedingly lax, and in every important town the local magistrate developed or maintained his own municipal system of weights and measures. A comparison of nomenclature in different languages shows that the foot has been the generally selected unit of length; and the Latin word *pondus,* meaning a weight, has been used with variations, such as *pound* and *pfund,* to express the popular unit of weight. With such unlimited local freedom, such imperfect means of communication, and such scanty diffusion of education, it is not remarkable that even so recently as a century ago the number of different units of length and weight, called by similar names, should be so great as almost to defy numeration. Even as late as 1850, in a 'Dictionary of Weights and Measures' at that time known, 5,227 of these were recorded. There were 135 varieties of foot; 60 of the inch; 29 of the pint; 53 of the mile, and 235 of the pound. The names foot and pound, or their equivalents in widely different languages, have been applied to magnitudes, nominally constant but practically variable, during the last 2,000 years. The Olympic foot, in use among the ancient Greeks, was traditionally derived from the foot of Hercules. To eradicate the popular devotion to these standards, variable as they may be, can not be accomplished in a generation. The range of variation among different values of the foot has been from 8.75 inches to 23.22 inches, or over 165 per cent.

Standards of weight and measure are thus the products of the people. The fundamental condition to be fulfilled is that a standard shall be definite and invariable. The function of legislation is not to create standards, but to adopt and protect them. This necessity was appreciated certainly as far back as the time of the Romans, but the recognition of it implies a degree of civilization that was not shared with them by the peoples they had nominally conquered. In England there is no record of such legislation prior to the thirteenth century. By statute of King Henry III., A. D. 1266, the combined standard of money, weight and capacity was defined by the statement that 'an English penny, called a sterling, round and without any clipping, shall weigh thirty-two wheat corns in the midst of the ear; and twenty pence do make an ounce, and twelve ounces one pound, and eight pounds do make a gallon of wine, and eight gallons of wine do make a London bushel, which is the eighth part of a quarter.' This pound, thus equal to the weight of 7,680 wheat grains, was known as the sterling or easterling pound, and had long been in use among the nations of eastern Europe. It is supposed to have been brought to England in the time of the Crusades. The troy pound and the avoirdupois pound additionally came into use, their origin and time of introduction being unknown. The pound sterling continued to be the legal standard until 1496, when it was superseded by the pound troy.

King Edward II., in 1324, provided by statute that the inch should have the length of 'three barley corns, round and dry, laid end to end.' Of these inches 12 were to make one foot, and 36 of them one yard. The length of a barley corn must have been known to be quite as variable as that of the royal arm. Yard sticks were indeed kept in the royal exchequer, but care in preservation seems to have been quite as unknown as methods of precision in construction.

By the middle of the eighteenth century the influence of such men as Sir Isaac Newton had produced a very perceptible effect on English civilization. The Royal Society of London, chartered in 1662 and including all the scientific leaders of the kingdom, recognized the chaotic condition of English weights and measures; and in 1742 a standard yard was constructed by one of its members, George Graham, who determined the ratio of its length to that of a pendulum beating seconds. This pendulum length he found to be 39.14 inches. It is most unfortunate that this length was not adopted as that of the yard, even if its value was not known with the utmost precision. Had the inch been defined as one fortieth part of this length, and the foot as ten inches, not only would the foot have been made to accord with the actual length of the average masculine foot, but a decimal division of it would have been established. The binary division of the yard would have been maintained, and its value would have been so nearly the same as that of the meter, afterward adopted as an international unit of length, that identification of the British and metric units would have been easy. But the people were not seeking ideals. Graham's yard was constructed for the Royal Society and there is no evidence of its adoption by the government. The official standard until 1824 was a brass rod made in 1570. It had been broken and mended so badly that the joint was described to be 'nearly as loose as that of a pair of tongs.' A copy of Graham's yard was made by Mr. Bird for a parliamentary committee in 1758 and another in 1760, but not adopted until 1824. This was known as the 'imperial standard yard.' At the same time a brass weight which had been in the custody of the House of Commons since 1758 was adopted as the 'imperial standard troy pound.' But the avoirdupois pound was also officially recognized, the difference between the two being that the troy pound was defined to be 5,760 grains and the avoirdupois pound 7,000 grains. The 'imperial standard gallon' was made the official standard of capacity for both liquid and dry measure. Under certain standard conditions of measurement this was defined to be the volume of 10 avoirdupois pounds of water, or 227.274 cubic inches. The wine gallon of 231 cubic inches had previously been the standard of capacity since 1706.

The subdivisions and multiples of these standards were such as to necessitate much confusion. The troy pound was divided into 12 ounces of 480 grains each, and the avoirdupois pound into 16 ounces of 437.5 grains each. The troy pound is less than the avoirdupois pound and the troy ounce greater than the avoirdupois ounce. A distinction has to be made additionally between dry ounces and fluid ounces. Various bushels and tons of widely different values continue in use. Although the original English standards were destroyed by fire in 1834, they were subsequently reproduced with reasonable accuracy. They are now the standards of the British empire with a total population of nearly 400,000,000 people, among whom a multitude of other unstandardized units of weight and measure are in current use.

The American colonies naturally employed such coins, weights and measures as were used in the mother country, and in no two of them were the 'systems' alike. A decimal system of currency proposed by Thomas Jefferson was introduced in 1792 and has continued in satisfactory use ever since. In taking this rational step the American republic set an example which has subsequently been followed by a large majority of the civilized nations of two hemispheres. Different monetary units are employed, such as the dollar, the franc and the florin, but the great advantage of decimal multiplication and division is almost universally recognized. The constitution authorizes congress to fix all standards of weight and measure for the entire country, and Mr. Jefferson urged the adoption of a decimal system for these as well as for our coinage. But this plan was not followed, and now after the lapse of a century American weights and measures are still in a state of confusion; some of them reasonably definite, others unintelligible except by the use of qualifying circumlocutions, and none of them connected by very simple numerical relations. A copy of the English yard was tentatively adopted in 1814 as the American linear standard. A copy of the troy pound was in 1828 made the standard of weight for the mint, and in 1830 the avoirdupois pound, deduced from the troy pound, was legalized as the standard of weight for ordinary commercial transactions. At the same time the wine gallon of 231 cubic inches was adopted as the standard of capacity for liquids, and the Winchester bushel of 2,150.42 cubic inches for solids. It will be observed, therefore, that the British gallon exceeds the American gallon by 20 per cent. The British bushel contains 2,218.192 cubic inches, and thus exceeds the American bushel by a little over 3 per cent. If we speak of a gallon or bushel, the meaning is thus not clear without further specification. But without reference to English units, or units that are obsolete or infrequently employed, we have in general use in America two different pounds, two different ounces, two different quarts, two different tons, two different miles, and a complex relation between linear, square and cubic measures, and between volume and weight. This diversity is not so confusing as it might be, because the foot and inch are perfectly definite in value, and a pound is generally understood to mean an avoirdupois pound.

In 1790, the same year in which Jefferson presented to American legislators his decimal system of coinage, weights and measures, Prince Talleyrand in France distributed among the members of the Constituent Assembly at Paris a proposal to found a new system of weights and measures upon some natural and invariable standard, with the hope that it might become a world system and thus displace the multitude of complexities which constituted a serious barrier to commerce. The cooperation of Great Britain was particularly desired, and a special invitation was conveyed to the British parliament to send commissioners from the Royal Society for the purpose of conference with a similar commission from the French Academy of Sciences. The British government withheld even the courtesy of an acknowledgment. Spain, Italy, the Netherlands, Denmark and Switzerland were represented in the conference. The result is now too well known for special recital. The metric system of weights and measures was born amid the throes of the French Revolution. With the reign of terror it had nothing in common. It was a model of simplicity and consistency, but it had two important elements of weakness. The first of these is found in the fact that there had been no popular demand for it. The second is that it was based on the false assumption that an absolute and invariable standard can be found in nature. Each of these elements is worth consideration.

The function of legislation in connection with science is to utilize science for the general welfare only so far as the people are prepared to accept improvement. In a community where ignorance prevails even sanitary science can not be enforced for the saving of human life from pestilence, unless military despotism is substituted for local self-government until the causes of pestilence are eradicated. Water as clear and sparkling as the freshest dew-drop may contain in solution tasteless poison that spreads typhoid fever or cholera among the ill-informed skeptics who are unwilling to be taxed for their own protection. The French people knew nothing of the branch of applied science now called metrology. They felt no evils as the outcome of a multitude of unrelated weights and measures, incomprehensible to most of the world. The new decimal system was easy to brand as the fiction of doctrinaires, just as the taxpayers in a fever-stricken community denounce and resist the officers of the law who close an infected spring of water. The logical outcome of the French revolution was the military despotism of Napoleon, and by this means the metric system was forced upon an unwilling people. The generation on whom the imposition was laid never really adopted it. The succeeding generations have been gradually losing the memory of the old weights and measures, and the inherent merits of the new system are such that relapse to the old barbarism is now impossible, whatever may be the modifications gradually imposed in practise upon a system of metrology which owed its existence to special creation rather than evolution. The case is quite comparable with the new era of sanitation in Cuba. Yellow fever has been almost wholly stamped out. The superiority of the new conditions is now recognized, and the Cubans will probably never return voluntarily to the régime of filth which fixed a scourge upon Havana for two centuries.

Prior to the French revolution various propositions and experimental attempts had been made to secure an absolute standard of length. In England Graham had tried to establish the length of a seconds pendulum as a standard, but without permanent success. In France several years were devoted by Delambre and Méchain to the determination of the length of an arc of the meridian between Dunkirk and Barcelona. The quadrant as computed from this survey was 10,000,000 times the length of the adopted standard, the meter. The outcome was no more absolute than any other product of human skilled labor. The opponents of the metric system have been fond of calling attention to the mistake in computed value of the meter. The labors of Bessel, Schubert and Clarke have established the existence of an error of about one part in 7,000. This means that the meter is shorter than it ought to be by an average hair's breadth; but this small error is quite sufficient to prove that the actual meter is an arbitrary standard. The fact is admitted as readily by the advocates as it is proclaimed by the opponents of the system. The most enthusiastic of these opponents have been the members of a small clique, led by the late Piazzi Smyth of Edinburgh, who claimed to have discovered in the pyramids of Egypt convincing evidence that the British inch is the only absolute unit, a definite fraction of the earth's polar diameter. Such conclusions are quite harmless; equally unassailable and incapable of proof. The real merit of the metric system is found in its definiteness and simplicity, and not at all in any approximate relation between its fundamental unit and the earth's polar circumference, or any other terrestrial dimension, whatever may have been the intention of its originators.

The metric system was adopted in France in 1795 and made obligatory in 1801. The change was too sudden for the people and compromise was found necessary. The full enforcement of the law dates from 1840, and the system has since become gradually and quite thoroughly established. France is a republic, and the law would long ago have been repealed if good reason for such action existed. At the close of the Franco-German war an important step in the unification of the new German empire was the substitution of the metric system for the many widely different local systems of metrology. The German people are now accustomed to it, and there is no more danger of its abandonment in Germany than in France. A list of forty-three countries could be given, the governments of which have adopted the metric system. This includes the greater part of continental Europe and of the American continent south of the United States. It has been legalized, but not made obligatory, in the United States and Great Britain. In Denmark it has not yet been fully adopted, but is largely used in trade, in coinage and in the railway system. In Austria, it has been established since 1876; in Norway and Sweden since 1889; in Turkey since 1891. In all cases it is reported to have given great satisfaction to the commercial classes, the chief obstacle being the ignorance and consequent opposition of the peasantry. From a carefully prepared list it is found that the population of the countries that have adopted the metric system is now a trifle less than 500,000,000. In 1863 it was about 140,000,000. The number has been more than trebled in forty years. In Russia a decree looking to its general adoption has been prepared by the minister of finance, approved by the administrative council, and is now awaiting the signature of the Czar. Should this be given, the system receives an addition of over 100,000,000 people to be put in training.

In the United States the first general legislation on the subject of weights and measures was an act of congress in 1866, by which the use of the metric system was made lawful, but not obligatory. No recognition of the theoretic superiority of any system is ever sufficient to induce the people to discard the system to which they are accustomed, however cumbrous this may be. The law of 1866 might be defined as merely legislative politeness. In 1875 an international conference was agreed upon by the most important nations of the world with a view to the promotion of some common system of metrology. The result was the establishment of the international bureau of weights and measures at Paris, maintained jointly by the participating governments. The first object to be attained was the preparation of a new international standard meter and a new international standard kilogram, certified copies of which were to be furnished to each government. The preparation of these was the work of a number of years. The copies sent to the United States were officially adopted by Congress, April 5, 1893, as the American national standards. The yard is hence legally defined as a definite fraction of a meter, and the pound as a definite fraction of a kilogram. This was an important step, but was regarded by many as of no practical importance, the use of the British standards being still protected by law.

The next step forward in this country was the adoption, July 12, 1894, of eight units for the measurement of electrical magnitudes.

Electricity as a quantitative science is founded on the metric system. The congress of electricians at Chicago in 1893 fixed the electrical units for the entire world, and these have been legalized by all the governments represented in that congress. In one branch of industry, of great and growing importance, the civilized world is thus united in the use of a common system of measurement. It would probably be hard to find an electrical engineer in England or America who is not in favor of the universal adoption of the metric system.

During the last dozen years there has been a growing popular demand among the commercial classes throughout the English speaking world for the general adoption of the metric system. This demand is not based on any theoretic ground, such as its simplicity and consistency, but on the commercial need of international uniformity. It would have no existence if all civilized nations used the British system. New markets can not be secured if customers are unable to understand the mode of measuring what is bought or must present their specifications in terms that are unsuited to the machinery employed in manufacture. Moreover, those who are already accustomed to a simpler system can not be expected to adopt in its place what is to them complex, unintelligible, indefinite and radically incapable of being made simple. Whatever may be the claims made by those who are accustomed to a bad system of metrology, or who have property that would be made valueless by its abolition, there is scarcely any conceivable prospect of the universal adoption of the British system. In the race for commercial supremacy there is little respect shown for theory, sentiment, old habits or corporate vested interests. The demands of trade must finally be met, even if vested interests should be strong enough to retard satisfactory legislation. The demand for international uniformity will continue to grow. The choice of the whole world has to be made between two systems of metrology, and only two, the British and the metric. All others have been practically eliminated from such a contest. If England and America should completely dominate the trade of the rest of the world the British system will be established; if not, it is doomed. Its total destruction will not be witnessed by any now living, but uniformity of weights and measures for the civilized world is as reasonably to be expected as was the establishment of Jefferson's monetary system throughout the union of American states.

In 1895 a select committee of the house of commons, after carefully considering commercial demands in England, urged upon the government that the metric system be at once legalized and that it be made compulsory by act of parliament after a lapse of two years. A deputation from thirty-nine chambers of commerce, including those of London, Edinburgh, Liverpool, Birmingham and Belfast, urged upon Mr. Balfour the importance of carrying out the recommendations of the committee. A large number of other associations representing many thousands of influential business men joined in the demand. Mr. Balfour admitted the merits of the metric system, but was unwilling that it be made compulsory in the near future, because he feared the effect on the small retail dealers and those who buy their goods from such dealers. He did not consider the British public yet ready for so important a change. The result was the legalizing of the metric system in Great Britain, but the defeat of the effort to make it compulsory. A great number of commercial associations, large and small, were added to the first list, and in not a single case did any body of wholesale or retail traders oppose the compulsory adoption of the metric weights and measures.

In 1896 a bill was introduced into congress at Washington for the compulsory use of the metric system in all departments of the government after July 1, 1898, and the adoption of it as the only legal system of weights and measures in the United States after January 1, 1901. This bill was reported favorably by the Committee on Coinage, Weights and Measures, but it was found necessary to delay action upon it. A second trial was made in 1902, and the committee secured the views of prominent representatives of a large number of different professions, trades and manufacturing interests. Of the many written communications, about nine tenths advocated the adoption of the metric system. Of the witnesses who appeared in person before the committee, which included 29 men of recognized standing in their respective callings, 23 were in favor and 6 of them opposed to the bill. Of the 6 opponents 4 represented large manufacturing interests involving the application of mechanical engineering, and 2 were connected with the revenue system of the government. The chief ground of opposition was the expense and inconvenience involved in making the change. Vested interests thus constitute by far the greatest obstacle next to conservatism.

Much could be written in this connection about the many considerations to be weighed by a congressional committee before reaching a final conclusion on a subject of such grave importance. The volume of testimony to which reference has just been made is a remarkably strong presentation of them. Any one who is enough interested to examine it can obtain a copy, gratuitously, by writing to the chairman of the Committee on Coinage, Weights and Measures at Washington.

Hon. J. F. Shafroth, of Colorado, has recently introduced a bill providing that after January 1, 1905, the metric system shall be made compulsory in all departments of the government in the transaction of business requiring the use of weight and measurement, except in completing the survey of the public lands, and that after January 1, 1906, it shall be the legal standard of weights and measures of the United States.

Should Mr. Shafroth's bill become a law, it is practically certain that a similar act will be passed by the British parliament soon afterward. Experience in Germany, Switzerland, Austria and other European countries within the last thirty years affords the assurance that, while temporary inconvenience may be expected, the transition will be soon accomplished in all important commercial centers; that persons of middle age and advanced years who have had no previous familiarity with the metric system will continue to use that to which they are accustomed; that the younger generation will everywhere appropriate and appreciate it; and that the agricultural population will be the last to become adapted to the change. Concerted opposition to the metric system by many whose capital would suffer depreciation by change is to be expected. The powerful influence of conservatism will be hard to overcome, however strong may be the arguments of those having commercial interests with Europe and South America. The passage of the metric bill may be again delayed. But the United States has become an exporting country and this necessitates two important changes. One is the removal of unnecessary tariff barriers to foreign trade. The other is the adoption of a system of weights and measures that is equally suited to domestic and foreign trade. Those who have been opposed to the recent American policy of forcible annexation of foreign countries have the partial compensation of knowing that it gives a strong impulse to the unification of weights and measures for the entire world. There may be honest difference of opinion among the advocates of the metric system regarding the advisability of assigning so early a date as 1906 for the legal establishment of this system in our country. Probably all of them will agree that 1905 is not too early a date for the exclusion of the old system and adoption of the new in the different departments of the government. The people will thus be induced to learn the metric system practically and compare its simplicity with the complexity of the system to which they have been accustomed. The opposition to it hitherto has come chiefly from those who have no practical acquaintance with it. They are quite excusable for thinking best to 'let well enough alone,' just as the majority of Englishmen would object to substituting our simple American system of decimal currency for their cumbrous system of farthings, pence, shillings, pounds, crowns and guineas. It is well to remember, moreover, that existing conditions in England and America are quite different from those under which Bismarck introduced the metric system into the newly formed German empire. From the Atlantic to the Pacific, from Mexico to the Arctic circle, there is but a single system of weights and measures, which has some few good features with its many bad ones, and which is satisfactory to most of those who use it. Change in our system of metrology is not needed for political unification. Any legal enactment imposing a sudden change will be apt to arouse enough popular opposition to ensure its repeal before the people have had a fair chance to give an impartial test to the new system. A probation period of ten years in the government departments might perhaps be better than one year; or possibly it might be wiser at present to avoid specifying the length of any probation period. It would be better for the demand to come from the people at the end of thirty years than for a repeal of the law to be forced after it has been in operation only a short time.

Much has been said about the superiority of a binary to a decimal system. It is admitted that the decimal system is better for purposes of computation, but alleged that in the ordinary practical affairs of life people divide into halves and quarters more readily than into tenths. There can be no objection to the simultaneous application of both methods, so far as convenience may suggest. A binary system does not lend itself to decimal notation, while a decimal system does admit of limited, but amply sufficient, binary subdivision. This has been abundantly shown in the use of American money. Half-dollars and quarter-dollars, as divisions, are entirely satisfactory to all advocates of a decimal system. Our fathers coined eighth-dollars and sixteenth-dollars also, but nobody seemed to want them. Half-meters and quarter-meters as linear divisions are quite as good as half-dollars and quarter-dollars. Our idea of a quarter of a dollar is no less definite if it be called twenty-five cents. In like manner, no one can object to calling twenty-five centimeters either a quarter of a meter or a metric foot, agreeing in length with the human foot. That decimal subdivision is quite as natural as binary subdivision is shown by the universal American tendency to express profits and losses as percentages. If there is any real superiority in binary subdivision all dividends should be expressed in thirty-seconds, or sixty-fourths, or hundred-and-twenty-eighths.

It has been urged that a duodecimal system is better than either a binary or a decimal system. This may be granted, but its introduction would involve practical difficulties much greater than any connected with the general adoption of the metric system, including the abolition of the British system. Its consideration has no more practical importance than a proposition to substitute Volapuk for the English language.

The late Sir Joseph Whitworth expressed the opinion that the adoption of the metric system would be easy if its advocates would only lengthen the meter from 39.37 to 40 inches. This would make the inch rather than the meter our unit of length. Such a change would on many accounts be exceedingly desirable. But its consideration could be only the result of compromise in an international conference for this purpose. It would require the majority of the nations of the civilized world to change their standard, with all the expense that this implies, for the sake of saving expense to English and American mechanical engineers and capitalists. For the sake of international uniformity such a conference might well be undertaken, although with the assurance that the continental engineers and capitalists would not regard the subject from our standpoint.

Objection has often been made to the nomenclature of the metric system, which is thought to be too diffuse, too high sounding and scholastic to appeal to the masses. Such names as hectare and kilometer are unwelcome to the farmer, who is well satisfied with his acres and miles. There is no good reason to prevent any needed modification in nomenclature so long as the fundamental units and the decimal relation between them are preserved. In our decimal currency the eagles, dimes and mills are for the most part forgotten, while dollars and cents are enough for most purposes. No great inconvenience has resulted from the use of the word 'nickel' for a five-cent piece, or the alleged 'pennies' and Californian 'bits' in the nomenclature of small change. Those who are habituated to the use of the metric system rarely ever speak of decimeters or dekameters, or decigrams or myriagrams. The fathers could not provide for an indefinite future. Elasticity is necessary, and new subordinate units are certainly allowable as long as they serve any useful purpose.

In conclusion, those who advocate the introduction of the metric system will need to be patient and considerate. Those who oppose it must look to the future as well as the present. The well-worn query, 'What has posterity done for me?' is good enough for the local politician but unworthy of the statesman.

THE CONSERVATION OF ENERGY IN THOSE OF ADVANCING YEARS. II.

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Developmental Processes in Ageing Tissues; Physiology of Decadence. Senile Involution.

THE brevity of this communication does not warrant a discussion of senility from the standpoint of the physician, but rather a presentation of such facts to the person who is growing old as may prove helpful and suggestive in postponing the more serious results of advancing years. It is, however, important to glance at the manner and processes by which the inevitable end is reached. The clinical picture of approaching death is divided by Tessier into those structural degenerations involving, first, the heart and blood vessels; second, the lungs; third, the kidneys; fourth, the digestive organs, and fifth, the brain. First of the heart, which is now recognized to be the organ which plays the chief part in the ending of life. Before we knew much about the subject it was natural to infer that the heart was chiefly at fault and the common phrase was often used of death by 'heart failure,' one which we now know to be scientifically correct but aforetime vaguely employed. Then discoveries were made that the arteries in the aged were nearly always diseased, and medical thinkers went so far as to assert that all instances of death in old age resulted from the hardening of the arteries. It is true that this is an accompanying phenomenon in most instances, and perhaps in all, but it is recognized to be not the most potent factor in a certain large proportion.

What is to be said here is not meant for a guide to the aged individual by which he may be encouraged to form independent judgments for himself, but rather to act as items of useful information, through which he can better interpret the statements and appreciate the importance of following the directions of his physician.

The heart of a healthy old person has become fatigued in its structure through a decadence of its nerve supply. The pulse is rather quicker than during middle life; it is more or less irregular and becomes increasingly so. In a healthy heart there is, however, a regular irregularity; a normal sequence of alterations in the rhythm and force which is only significant when studied by the trained physician. The phenomenon which is one of the most constant and inevitable, as the effects of age begin to make themselves felt, is shortness of breath on exertion. This has to do more with faults in the action of the circulation and the vaso-motor nerves than in the lungs. The old man finds himself distressed in his breathing while undergoing a degree of exertion which aforetime would produce no noticeable effects. The heart muscle is old, relaxed and softened and contracts imperfectly and readily shows exhaustion. This need not produce alarm, but if the condition rapidly increases it may be significant of some important change and should be referred to the medical adviser. In fact, it can not be repeated too often that the more constantly the aged person remains under observation of a wise physician, the more safely can it be promised that he will live happily and long. There is a symptom which is most terrifying and frequently occurs in the aged, and that is a sudden agonizing chest pain, during which the sufferer, unless he be of unusual mental equipoise, feels that he shall instantly die. This may come on suddenly without previous warning and requires the best medical advice, but it almost always passes and may recur many times and is capable of much relief. It may be a symptom of chronic myocardial degeneration.

The lungs also, in most instances, share in the process of death. The changes which occur in the aged lung are degenerative and need have nothing to do with any previously disordered processes in them. Again it may happen that certain changes common in old age take place and prove to be most distressing; the chief of these are asthma, chronic pneumonia and bronchitis. Pneumonia in the aged is a very serious affection, and it is stated that the largest number of deaths in old people are caused, or accompanied by, acute broncho-pneumonia.

The digestive organs sometimes give away while the rest of the organism remains in fairly good condition. Sir William Thomson has written most charmingly upon the digestive disorders of elderly folk, and it would be well for every old person to read his suggestive essays. Unless care is observed in regulating the diet (and the chief point here is rather a reduction in the amount than particularizing as to the items of food taken), distressing phenomena will constantly arise. Fortunately this is easily avoided, although not so readily cured. Sir William Thomson makes the assertion that the disappearance of the teeth is a plain indication of the return to a second childhood, and therefore the food should be of such a character as may not require the assistance of the teeth in mastication. He advises most wisely, although his recommendation can not be taken literally, that the teeth be not replaced by artificial ones, for thereby is a peril lest more food be taken than the organism can dispose of. The fact that the various organs concerned in the elaboration of food share very early in the degenerative changes of age makes it clear that the character of the food taken should be so simple in kind that no great strain would be placed upon these atrophied organs. The gastric juice is secreted in less quantity, so of the pancreatic, the biliary and the intestinal juices. The lessened quantity of bile makes for constipation and the formation of gall-stones and impairs absorption, and assimilation is thus interfered with. The kidneys, the chief source of elimination of a most elaborate series of poisons, become enfeebled in their action and hence should not be overtaxed by either the quantity or the quality of the work they are called upon to perform. Finally the brain may be the part which gives way most prominently, and then we may find hemorrhages into its structure, a softening begins, and alteration in mentality which point the way to more remote and serious changes.

The physiology of old age may be described briefly as a progressive diminution in all the functional activities. There is in the life of every normal individual a constant and proportional relationship between the development of parts and tissues and the natural progress toward dissolution. The function which is in most immediate relationship to the reparative power of the cells is the one which will be first affected, so soon as old age begins. The four particular acts of nutrition may be succinctly described as: first, contact of the cell with the nutritive elements; second, the phenomena by which sustenance is drawn from this material, namely, assimilation; third, the changes through which the assimilated products pass, namely, dissimilation; and fourth, the phenomena of the ejectment of the non-assimilated substances. In senescence the first change to be noted in these essential steps in nutrition is to be seen in assimilation. The reparative power of the cells is lessened and the elements of repair tend to be furnished in smaller quantities and soon pass beyond the power of maintaining cellular integrity. Next, there is a diminishing cell resistance leading to atrophy and xerosis. Xerosis (Tessier) is the normal hardening of the tissues in contradistinction to the abnormal sclerosis. With diminution in the power of assimilation there will appear modifications in the normal processes of dissimilation. The difficulties which the cell finds in securing the necessary pabulum tends toward inertia in the phenomena of metabolism. Next the products of incomplete oxidation accumulate, are made difficult to get rid of; they are more damaging to the integrity of the structure of the organ, and the tissues undergoing normal senescence are in constant peril of suffering disease changes. It is the presence of these toxins which places the physiologic processes of senility close to the line of pathology with incomplete oxidation; they tend to accumulate, to infiltrate and to work harm. Chemical changes are less active then, and more poisons form than can be thrown off; gout, rheumatism and their simulants arise. The standards for comparison in the phenomena of waste and repair are not to be formulated. The physician can not know, in the light of present knowledge, just when the equilibrium is lost and when the subject under observation has passed the point where senilization has gone through several changes, and proceeds rapidly, and can not be checked.

Life will flow on with normal energy so long as the noble elements, the more highly differentiated cells, are in excess both in processes and activity. The noble elements are those cells which take upon themselves the preponderating role in accomplishing the function of an organ, in contradistinction to those which play but a secondary part as forming the mechanical support of the organ. Since these can not be replaced in due proportion, function will be interfered with and senescence will begin. Connective tissue now tends to fill all gaps and gradually to invade the tissues, and scleroses will arise, placing obstacles in the way of functional discharge; this constitutes disease. "Inasmuch as the individual is merely an aggregation of special organs adapted to a common existence, the increasing deterioration of these functional activities leads toward gradual deterioration of the individual himself, who will gently fade away out of existence" (Tessier).

The progress of atrophic changes is not regular, either in the general system or in the special organ. All the elements of the mass do not live to the same age. The constituent elements undergo a perpetual restoration, the older disappearing and being replaced by others which have been long maintained in a state of less differentiation, hence of less specialization. As the completed elements disappear the younger ones are matured, hence the compensation is established between atrophy and repair. This movement of partial renovation in tissues is a picture in little of life, the birth of each element, its functional life, senility and death. The explanation of why irregularity should occur in the nutritive activities in the tissues of each organism, and equally in the whole of some organisms, causing individual and constitutional variations, is not so clear. Chemical processes, presumably similar to the small modifications in the cellular arrangements, and the forces that work, must be recognized. In time we may—indeed we must—know what these dynamic features are; then we shall have reached the first step in controlling these variations from a sound working basis. It is certain that these dynamic modifications can not progress indefinitely without producing tangible modifications and alterations in molecular activities; this constitutes disease. Atrophy is an anatomical phase of senility, whose irregular distribution is explained by the inequality of cellular existence, and this is again dependent upon the initial impulse of contraction and upon varying states in the medium, and this by the introduction into the tissues of matters foreign to its normal structure. When this occurs it is degeneration. The study of pathologic changes, by which most of the observations have been made upon the conditions governing senile processes, induces a tendency to start from wrong premises. It is important that these researches should be strongly modified by a comparison between normal and physiologic changes, otherwise right conclusions are obscured. This practical point must never be lost sight of by observers and clinicians in the study of the individual and his ailments. In the study of the processes of the individual the ailments are too frequently the only conditions considered and the normal changes overlooked.

Clinicians recognize what they call diatheses. A diathesis is a tendency toward disease, and many of these can be recognized in their incipience and differentiated in such manner that preventive measures can be employed and earlier changes limited and improved. Disease is the domain of pathology, the study of abnormal conditions induced by changes outside the realm of individual processes. The diathesis gives evidence of a lessened coefficient of resistance, a lowering in noble activities and exhaustion of the powers of repair. This is probably because the power of attraction is not the same in each person and is of variable intensity. Protoplasm has not the same proportions in its composition, hence variations arise in the phases of its evolution. Assuming then the variability in chemic structure, and hence a variable power of attraction in protoplasm, hence, also in the coefficient of resistance, these thoughts will aid in explaining congenital and queer constitutional peculiarities, and often inexplicable differences in races, families and individuals. It is a matter of common observation that in some families senile changes occur much more early than in others, and yet there may be little of degenerative change apparent or probable because of the vigor of the individual. As the gradual steps of growth lead to development, so does the phase of existence called senescence merge insidiously toward the ending called death, through a progressive and insensible diminution in all the organic activities. Death should be regarded as a normal function. Ordinarily it is free from pain and hence should be free from sadness.

Obesity.

Excessive fatness, or polysarcia, is not confined to advancing years, it is observed at all ages; but the quality of the accumulation in early years differs from that seen in late middle life. During the earlier years excessive gain in weight is usually the product of full digestive capacity with a somewhat lessened eliminative power and can be met by reduction in diet and active exercises, and is, as a rule, controllable. With that form of obesity which is not altogether manageable in young people or those on the hither side of middle life we have nothing to do, except in so far as we should discuss this condition and its progress when encountered in later years. Again in women more particularly, there is oftentimes a sudden gain in weight, sometimes to a very annoying and disabling degree, following the change of life. This is an abnormality, and is sometimes based upon pathologic changes in the thyroid gland analogous to myxedema. In men at about the same relative period an enormous gain in weight occasionally arises and is a serious annoyance and anxiety. A few points in regard to the control and reduction of this warrant discussion, although they need not be elaborated. Where this gain in weight seems to be free from any abnormality except difficulties in the elimination or utilization of fat, it is proper to initiate active treatment by careful diet according to the methods of Banting, Ebstien, Oertel, along with specially directed exercises. In persons who are obviously not vigorous, as in those instances where marked anemia is present, there should be a careful search for evidences of disease beginning, or established, and treatment for the condition outlined accordingly. Von Noorden emphasizes the necessity of being on our guard in treating conditions of obesity which arise in women from fifty to sixty years of age. The greatest precautions must be used in dealing with these, because under almost any régime they will lose strength, frequently to an alarming extent, and what is more fail to regain it. The same statement holds good, to a less degree, in men of the same age. It would be interesting to formulate the different kinds and degrees of obesity and the pathologic changes which often accompany this state, forming it may be the cause on which the obesity arises, or again the results, direct or indirect, of the excessive weight. It is enough for our purpose here to offer some directions as to how this objectionable state may be relieved without producing harm. First, it is necessary to bear in mind that under the direct advice and continued attention of the physician is the only safe mode of procedure. Where there is found, as often happens, marked weakness of the heart and circulation the greatest care must be observed, and measures should be adopted having direct regard for the possibilities of the individual and varied from time to time under intelligent supervision. It is always a dangerous thing for persons to undertake their own treatment for obesity if they make use of drugs, because great harm can be done; it may be irretrievable. There is no objection, however, to moderating the diet, increasing exercise, and, above all, to employing systematized physical training for the purpose of improving elasticity in all the tissues. It is only safe to do so under medical advice. Oertel in 1885 and after, has done work which marks an epoch. The principle upon which he proceeds is that even where there is found to be pronounced weakness of the heart muscle, and other disturbances in circulation, these may be met by steadily increasing the amount of physical work done, especially by hill climbing. This walking up slopes has the merit of bringing out skin moisture and taxing the respiratory capacity much more promptly and completely and is more capable of regulation than any other form of exertion, at least any which would be admissible. It is only possible for people relatively young or strong to begin in this way. Our subject is polysarcia in people of advancing years, and hence greater caution must be exercised in outlining activities than for younger folk. The general principles of exercises given at the end of this paper need not be repeated here, but should be read in connection with the measures now to be outlined. In over-stoutness of late middle life, accompanied by good health, it is essential to use first fairly active increasing extensor movements with elasticizing measures, active and passive stretchings, loosening up of the hip joints particularly, and above all, thorough drill in regaining proper attitudes. This should be followed by systematic, accurate training in breathing till a normal capacity is attained, almost never found in stout people unless acquired through teaching. In a paper elsewhere I have elaborated these thoughts (*Internat. Med. Magazine,* July, 1901).

When we have to do with the fat anemic person vastly more care must be used. The heart in these cases is likely to be infiltrated by fat and the muscular fibers clogged and inelastic, and must be taught slowly to regain their contractile vigor. At first, climbing stairs under direction is about as much as can be attempted, and any house will serve, merely regulating the number of steps walked up and down (both being of benefit) and the rate of speed carefully specified. Tall office buildings serve admirably for the purpose. Polysarcia is such a disabling condition that it is well worth prolonged remedial efforts. Success is possible, and indeed always probable, within limitations. The unaided efforts of the patient can readily lead to harm, sometimes calamity. There is one essential rule in dealing with the cases under consideration, and that is the time for treatment can not be measured by weeks, should not be measured by months and can only safely and satisfactorily be measured by years. One instance will help to illustrate my point. I had a gentleman under my care of sixty-one years of age, who had learned to ride a bicycle before meeting me and found it impossible to use this much because of the distress it produced in breathing. I saw him only rarely at intervals of months, and advised him by letter chiefly in connection with his own physician. He was advised to adopt the rule of riding regularly but briefly on the level roads of his own country place. After some months these short excursions produced no distress. In a year's time he was able to start out upon the open roads, but was compelled to dismount at every small rise of grade. In another year he was able to ride up moderate grades on a good road. At the end of the second year he was riding with comfort and pleasure. At the end of the third year he rode all about the country where the roads were good and for hours at a time. The loss in weight scarcely showed in the first two years, but after that it was sufficiently great to be satisfactory. At the age of seventy-six he feels himself to be all of twenty years younger than when he began.

The Menopause.

There is a time about the middle of the life of women which is called the critical period and is supposed to be fraught with many dangers and grave disturbances. This period of the climacteric has been grossly exaggerated, and it is by no means necessary to look forward with dread to the time when menstruation ceases. Man reaches the period of highest development at forty-one years, and woman at thirty-nine. The following seven to ten years may be called the age or epoch of invigoration in both the sexes. The tissues have then become most stable and the nutrition of the body is at its best. It is one of the epochs of development and naturally is accompanied by certain characteristic features. In man these epochs are marked as follows: Dentition, pubescence and the climacteric of age. These are all practically developmental phases, although the last is usually accompanied by degenerative changes in one or another vital organ by which resistance in the tissues is lessened, allowing relatively slight influences finally to cause death. In woman there is generally recognized another, styled the change of life, or menopause. Modern investigations seem to demonstrate beyond a doubt that this change of life is merely a conservative process of nature to provide for a higher and more stable phase of existence, an economic lopping off of a function no longer needed, preparing the individual for different forms of activity, but is in no sense pathologic. It is not sexual or physical decrepitude, but belongs to the age of invigoration, marking the fullness of the bodily and mental powers. There are rather more decided changes in the blood-making and blood-elaborating organs in women, toward the end of life, than in men. Man's greater activity enables him to escape this contrast, because as a rule he has called more upon his motor machinery in using up injested and assimilated material. The life of woman leads her to become more impressionable and to watch over her menstrual days, think of them, make allowances for the exigencies which may arise at such times, and to expect various disturbances and discomforts. If her mind becomes fixed upon some one small ailment or other, especially connected with this function, there is almost an inevitable hyperconsciousness and a continuance or an exaggerated degree of attention which is practically hysterical even in the best of women. Such disturbances as do arise about the time of the menopause are largely due to a normal failure of the organism to offer the same degree of resistance to intestinal and other poisons, and the great eliminating organs begin to exhibit a gradual lessening in functional activity. The theories of immunity rest upon the assumption of the presence of some proteid body in the blood which endows the whole system with powers of resistance to toxins. Exhaustion, especially such as is induced by the emotions, fatigue, grief, anger and fear, are well known to weaken the protective power of these mysterious agencies. At the time of the so-called change of life, woman is usually burdened with the maximum of her cares and labors and too often at this time the severest griefs assail. If she be single there is a species of spiritual awakening and the realization that youth is utterly past. In married women the disappointments which follow upon enthusiastic expectations become manifest, and in numberless ways strains are thrust upon the organism. It must be remembered that the greatest maturity of the powers, also, are evident at this time, and therefore she should be capable of meeting all exigencies. The whole question may be summed up in a few words: if a woman, married or single, will so order her life that she retains to the best of her ability her physical and mental vigor, and if she also sets her face sedulously toward looking upon the bright side of existence and ignores emotional impressions of a disagreeable character, she has nothing to fear as life moves steadily on the downward incline.

THE ROYAL PRUSSIAN ACADEMY OF SCIENCE. BERLIN. I.*

BY EDWARD F. WILLIAMS,

CHICAGO, ILLINOIS.

History of the Academy from its founding by Leibniz and the Elector of Brandenburg in 1700 to the death of Frederick William I. in 1740.

THE history of the Royal Prussian Academy of Science is in reality the history of the development of science in Prussia, one may say throughout the territory covered by the present German empire. Founded July 11, 1700, by the Elector Frederick III. of Brandenburg at the solicitation of his wife Sophie Charlotte and of Leibniz, it not only gave an impulse to scientific research and scholarly investigation in every department of learning in Berlin and throughout Prussia, but became the model after which other societies with similar aims in the German-speaking world were brought into existence. Not quite as old as the French Academy nor as the Royal Society of Great Britain, nor as the Lincei in Rome, it has done as good work as any of them and exerted quite as wide an influence.

The period embraced in its life covers the period of the reconstruction of the German university and its growth from the unsatisfactory institution of the first quarter of the eighteenth century to its present commanding position in the world of learning. It covers the period in which the *gymnasia* were remodeled and the foundations laid of that system of common schools (Volksschule) for which Germany is now famous. It covers also the period of French oppression, of the re-awakening of the national spirit and of the contests which secured political freedom and a united German empire.

In 1694 the Elector Frederick founded the University of Halle, not long after, the Medical Society of Berlin and, in 1696, the Academy of Arts. He assumed the rank of king on January 18, 1701. He inherited a love of poetry and of learning from his father, the Great Elector, who refounded the universities of Königsberg and Frankfurt and brought the University of Duisberg into existence. He had planned also a universal university at Brandenburg to be free to

* For the facts presented in this article the writer is chiefly indebted to Professor Adolf Harnack's masterly history of the academy in four quarto volumes, although other sources of information have not been overlooked.

all the world, an asylum for all students of science and art, and to be undisturbed even by war.

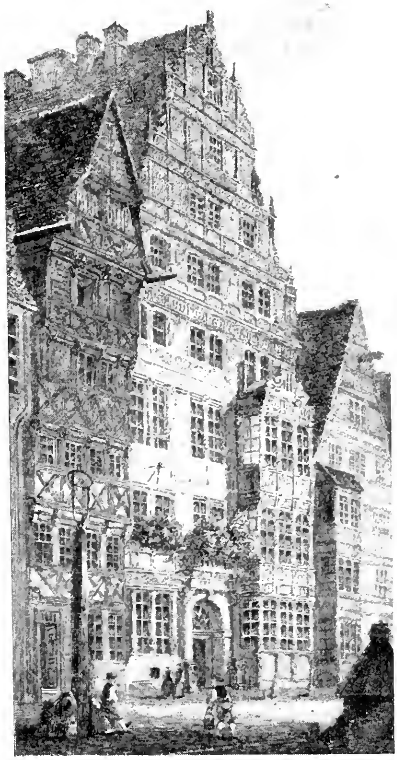
Leibniz (1646–1716), though unwilling to break with the old learning which the universities cherished, had breathed the breath of the new learning which came in with the Renaissance and the Reformation. Holding fast to all that was valuable in the traditions of the past, he early became an ardent advocate of the new methods of study which science, even in its beginnings, introduced, and through the founding of academies in the great capitals of Europe sought to unite the tendencies of the time with the protestant spirit of research and criticism. A many-sided man, philosopher, theologian, jurist, politician, philologist, physicist, an acute observer, fond of experiment, with a constructive mind, restless in his eagerness for knowledge, he did more than any man of his era to forward the study of nature and to emphasize its unity. Through the establishment of an academy in Germany under royal patronage he thought he could demonstrate the harmony of the world in study and research and realize the unity of human society. His first proposal for a society for the study of science was made in 1667 when he was but twenty-one years old, his last only seventeen days before his death. He suggested and furthered, so far as he could, the union of all the learned societies of Europe, a plan which has been partially realized in our own time. He lived in Hannover, where he made himself useful to the Brunswick princes as a historian, although he did not possess their complete confidence as a politician. Having observed the working of the French Academy when on a visit to Paris in 1675, the following year he proposed a German academy somewhat on its model, and even named the forty-eight men who were to compose it. He proposed later, as protestants seemed indifferent to his project, that the Pope divide the fields of learning among the catholic orders, assigning the study of nature to the Benedictines and Cistercians, that of law to the Dominicans and the Jesuits, that of language to other orders, and to the Franciscans the care of souls. If the princes of the House of Brunswick failed to give him their entire confidence, he had an unfailing friend in the Princess Sophie (1630–1714), daughter of Frederick V. of the Palatinate, and mother of George I. of England. It was through her daughter, Sophie Charlotte, who married the elector of Brandenburg September 28, 1684, and who had been educated under the eye of Leibniz, that he realized at last his hope of founding an academy in Berlin. Of this woman Frederick the Great said she had both 'the spirit of society and of true culture,' and that 'she brought the love of science and the arts into Prussia.' She was a gifted, charming woman, and so eager for knowledge that even Leibniz was wont to say of her that she was never satisfied with reasons which were sufficient for others, she 'must know the why of the why.' Although Leibniz even in the decade from 1681 to 1691 had a low idea of the culture of Prussia, he was not long in discovering that it was only under the leadership of the Prussian elector that the German protestant states

à Paris chés Daumont rue St. Martin

could be united in an academy. Hence his efforts to interest Sophie Charlotte in his enterprise. Through Prussia, he wrote her, he 'saw the gateway to Russia, and through Russia the gateway to China.'

For political reasons, probably, there was no regular correspondence until 1697. Meanwhile Leibniz had interested many scholars in his project, among them Count von Dunckelmann, in whose parlors scientific meetings had been held in Berlin for ten years. Jabloniski, a Bohemian by birth, court preacher in Berlin, a man of great knowledge and natural ability, was one of the most efficient aids which Leibniz had in bringing the academy into existence. Much had been said about establishing an observatory in the Prussian capital. The wife of the elector exerted all her influence in favor of it as early as 1697. From this time on the clearly formed plans for an academy with which the observatory should be connected were carefully discussed. In a letter to the Princess Charlotte, dated December 19, 1697, Leibniz writes that he has been invited to Berlin, 'the cradle of the arts and sciences,' where 'Solomon and the Queen of Sheba are.' While on a long visit in Hannover during the summer of 1698 the princess had opportunity to discuss with Leibniz, unhindered, their plans for an academy and scientific institute in Berlin. Jabloniski was sent to Hannover by the elector to see Leibniz and returned to Berlin greatly impressed with his ability, and urged the elector to invite him to the city. This was done through the Princess Charlotte. For more than a year little progress in founding the academy was made, though the leading scholars of Berlin desired it. Means for its support were wanting. Aid came from an unexpected source. Professor Erhard Weigel, of Jena, was anxious to correct the calendar, and Leibniz at once saw that if this corrected calendar were made a monopoly the cost of an academy could be paid out of the profits on its sale. Messrs. Rabener, Curveau and Jabloniski memorialized the elector, the monopoly was granted and an order for the formation of an academy, with which the observatory was united, was issued on the day the memorial was presented. Leibniz, who had recently been made a member of the French Academy, was appointed its president. On January 18, 1701, Prussia became a kingdom and the elector a king.

The academy began its life under favorable circumstances. Although the means of support were inadequate, the ideas of the men who formed it were large and comprehensive. The plans then made, visionary as they seemed to some, have since been fully realized. Councilor Albinus, Chauvin, Dr. Jaegewitz, Naudi, the mathematician, Chief Engineer Baer, Privy Councilors Rabener and Cuneau, and Jabloniski, the court preacher, made up the eight who with Leibniz formed it. They were all imbued with the spirit and the ideas of the president. The academy was to be a place where the study of physics, chemistry, astronomy, geometry, mechanics, optics, algebra and similar useful subjects should be furthered. Not all of these branches of study were to be pushed at once, no one of them until men eminent in each of them could be brought to Berlin and elected to membership in the academy. The statutes of the academy were framed after those of the French Academy and the Royal Society of Great Britain. Leibniz was to live in Hannover, but to come to Berlin when necessary and to have the expenses of the journey paid. The astronomer Kirch alone was to receive a salary. Kirch moved from Guben to Berlin, took up his abode in the second story of the building which the government had furnished for an observatory, brought with him his own instruments, which were used in common with those the government owned, and trusted to the income from a calendar, which he himself was to make, for his support. The income from this source was estimated at about $1,875 and the expense for the president, the astronomer, his assistant, a secretary who should look after the business of the academy, a servant, instruments, books, experiments, printing, correspondence, medals and miscellanies, at a trifle more. Perhaps no great enterprise has ever been undertaken more confidently on the part of its leaders with such small pecuniary resources at its command. The elector wished provision made for the teaching and improving of the German language. To him should be given the credit of forming the philological-historical department of the academy. To his wife belongs the credit of establishing its astronomical department, and to Leibniz of its scientific departments. It was gravely proposed by Leibniz that the academy should be also a missionary institution and should send the gospel to the heathen. On this ground the churches might be asked to contribute to its support. He would have it look after the sanitary condition of the homes of the people, and the character of their food. He had many plans for an increased income, but none of them proved effective. Even the calendar monopoly met with opposition from booksellers and was obtained with some difficulty. The letters actually forming the academy were dated July 11, 1700, the elector's birthday, and by them its members were required to give careful attention to the German language and history, and especially to the political and ecclesiastical history of Brandenburg. The elector made himself the protector of the academy, but directed it to govern itself through a council of its own members. This council was to select and receive new members, subject to his approval. Three classes were organized, one for the study of physics and mathematics, another for the study of the German language, and a third for the study of literature. No provision was made for the study of philosophy, because Leibniz thought its principles unsettled, and that its interests would be best promoted by considering it in connection with other subjects. The members were divided into ordinary, corresponding, home and foreign, and honorary members. John Theodore Jabloniski, an older brother of the court preacher, was made secretary, and at the same time directed to perform the duties of archivist, cashier, curator of the museum, overseer of matters pertaining to the publishing and sale of the calendar, and to act as a reporter for Leibniz. Many of the difficulties connected with the academy during its earlier years grew out of the fact that the two Jablonskis were so intimately concerned with its management. Yet the secretary was a man of rare learning, and in many ways well adapted to his position. His brother was a member of the academy for forty-one years, was deeply interested in it, and for some years after the death of Leibniz was the means of keeping it alive.



House of Leibniz at Hannover.

During the first decade of its existence the academy did very little. Some of its members were jealous of Leibniz, but he paid no attention to this fact, and did his work as if nothing had happened. The king wanted the academy to add to the glory of his reign, but would furnish no means other than those which came from the calendar monopoly for its support. Kirch and his wife, who was his efficient aid, made the calendar accurate and trustworthy and gave what time they could to astronomical study. Kirch's astronomical work was confined to the study of comets, sunspots and variable stars. But the income of the academy only just kept it alive.

The French language was used in the discussions and reports. Indeed, at this time the French population of Berlin contained within its ranks a larger number of distinguished men than the German. It is not surprising, therefore, that so many of the leading members of the academy were for so many years of French origin. The progressive element of the city was French. Their preachers and authors were the only men in Berlin who could meet the Benedictine church historians on their own ground. The German element was well represented by John Leonard Frisch, director of the Gray Cloister Gymnasium, who did more work for the academy during his connection with it than any one else. He found time to compose papers on the silk manufacture of Berlin, on insects and parasites, which were illustrated with his own drawings, and to begin an extensive work on birds. He was a student of the Slavic languages, and through his Latin dictionary, which one of the Grimms said would not grow old, contributed very much to German lexicography. As a student of chemistry he greatly improved the famous Berlin blues. In 1703 there were 22 members of the academy residing in Berlin, 19 in 1707, 20 in 1711, and at this time there were 32 foreign members. During the sixteen years which he led the academy, Leibniz wrote between five and six hundred letters on its behalf. This was in addition to the papers he contributed to its sessions and to the work he did on the two or three volumes it published.

The death of the queen, on February 10, 1705, was a serious loss to the academy as well as to Leibniz. Work on the building to be used as an observatory proceeded so slowly that the astronomer labored at a great disadvantage. Still he discovered a comet and made some valuable observations. He died after ten years' service and was succeeded by his assistant, John Henry Hoffmann, who was followed by the younger Kirch, who endeavored to carry forward and greatly extend his father's work. But the academy was cramped through lack of means. These were so small that it could only publish a brief report of an eclipse of the sun, and of a few meteorological observations made in Belgrade by Schutze. Fifty thalers ($37.50) were sent Christian Sturm, of Frankfurt a. O., for scientific observations which proved of little value, and seventy-five dollars were set aside for the purchase of a Hebrew Bible found in China.

Sophie Charlotte
Königin von Preussen

As early as 1705–6 it looked as if the academy could not survive. Its condition was desperate. Leibniz came to Berlin on its behalf and was more successful than usual in securing the favor of the king, who at this time gave it twenty-one hundred thalers ($1,575) for the purchase of ground on Dorotheen Street which it still owns. Volume I. of the Berlin Miscellanies, edited by Leibniz and Cuneau, appeared in 1707. Yet in 1709 La Croze, the royal librarian, said the academy was 'a society of obscure men,' but its fame was soon increased by the election to membership in it of Hoffmann, the famous physicist of Halle. In May, 1710, a quarto volume containing sixty treatises, twelve of them by Leibniz, was published. This indicated renewed life in the academy.

This year Leibniz was discredited by the king through the appointment over him of Minister von Printzen as president. This was done without consulting him and also without his knowledge, and as if to annoy him, a salary of seventy-five dollars was ordered paid to the heads of the four classes into which the members of the academy were then divided. These classes were physics, which included medicine and chemistry; mathematics and astronomy; the German language, to which the political and ecclesiastical history of Brandenburg especially were attached, and literature, a department whose members were also to consider methods for spreading the gospel among unbelievers. The government of the academy remained in the hands of a council formed by the heads of these classes with the addition of the *fiscus,* who was appointed by the king. Other members of the academy had no voice in its management. It was now decided that the sessions, which had been rather irregular, should henceforth be held on Thursday every week at 4 P.M., and that there should be a general meeting once a month, so that the whole work of the academy might be known to each one of its members. The public recognition of the academy was given on January 19, 1711, by the king himself. Leibniz excused his absence on the ground of ill

health, though it is easy to see that there were sufficient reasons of another character why a man of high spirit like himself should not be present. In the long and rather trite Latin oration by von Printzen, and in a second oration by Jabloniski, there was no mention of him, though the published reports give him credit for his services in founding and directing the academy. At this time the membership had increased to 38 or, if the honorary and acting presidents be counted, to 40.

The king died on February 25, 1712. The history of the academy under his successor, Frederick William I., is somewhat disappointing. Leibniz, though doing all in his power for the academy until his death in 1716, turned, in his later years, to other helpers than the king of Prussia for aid in his projects: to the king of Saxony; to the Czar, who met him cordially and made him many promises and to the government of Austria. Through these centers of learning and investigation he hoped to be able to direct and control scientific study on the continent of Europe.

Still the Berlin Academy was not without significance. Hoffmann the physicist was not idle. Work on a German dictionary was begun early in the new reign, but for reasons which do not appear it was given up in 1721. In 1712 it was decided to revise Luther's Bible and to begin with the New Testament, but, after working on this revision till 1743, it also was abandoned. Perhaps the failure of these great projects may suggest some of the reasons why the academy had failed during Leibniz's lifetime to realize the hopes he had cherished for it. In his day and for some years afterwards few scientific men of the first rank made Berlin their home. Moreover, the government of the academy was autocratic. Some of the best men in the city, men who ought to have been among its members, felt that they could do better work outside than within its ranks. There were some quacks in Berlin, like a certain Dr. Gundelsheim, who declined an election to the academy, characterizing it as a nuisance in the learned world, and useless, and so ridiculed and defamed its most prominent member, Hoffmann, as to compel him to leave the city. As Crown Prince, Frederick William had despised the academy. Penurious by nature, he cared little for any society or institution which sought merely to increase knowledge without regard to its utility. True, he continued the calendar monopoly, but cut off some other privileges the academy had enjoyed and commanded it to reduce expenses to the lowest point. He consented to preserve its life only on condition that it do something for medicine and technology. Leibniz saw the situation and did his best to persuade the academy to undertake a work which would gratify the king and secure his favor. For some reason it failed to heed his advice. Not till ten years later did Volume II. of the Berlin Miscellanies appear. Meanwhile the theater, which had been prepared for anatomical study, was secured by Dr. Gundelsheim, who had gained the king's confidence, and made the center of bitter opposition to the academy. Although it contained the valuable cabinet of Spener, he alone of all the members of the academy was permitted to examine it. The observatory was compelled to pay rent for rooms hitherto furnished without cost, and subjected to the mortification of seeing rooms in the building which had been erected for its sole use offered for rent. Spener's death in 1717, just when he had begun to gain the king's respect and confidence, was another misfortune for the academy. Dr. Gundelsheim had now no one to oppose him. It need not be said that the academy soon suffered from his hostility. A full account of its expenses was demanded. The back salary due Leibniz remained in arrears, and after the king had looked over the balance sheet, he reduced the salary which had been only $450 one half, and ordered the $75 saved in this and other ways paid to Dr. Gundelsheim. The reduction of the salary of the president seems to have caused little sorrow in the academy. Indeed it has been said that its members would willingly have cut it off altogether could the salary of the secretary have been kept where it was. Dr. Gundelsheim died in June, 1715. Meanwhile Leibniz, notwithstanding the ill treatment he had received, continued to exert himself on behalf of the institution he loved. He urged its members to greater efforts and sought to secure the publication of the second volume of miscellanies. But the death of some of the most faithful members and the indifference which the public felt toward it left its future doubtful. Jabloniski was easily its most influential member, as Frisch continued to be its most industrious.

Leibniz died on November 14, 1716. No settlement had been made for his unpaid salary and none was ever made with his heirs. He died in neglect. Hannover took no notice of his death, neither did the academy in Berlin. Fontenelle, by order of the French Academy, pronounced a worthy eulogy in his honor in Paris on November 13, 1717. This treatment of its founder will ever remain a blot on the history of the academy, although its observance of Leibniz Day in later years and at present indicates a better appreciation of his abilities and his services for science and literature than the men of his own generation seem to have had.

The history of the academy from the death of Leibniz in 1716 to the death of the king in 1740 has comparatively little significance. Its life was monotonous, far from what it ought to have been. With it the king could have little sympathy. His strength was in other directions than as a patron of learning. He laid the foundations of a prosperous state upon which his son wisely built. He impressed the people with the need of industry and economy, but he cared nothing for science unless it proved itself useful. Nevertheless, useless as he deemed them to be, he disturbed neither the universities nor the academy. He contented himself with ridiculing the pretensions of the members of the latter and their methods of study. Yet he had some respect for the science of medicine and that of chemistry. In these two branches of study Berlin, during this period, was eminent. But apart from the Gymnasium Director Frisch and the Royal Librarian La Croze there were in the city no philologists, historians, jurists or theologians of the first rank. If the king permitted the academy to live, he took pleasure in crippling its resources and in compelling it to pay salaries to men outside its membership, men who experimented in medicine and chemistry and were willing to carry out his wishes. During the period 1716–1740 only five volumes of miscellanies were published aside from the observations which appeared in the calendar. The fate of the academy might have been better had it issued, as Leibniz wished it to do, a volume every year.

Sixteen months after the death of Leibniz the vacant presidency was filled by the appointment to it of Jacob Paul Gundling, a man of considerable knowledge, a fine story teller and the butt of the king's wit. He was the author of about a dozen volumes on historical and economic subjects, but was drunk a good deal of the time and altogether unfit to hold an office to which a man like Leibniz had given dignity. Thirteen years later, in 1733, acting on the advice of minister von Vierecke, the king made Jabloniski president and the academy began to show signs of a new life. A few famous men had settled in Berlin and some of them had accepted membership in the academy. But complete deliverance came only with the king's death and the accession to the throne, May 31, 1740, of his son Frederick the Great, who in almost all respects was the opposite of his father. This was the beginning of the new era, an era in which French thought prevailed, the era of Maupertuis, D'Alembert and Condorcet.

The Tropical Station of the New York Botanical Garden, at Cinchona, Jamaica.

THE TROPICAL STATION AT CINCHONA, JAMAICA.

By Dr. N. L. Britton,
DIRECTOR-IN-CHIEF OF THE NEW YORK BOTANICAL GARDEN.

A GREAT need in the formation of the collections of tropical and subtropical plants of the New York Botanical Garden and elsewhere in the United States has been a suitable place in the American tropics where seeds could be germinated and cuttings and seedlings grown under natural conditions for periods up to two or three years, before their transportation. Plants can be germinated and grown under glass, but in many instances it is desirable or even necessary that they should be cultivated in the open, and the care of such nurseries is far less expensive than that of propagating houses. Larger plants collected in the tropical forests are also transported to the temperate zone only with difficulty and with considerable loss unless they have been again rooted in the tropics and sent north in pots or tubs, sections of bamboo stems being readily available for this purpose. I came to realize this condition on my trip to the West Indies in the autumn of 1901, in company with Mr. Cowell, director of the Buffalo Botanic Garden, and we discussed the project for the establishment of a nursery a great deal, and concluded that in order to make as complete an exhibition of tender plants as possible in our northern conservatories such an adjunct to our work was necessary.

During Professor Underwood's recent extended visit to the island of Jamaica, while pursuing his investigation of the ferns of tropical America, he learned that the building and grounds of the colonial government at Cinchona were offered for rental and he at once communicated this fact to me. It has long been the desire of all American botanists that arrangements should in some way be made for a laboratory in the American tropics, to which investigators could conveniently go for the purpose of carrying on studies of tropical and subtropical plants growing under natural conditions, instead of under the necessarily artificial conditions which glass houses afford in the temperate zone. This matter was taken up as long ago as 1897, when the island of Jamaica was visited by Dr. D. T. MacDougal and Professor D. H. Campbell, who, at the request of other American botanists, made an examination of available sites for such a laboratory, and decided that this very place, Cinchona, was the one probably best adapted to the purpose in view. At that time, however, the Department of Public Gardens and Plantations of Jamaica was using these buildings and grounds as a part of their agricultural and horticultural system of gardens and experimental plantations, and this, together with other reasons, caused the postponement of the movement.

During the autumn of 1902 Mr. William Fawcett, the director of the public gardens and plantations of the island, was in New York, together with Sir Daniel Morris, the imperial commissioner of agriculture for the British West Indies, and at that time the matter was discussed again with them, and this gave an emphasis to the reconsideration of earlier plans, for both nursery and laboratory. The decision of the colonial government to rent Cinchona, and transfer most of the work there carried on to other plantations, was reached

A LABORATORY AT THE TROPICAL STATION, CINCHONA, JAMAICA.

only last summer, and as it was feared in Jamaica that the property might be diverted from its most desirable purposes, I concluded, after consultation with a number of persons interested, to assume the rental of the property, with the idea of carrying out both plans if possible. Dr. MacDougal immediately went to Jamaica, after Professor Underwood's return, and made the necessary arrangements for the lease and for the caretaking of the property. I communicated this action by mail to over sixty of the botanists and horticulturists of this country and Europe, who expressed the most enthusiastic appreciation of the scheme. My action was approved by the scientific directors of the New York Botanical Garden in October, and arrangements have since been made to commence the carrying out of plans both for the nursery and the laboratory, in cooperation with the Department of Public Gardens and Plantations of Jamaica.

The government of Jamaica began cultural experiments with *Cinchona* in 1860 with seeds sent out by Sir Joseph Hooker, from Kew, and after preliminary trials a tract of six hundred acres of land on the southern slopes of the Blue Mountains between the elevations of 4,000 and 6,000 feet was set aside as a plantation in 1868 and forty

A LABORATORY AT THE TROPICAL STATION, CINCHONA, JAMAICA.

acres planted with five species of *Cinchona*, the quinine trees of the Andes. A number of other trees from various parts of the world were also introduced and still flourish in this location. The reservation was increased at various times until the areas used for various experimental purposes included much more extensive plantations at the above and at lower altitudes. Headquarters for the work were established on a spur extending southward from the main range of the Blue Mountains at an elevation of about 5,000 feet. It is this central station with about ten acres of land, designated by the Jamaican government as Bellevue House and Grounds, that has been secured for the use of the garden.

The buildings include a furnished residence, stable and servants' quarters, two glass houses, three buildings suitable for laboratories and offices, a storehouse and a small building designed for lodging visitors to the station, the entire suite being admirably adapted for the purposes for which it has been secured.

The grounds contain a large number of introduced ferns, shrubs and trees, together with many native species. The valley of the Clyde River at an elevation of about 3,000 feet is within a mile; New Haven Gap and Morse's Gap, three miles distant at a level not much different from the station, furnish unequaled opportunities for the examination of a primitive tropical forest. The summit of John Crow peak may be reached from Morse's Gap, and here at an elevation of 6,000 feet the forest of tree ferns is so luxuriant that a view of the surrounding lower country is obtained with difficulty. The wealth of ferns, hepatics and other lower forms as well as of seed-plants that may be found here is remarkable. In addition, the flora of the coastal region of the island, and the vast collections in Hope Gardens and Castleton Gardens place within easy reach of the visitor an enormous number of species native to regions with a range of conditions from the most humid to those of extreme aridity. The algal flora of the coast is also easily accessible.

The government record proves the general climatic conditions prevalent at Cinchona to be very equable. Thus the lowest temperature reached in the winter of 1899–00 was 53.90° and the highest temperature of the following summer was 70.4°.

The station at Cinchona is in direct communication with Kingston, a city of 60,000 inhabitants, from which place nearly all supplies are obtained.

In addition to the facilities offered by the station at Cinchona, the government of Jamaica, by the courtesy of Hon. Wm. Fawcett, director of the Public Gardens and Plantations, has granted to the garden substantial privileges which will be of great value to visiting investigators. Among these may be mentioned the opportunities for study at Hope Garden, which lies near sea-level near Kingston, including the use of a table in the laboratory, and of the library of about twelve hundred volumes. Botanists are also to be allowed to withdraw books from this library for use at Cinchona under conditions imposed by Mr. Fawcett. Castleton Garden and the other plantations of the government are likewise open to the student.

All persons who may apply for permission to study at Cinchona must submit such evidence as the director-in-chief of the New York Botanical Garden may require that they are competent to pursue investigation to advantage. While in residence at Cinchona they will be under the supervision of the Hon. William Fawcett, director of Public Gardens and Plantations, to whose interest and advice the establishment of this American Tropical Laboratory is largely due.

EDUCATION AND INDUSTRY.

By Professor EDW. D. JONES,
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EDUCATION is one of the most important undertakings of life. Of the four great institutions by means of which society accomplishes its purposes, the home, school, church and state, the institution which reduces education to systematic form is one. The evolution of society involves all these institutions in a constant process of readjustment to new conditions. Every great social and industrial change has therefore rendered necessary readjustment of the system of education in use.

In countries where political privileges are restricted to a few and where economic conditions are stagnant, passport to society is the knowledge of a mass of traditional lore chiefly theological and metaphysical in character, supplemented by the rudiments of the exact sciences. The Renaissance unlocked for Europe the wealth of classical learning and the fraternity of the learners speedily came to consist of those who had received this knowledge and who could discuss it through the vehicle of the classical languages. The rapid drawing back of the curtain of mystery from the face of the earth during the age of the discoveries and the subsequent slow development of the natural sciences introduced a third great element to the curriculum of educational institutions; namely, science. The organization of the great states of western Europe necessitated the study of politics, history, jurisprudence and public finance. Eventually a home-grown culture in western Europe and America made possible the profitable study of modern languages and literatures. And now comes a new condition, the result of a recent and wonderful evolution, destined to influence the place and function of the school in society as powerfully as any of those that have gone before it. The growth of industry from the crude methods of the handworker, following the dim lights of tradition, to the cooperative effort and applied science of modern times, paralleled as it has been by the evolution of commerce from venturesome and piratical expeditions to a world-wide exchange of goods, which has become as essential to modern society as the circulation of the blood is to the human body, has again made necessary a modification of educational institutions. This marvelous evolution of industry and commerce has created material for an important group of new sciences, has brought into existence many new professions, and it forms a new world of human endeavor in which new culture and new and worthy ideals must be created and held aloft. Here is room for the work of the school as a patron of research, as a teaching institution, and as a champion and evangel of high ideals.

Inasmuch as a major portion of the time of a considerable fraction of the human race has been long engaged in earning a livelihood by means of those industrial pursuits for which the school is now beginning to formulate a specific course of preparation it is not remarkable that this kind of education is now engaging public thought, but rather remarkable that it should have been so long neglected.

The organization of a national system of education adequate to prepare for industry involves the many-sided problem of providing for the needs of each of the main classes of persons found in industrial society. Such a system must provide for the workmen who compose the rank and file of the mechanical or operative departments of a business, and it also must give the scientific and technical training required by the managers and superintendents of those departments. It must include training for the office force which composes the executive branch of that part of a business which has to do with the financial and commercial policy, and finally it must provide an adequate education for those who determine and superintend the execution of this policy.

We may therefore divide the school equipment, which has been provided specifically to prepare young persons for commercial and industrial pursuits, according as it relates to one or another of the above classes, distinguishing: (1) Trade and manual training; (2) professional and technical education; (3) training for office work, and (4) higher commercial education.

Trade and Manual Training aims to produce the skilled artisan; and this it endeavors to do by giving the youth, in addition to his general elementary education, a further mental equipment, involving the knowledge of the qualities of materials and the methods of manipulating tools, machinery and materials to attain desired results. It also aims to give him a knowledge of the proportions necessary to secure strength or beauty, and the capacity to see the possibilities of materials and of his art. There is necessarily an important physical element involved in this kind of training. Not only must the mind be receptive, but the eye must be taught to see things as they are; not only must the imagination be awakened, but the hand must be skilled to execute the conceptions of the mind.

The subjects usually taught in manual training schools are free hand and mechanical drawing, clay modeling, carving, sewing, cooking, carpentry and forging. These subjects are appropriate for students between the fifth and eighth grades. They are chiefly taught in the public schools, being found in 1899 in the schools of 170 American cities. At the same period, however, there were 125 private schools teaching manual training.

In previous industrial periods a supply of skilled artisans, though not an adequate one, was secured by the handing down of the traditions of craft from father to son. This method was suited to the household system of industry. At a later time the supply was made sure by a careful supervision of apprenticeship, and this proved successful so long as the shop system endured. The dominant industrial organization previous to the introduction of the factory system was the guild—an institution which, in addition to other duties discharged, made itself responsible for the regulation of apprenticeship and for the preservation of standards of workmanship. These standards it was able to fix since it included both masters and workmen, and it maintained them by means of the masterpiece, the trade-mark and the power of excluding incompetent workmen from the trade and inferior articles from the market. The present industrial system has broken down all these regulations. The traditions of craft do not preserve validity long enough in this age of rapid mechanical evolution to be handed down with profit from father to son. The freedom of choice of occupation and the constant ebb and flow of population between producing regions now prevent the accumulation of any great store of traditional skill and knowledge among the workmen of any one locality. The factory system has rendered apprenticeship impracticable, not only because there is no time for the employee to teach and the novitiate to learn, but because the subdivision of labor is so great that a systematic progression of tasks must needs be arranged to give the beginner even a comprehensive knowledge of a rule-of-thumb character concerning a trade; and this the modern competitive institution is usually not in a position to grant. Furthermore, the guild has disappeared and in its place have come the trades unions, composed exclusively of employees, and having as their primary object warfare through the strike to secure higher wages and shorter hours of labor. The trades unions have not undertaken to set standards of excellence in workmanship or material as did the guild, nor can they do so, for they do not control the processes of industry as did the guild. The attention paid by them to apprenticeship is not for the purpose of educating the artisan but to restrict the number of persons in a trade and so affect wages.

The old system has crumbled to pieces, and yet never was there greater need of an intelligent artisan class than at present. Never have the machine and the routine of production so threatened to dwarf the worker; never has there been more wealth under the control of those of artistic aspirations ready to pay for the best creative work of the artisan. Never has there been greater need of joy and pride in work and healthful mental stimulus in it to offset the deadening effects of a narrow spirit of commercialism; never has society more needed a sound middle class capable of right thinking and sufficient initiative to hold together the extremes of wealth and poverty that our wonderful economic system now produces.

The school is called upon to provide the education necessary for the artisan, and this it can do better than the practice of an industrial art alone, because it can arrange such a gradation of tasks as will insure the most rapid and permanent acquisition of skill and mental power. The school can give manual training without interrupting the general education of the youth. As dexterity in some lines is easiest acquired in youth, it can insure this without the waste of mind and body involved in child labor. The school, furthermore, can constantly relate the precepts of the arts to the principles of the sciences on which they rest and can add to this an artistic education which will awaken ability beyond that which any training in the workshop or factory can evoke.

Professional and Technical Education is of a more advanced order, and therefore not only requires more expensive equipment so that it is limited to a relatively small number of institutions, but is divided into professional courses corresponding closely to the professions and to the customary groupings of productive industries. This branch of education requires little explanation, let alone defense, in this country. It is the earliest form of education for industry to be developed here and it has passed beyond the experimental stage.

Of professional schools there were but two in this country at the time of the declaration of independence, and these were both medical schools. In 1899 the Commissioner of Education reported 917 professional schools, including schools of theology, medicine, law, pharmacy, dentistry, veterinary science and training schools for nurses, having a total attendance of 65,152.

As an illustration of a technical school we may cite the Rensselaer Polytechnic Institute of Troy, N. Y., one of the first of its kind in this country. It was founded in 1824 and, because of its early start and high rank, has exerted a great influence upon American railway engineering. The Philadelphia Textile School, the New York School for Carriage Draftsmen, the Michigan Agriculture College and the School of Mines of the same state are institutions of this class, as are the many polytechnic, mechanical and agricultural schools of the country, and schools of forestry, architecture, etc.

Through the liberality of the federal government many excellent agricultural colleges now exist in the United States, but a wonderful future lies before our agriculture when it shall be thoroughly permeated by the modern scientific and system-loving spirit, and its various branches shall follow the dictates of science, under the guidance of trained men. This the recent history of the dairy industries amply proves. The mineral industries of this country have been conquered by scientific experts within the past fifteen years, and the recent improvements in smelting and refining are due to men from the universities and schools of mines. The manufacturing industries of this country in a like manner need and can greatly profit by a steady supply of technical experts who shall do for us what the graduates of German schools have done for the German chemical and textile industries.

Training for Office Work has remained in the hands of private institutions for the most part in this country. These schools, usually known as 'commercial colleges,' aim to fit young people of both sexes for clerical positions in offices and for employment as bookkeepers or stenographers. The chief subjects taught are penmanship, correspondence, stenography, typewriting, commercial arithmetic, bookkeeping and 'business practice.' The demand for persons to fill clerical positions has steadily increased for many years owing to the development of systems of stenography and to the invention of the typewriter and to the more elaborate form in which the record of business transactions is now kept. As the size of the individual business has increased and the territory covered by its operations has widened and the period of time involved in its calculations has lengthened, the need of carefully kept records has become apparent. The growth of the corporate form of business organization, furthermore, has made it necessary to protect the interest of shareholders by complex systems of accounting, involving sufficient checks and balances and frequent audits.

The 'commercial college' has responded in a more or less unsatisfactory manner to the calls made upon it. This is due in part to the fact that they are private institutions, run as money-making businesses, and without any uniformly enforced standards such as they might have attained for themselves through organization, or such as are enforced upon preparatory schools and high schools by university requirements for admission. Studies may be pursued in them in a wholly elective manner, as fees are paid, and so it has happened that they have been used as an educational short-cut by scholars of every variety of ability and education from the high school graduate, who may spend a year or more in them, to the youth from the country district school, who may study for two or three months. In accounting for the unsatisfactory work of this system of schools as a whole two other circumstances should be taken into account. One is that the business community has been expecting a kind of education from them which they were not organized to give and are not in a position to give, and the other is that educators who are capable of giving assistance have, for the most part, not assumed a helpful attitude toward the problem presented by them.

The aggregate of interests represented by these schools in this country is enormous, and the problems connected with them are serious and merit attention. It has been estimated that there are now 2,000 'commercial colleges' in the United States, employing 15,000 teachers, and having an attendance of 160,000 pupils. The best of these establishments in the large cities are handsomely equipped for the work they set out to do and amount practically to private commercial high schools.

In recent years this problem of education for office work has been complicated by the establishment of commercial courses in high schools. The high school has the advantage in that it can formulate a systematic course of study covering the special training desired, and can couple with it a fairly adequate general secondary education. By having a larger scholar population and holding it for a series of years the high school is able, furthermore, to carry out in its commercial course a more ambitious program of study than the 'commercial college' with its floating population, and so it can group and systematize its work to the best advantage. It remains, however, to be seen what relation the public high school and the private school will eventually sustain to one another in this branch of education.

Higher Commercial Education is the effort of universities to respond to the call for a course of education which shall fit young men for the more responsible positions in industry. It aims to provide the theoretical and systematic part of the education of those who are to determine and execute the commercial and financial policy of businesses. It has more particularly in view at present persons who will occupy such positions as managers of departments, foreign agents and buyers of large concerns, officials of banks, insurance and transportation companies, merchants, journalists, government employees at home or abroad, as members of the consular and diplomatic service, etc.

There are three chief reasons why higher commercial education has become an imperative demand of the times and why the great universities of this country as of other countries are responding to the call made upon them by public opinion. These are briefly, that business has become an intellectual pursuit, that in business a sufficient training is not found for the adequate performance of its own tasks, and finally, that in the juncture thus created the universities are being actuated by a new, broad and constructive policy to take hold of the problem.

To consider these separately, the first reason is that the higher tasks and the more responsible positions of industry now involve an intellectual pursuit making profound demands upon the intelligence of those who undertake them. As Mr. Arthur Balfour, the first lord of the English treasury, has recently said, "In the marvelously complicated phenomena of modern trade, commerce, production and manufacture there is ample scope for the most scientific minds and the most critical intellects; and if commerce is to be treated from the higher and wider viewpoint it must be approached in the broader spirit of impartial scientific investigation."

The economic system in vogue before the industrial revolution hardly gave an opportunity for much of a science of productive industry or for systematic courses of study preparatory to the task of guiding industrial forces. That revolution enlarged the individual business unit through the use of machinery in connection with great sources of power, and of labor through an elaborate differentiation of tasks, the result being to make the government of the internal affairs of a business resemble the work of governing states. It enlarged the market also by means of improved means of transportation and communication, and not only brought the entire earth into the field of commercial vision, but threw the new giants of production into such a keen and relentless competition that the utmost precision of knowledge, genius for administration and mental and physical staying-power has been sought after for leadership.

With these changes in progress and partly completed, industry has at once shown an irresistible tendency to come under the sway of science. A new concern of large size now starts with a charter and a plan of internal organization, the work of professional organizers and as carefully drawn as the constitution of a state might be. Eventually the mill architect lays out the plant. The head chemist and consulting engineer take charge of the operative departments; the conditioning laboratory checks off the results of the buyer's work; the credit man rules the selling agencies and compiles his data as systematically as the much-abused charity organization society; and the advertising manager works with a like systematic use of records. Risks are transferred, whenever possible, to insurance companies which study them with all the methods known to statistics. Legal liabilities are attended to by a special corporation attorney. All the records of the activities of the concern are compiled under the direction of the accountant and are periodically examined and certified to by a professional auditor. At every point the business has touched upon a science or a possible science.

This new régime, while it has given to industry such a character of intricacy, has given to its laws such precision, to its processes such rapidity and continuity, and to its leaders such a scope for power that men of systematically trained perceptive faculties and reasoning powers are required for it.

These methods also have already brought into view such a body of systematized experience that it is possible to begin the formulation of the principles of wealth production. And this will provide a subject-matter which can be studied apart from practice, according to the methods of an educational institution, and which will be of practical value because it has grown out of practice and governs it.

In an important sense the advance made by higher commercial education will condition the advance made by the other branches of education preparatory to industry, since the men in the responsible positions in our industry must needs have scientific and commercial training to appreciate its value in the men they employ.

The second reason for higher commercial education lies in the fact that it is becoming increasingly difficult for young men to acquire a knowledge of the principles underlying business through engaging in the activities of business. This is true if it is true that industry is becoming applied science, for science is systematized knowledge, and systematic knowledge is only to be gained by systematic study. The division of labor now customary in a business of any size is such that a broad experience and knowledge of the business can not be gained from service in a subordinate position. Either there must be unusually favorable promotion from department to department, coupled with outside study; a plan followed by some of our prominent families in educating their sons, or an appropriate course of study must be arranged in an educational institution, or else we must fall back upon the chance of finding a man of unusual genius. We have in considerable measure been trusting to the most uncertain plan of all, the discovery of the self-made man of genius. As a result we have a tendency to build industrial organizations to undue size, the endeavor being to get important interests under the control of the comparatively small number of men who can be implicitly depended on. Thus we vastly overpay for the exercise of a certain kind of talent and run the risk of many industrial evils with our top-heavy system.

The tendencies of the industrial system now dominant, as regards the production of managerial ability, are, however, in considerable degree, still unrevealed to us because of a generation of remarkable leaders which has not yet passed from the stage of action and which was evoked by the evolution that built up our present magnificent national industries. These men began in the day of small things when a few hundred dollars sufficed to set up a manufactory with costs of production as low as others and with high tariffs and transportation rates to protect a market from outsiders. They grew with the industrial system. As their businesses grew their opportunities and experience and power grew by natural and easy stages, and they emerged from a nicely adjusted and progressive evolution knowing their industries from top to bottom. These men show the knowledge of detail due to the day of small beginnings and the even hand in administration due to gradually imposed responsibilities. In the future we can not with any confidence look forward to a succeeding generation recruited in the same way, for the system has changed. Unless the evolution of industry which trained the leaders of to-day can be simulated within industrial establishments by a system of apprenticeship broader and more scientific than the old as the new industry is greater than the old, and leading up to the highest administrative duties, then preparation must be arranged outside them in the school and university.

It needs scarcely to be pointed out that business is carried on primarily for the sake of producing wealth and that the machinery and method devised for this purpose is only incidentally of value as a training school for the young. To equip an institution specifically for the purpose it is to serve, whether it be to produce locomotives or cotton cloth, is well enough understood in these days of specialization. So to equip an institution as to rapidly and surely and economically develop the latent powers of the mind required in business and to impart knowledge of practical value is simply to set about doing an educational work in an equally direct and logical way.

The very precision of organization which makes it so difficult for the subordinate to gain the knowledge and experience necessary for leadership provides the mechanism which most perfectly responds to the *entrepreneur* and endows him with power never before equaled in industry. Never was the capable manager more in demand than now; never was the hunt for the right man more anxious than it is now. There is not a more important question that can arise within industry than this one of proper management. How shall society insure the perpetuation of adequate leadership? This question is peculiarly pressing for the United States, not so much because of immediate needs as because we are bounding forward rapidly in our industrial evolution, framing greater structures of trade than the world has ever seen before.

Our great country lying in one continuous area, undivided by physical barriers and capable of furnishing every variety of raw material; in the possession of a progressive race with like degree of enterprise and honesty in all sections and employing the same trade usages and laws, possesses a capacity which a like area divided into many small states, although in the possession of an equal population of different races, could not have. No matter how large the industrial unit ultimately required to secure all possible economies of production, here the various raw materials can be secured, here all the branches of the business may be carried on without crossing the boundaries of nations and encountering tariffs and racial and national rivalries. Here business can be transacted with the utmost facility because among people with one language, system of money and weights and measures, and working with the same spirit of alertness and ambition, under one system of laws and customs. The United States may well be the country destined to test to the uttermost the possibilities of organization in industry.

But we shall not be without rivals in the world's trade. Countries which can not match us in resources and population will turn inevitably to more scientific and systematic methods. Already the Germans are applying the same methods to the preparation for commercial war that brought them out from the anarchy into which they fell after their defeat by Napoleon and made them the foremost military nation in Europe. England also is awakening to the necessity of applying education to the preparation for business life. Lord Rosebery, in a speech delivered before the Wolverhampton Chamber of Commerce which has since become celebrated, said, after reviewing the dangers threatening British trade from German and American competition: "What is the remedy for this? What is poor old John Bull to do before he is suppressed and defeated by these newer competitors? If I might say a word it would be to echo what has already been said by the chairman —educate. I believe our raw material of men is the best in the world. But I do believe that our commercial men require educating, training scientifically from the bottom to the top. I believe that is a feeling which has become very common in this country. I see a great many articles now in the papers as to the decline of our trade, and several of our leading newspapers are, as you know, devoting articles to this subject, which I read with profit, but as to which I do not pretend to pronounce a definite judgment. But I do think all these articles, whether they be pessimistic or optimistic—and I am bound to say they are generally pessimistic—are united on this point of education.''

Before we consider the adaptation of a university course to business training let us notice the various systems which have been or are now employed in educating or choosing young men who are designed for industrial leadership. The oldest system now in use is that of patronage, which still survives in France. This system belongs to a long established and somewhat static industrial community, in which advancement is slow and restricted to those who are specially favored. The solicitation of the favor of a distinguished relative or friend or local dignitary to assist in introducing a young man to a desirable position is in a sense only a rigid and systematized form of the rather loose system of recommendation everywhere in use, and, in a degree, it is as natural as the giving of favor to friends and relatives which is everywhere a factor in the preferment of many. To erect this into a system, however, is repugnant to the spirit of American youth and their employers. Allied to this is the English custom known as the 'counting-room system,' which consists in the placing of the son of a member of a firm in the business at an early age and graduating him rapidly from department to department in such a manner that when he finally obtains a junior partnership he has some knowledge of the operations of the business. The result of this plan is to keep businesses in families for generations and to create a spirit of family pride in the integrity and prosperity of a business which is heartily commendable. The Swiss as an industrial people are noted for the degree to which businesses are in this way kept within families. Some defects of the system are the tendency to coerce young men into occupations for which they have no taste or ability, the tendency to family exclusiveness and the neglect of young men who have only their merits to recommend them for promotion. This system is in reality a special form of apprenticeship arranged for the few.

Closely allied to the above is the recruiting of the managers of the colonial houses or foreign selling agencies of a concern from promising young men in subordinate positions in the home office and, in turn, recruiting the superior officers of the home concern from successful branch managers. This system of using the foreign offices as feeders has played some part in England and is used in Germany. It has the merit of insuring to the home office accurate knowledge of the tastes, customs, laws and languages of foreign markets, and of keeping the home office and agencies in touch through the transfusion of blood.

Travel has for many generations been used in western Europe as a fitting supplement to the education of a young man at the conclusion of the period of schooling. It undeniably broadens the personality and develops culture through the variety of knowledge it imparts and the contact with people which it involves. It is, however, an expensive way of accumulating knowledge, and the knowledge gained is likely to be of a fragmentary and superficial character unless the traveler have uncommon tenacity and singleness of purpose. Before travel became the favorite recreation of the wealthy and the countries that have much to teach came to be deluged with the never-ending stream of sight-seers it was, perhaps, possible to gain in a short time valuable information regarding the industrial life of a people. Now the avenues of travel have been smoothed to a cosmopolitan sameness and these avenues lead to the 'sights' which, for the most part, convey little information of practical value to the young man preparing for commercial life. Meanwhile, since international rivalry in trade has become acute, the processes of production which might be studied with profit are being jealously guarded and kept secret from foreign visitors. So greatly has the system of news gathering improved and so voluminous and accurate have become the reports of consular officers that the traveler abroad must often return home to learn from literature easily accessible facts that are difficult to acquire through personal observation. Travel is quite appropriate for a people that have everything to learn and desire to import *en bloc* the system of older developed commercial states, but for a country having marked characteristics of superiority and possessing the lead in many things the problem of keeping this preeminence is not solved by any scheme of borrowing ideas, no matter how systematically and intelligently carried out. It is deserving of notice, however, that travel may be utilized by American manufacturers to a greater degree than it has been to give them a knowledge of the tastes of their foreign customers.

Education abroad is in many ways analogous to travel. It has been employed in recent years with success by Japan and is best adapted to the requirements of a nation taking its first steps in a new culture. For the United States this plan has many of the limitations of foreign travel, and it carries with it the added danger that the young man who remains abroad for a long season in the formative period of life will find himself on return out of touch with the ideals and customs dominating the industrial society in which he is to live, and that thereby the effectiveness of his personality will be greatly decreased.

These are some of the methods which have been devised to improve upon the wasteful state of individualistic struggle in which the leader is chosen through the survival of the fittest simply as the exceptional man is able to fight his way up from the ranks and grasp leadership as the perquisite of the ownership of property. None of these methods alone is adequate for the needs of modern industry; most of them are out of harmony with the traditions of American civilization. In the search for a solution of the problem experience points us to no other institution so promising as the school. It is the most mobile and elastic of all our great institutions and is easily adapted to new purposes, while it is at the same time incomparably the most economical of our institutions in proportion to the work accomplished by it. We have never as a people been disappointed in the accomplishment of any educational task we have set the school to perform, and the school has not been obliged to withdraw from any task that has once been assigned to it.

Such being the conditions of the problem, the third reason why higher commercial education is making rapid headway at the present time lies in the response which institutions of higher education have made in this country to the demands upon them in this connection. This in itself is one of the most encouraging manifestations of a new and broader conception of the university as an institution whose functions are to gather in to itself and conserve all knowledge, to represent the interests of all classes of the community which supports it, and to be as broadly useful as is possible, consistent with true learning in the training of men for the various activities of life. This sentiment which characterizes the thought of university circles to-day, in contrast to a narrower and more exclusive ideal once dominant, was well expressed by President Nicholas Murray Butler, in his inaugural address at Columbia University. He said, "In these modern days the university is not apart from the activities of the world, but in them and of them. To fulfill its high calling the university must give, and give freely, to its students; to the world of learning and of scholarship; to the development of trade, commerce and industry; to the community in which it has its home, and to the state and nation whose foster child it is."

Not only will the community be benefited, but the universities will be benefited by every new avenue of usefulness opened for the school. Already our universities through their libraries and collections are made the custodians of the community's knowledge. To these centers should be gathered as much as possible of the data upon which may be ultimately built an adequate science of wealth production. Much of this knowledge now perishes unrecorded with the men whose life energy has been expended in assembling it. This is a great loss to the race. The world of business is, in a sense, a laboratory where are discovered the principles of industry and commerce. These discoveries should in some way be systematically garnered and so treasured that the rising generation shall have access to them. Our universities also comprise an assemblage of men of expert knowledge who would, many of them, greatly profit by being brought into closer touch with the world of affairs about them. The advance of the university into the field of higher commercial education can only be made successful by devising means of bringing the university into closer contact with the industrial and commercial institutions of the country. This is desirable not only for the sake of keeping the learning of the university from becoming stagnant with antiquated knowledge and to permit the rendering of the most effective service, but is necessary to prevent any serious hiatus between the academic life of the student and his later business career. The task of those interested in the advancement of commercial education appears to be a two-fold one; to prepare the necessary course of instruction, and to obtain from the business community the close sympathy and cooperation essential to the achievement of any large success.

The course of instruction finally adopted will necessarily be framed to correspond with the ideal which is formed of the business man as a person of power and knowledge. In the forming of this ideal there is need of much discriminating observation. All will agree upon the need of honesty and dependability and a certain complement of attractive personal qualities, and tenacity of purpose, and fertility of resource, which is closely allied to it. There is required also executive ability, a most complex manifestation of the personality involving character as well as rapid mental processes and the power to subordinate detail and quickly choose the vital points of a matter. The business man has constant need of the power to judge men, and of retentiveness of memory, together with that healthful working together of all the powers of mind involved in good judgment or common sense. The question must be answered, How in the choice of these and other characteristics does the educational problem of the future business man differ from the education of the man who is to get ahead in other walks of life? So far as this problem of evoking the latent powers of mind and heart is concerned, more undoubtedly depends upon the environment of the student's life, the ideals held before him, the methods of teaching, and the care taken to cultivate his powers of initiative, than upon the specific things studied. It may be suspicioned that courses of higher commercial education which differ in no particular from other university courses, except in the choice of studies, are half-hearted attempts at the solution of a new problem the real difficulties of which are not appreciated.

Turning to the subject-matter composing the courses in higher commercial education, provided by some fifteen of our larger universities, we find the most prominent place among the studies designed to give general culture occupied by history. The first place among studies calculated to give special training is given to economics, which explains the general principles underlying the present structure of economic society. This includes, besides systematic courses, studies in applied economics, statistics, money, banking and finance. Under the caption 'Commerce and Industry' may be grouped studies in the principles of commerce and the geography, materials, customs and usages of commerce and also detailed examination into the structure and processes of the extractive and manufacturing industries. Attention should be called to the at present very meagerly developed study of industrial organization, which has to do with the administrative relations existing within an individual business, especially if it be of large size, and with the methods of utilizing the resources of investors in financing new undertakings. A very important group are the applied sciences, including industrial chemistry, the application of physics to industry, economic geology, etc. Among other subjects generally included are the modern languages and commercial law, the latter covering not only the legal liabilities attending industrial acts, but the principles upon which the state interferes to regulate the competitive struggle. The successful conduct of such a program of study obviously involves the cooperation of several departments of a university; the humanities are represented in the history, economics and languages; the scientific department in the various courses of applied science; the law department in commercial law; while the studies in 'commerce and industry' provide a new group which serves as a central topic about which the others are arranged.

The university must not be expected to show its full effectiveness in the new field it has entered until a considerable amount of preliminary work has been done in the collecting and classifying of knowledge, the preparation of text-books and the adapting of methods of instruction to the nature of the new subjects taught. Higher commercial education does not aim to fit the individual for the immediate assumption of responsible commercial tasks any more than engineering schools fit young men to step at once to the position of engineer-in-chief. There is a body of detail connected with the operation of most businesses which can only be learned in practice. The university is aiming to train the youth to clear thinking and to equip him with a knowledge of the general principles upon which sound business practice rests, trusting that with such a preparation his later advancement will be such that the years of study will prove years well spent and that, in addition to a compensating financial return, life will contain a richer reward of the higher utilities and a larger sphere of usefulness, because of the early implanted love of truth.

EVOLUTION NOT THE ORIGIN OF SPECIES.

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IT is a misfortune frequently lamented that new truth, the most precious attainment of each generation, is also the most unwelcome. We do not hasten to sweep out our stock of laboriously collected ideas, even after the worthlessness of the assortment has been declared. This conservatism of vested intellectual interests not only postpones the utilization of the results of scientific inquiry, but it has an even worse effect when it impedes further investigation and warps our perception of facts.

The great obstacle in the popularization of the fundamental and obvious biological fact of evolution was the theological dogma of the separate creation of species, and toward the overthrow of this the arguments of Darwin and his immediate followers were, of necessity, directed. After four decades the debate upon the general question may be said to have closed. The thoughtful public believes that species were not made like cakes by the baker, but that the diversity of organic nature has been attained by gradual changes and transformations, a process commonly thought of as 'evolution.' As soon, however, as we pass into the field of biology proper, and seek to know the nature and causes of this process, all unanimity of opinion vanishes. The fact of evolution is no longer doubted, but biologists are still writing thousands of pages annually in support of the most diverse and contradictory interpretations of evolutionary phenomena.

In spite of the external simplicity of the idea, evolution affords extremely complex and elusive problems, and in addition to the inherent difficulty of these, discussion is still cumbered with the original terminology. Vast quantities of argumentation wasted in attempting to convince theologians that they did not know how species were made are already forgotten, but a more troublesome legacy remains, in that the words and ideas upon which attention became focused during that struggle still darken our views of biological problems.

Evolutionists, too intent on a practical explanation of the diversity of species, seized upon the idea that organisms become adapted to environment, and disregarded the more fundamental fact that species are not by nature stationary, but have an independent motion of their own. This oversight brought us the impossible task of explaining how external conditions produce evolutionary changes, and prevented the perception that adaptations are due to external causes only as environment may influence the direction of the normal and necessary movement of the species.

That evolution is thus an active, universal and truly physiological process is not considered in current theories, largely because thought and language have continued to follow the bias of the original controversy in seeking in evolution an explanation of the origin of species and in expecting, conversely, that an explanation of the origin of species would also explain evolution. It is, therefore, a matter of literary as well as of scientific difficulty to present an alternative view, that the multiplication of species is in no proper sense a result of evolution, but is due to entirely distinct causes more often antagonistic than favorable to evolutionary progress.

Evolution versus Taxonomy.

The early evolutionists were all systematists deeply impressed by the vast complexity of organic nature, a sentiment which we may still indulge, since two centuries of labor have but made a beginning in the task of describing and assigning names to the millions of groups of organisms. Nevertheless, it is to be regretted that biological evolution was viewed and expounded so exclusively from the standpoint of the taxonomist, since his interests are greatly at variance with those of the evolutionist, and the confusion of the two distinct lines of investigation has done much to perpetuate the erroneous identification of the origin of species with the process of evolution.

The evolution best appreciated by the taxonomist is one which has produced species separable by definite and easily definable characters. He finds such species on islands and in other circumscribed regions and thereupon decides that isolation is an important evolutionary factor, failing at the same time to perceive that the 'constancy' which he ascribes to insular species is merely a uniformity made possible by the limited area of distribution, and hence often absent in species of more extensive range. Small segregations of individuals acquire uniformity of characters more promptly than if they were larger, and the sooner afford diagnostic differences of use to the systematist. This does not, however, decrease the probability that evolutionary change is slower in small groups than in those which the systematist abominates—large assemblages of individuals, offering great variety of characters, but without uniformity of combinations.

The systematist is prone to believe that there has been more evolution in a genus of ten definable species than in another occupying the same geographical region, but consisting of only one species. For the evolutionist, however, the segregation of the numerous species means that the conditions are less uniformly favorable for the subdivided genus than for the other. Among fossil organisms, also, the more generalized the types the wider was the distribution, the separation of local genera and species following with less favorable circumstances or greater competition. Segregation multiplies species by separating groups of organic individuals, just as the ocean might form many islands from a partially submerged continent. Species are biological islands, but we do not go farther in biology than in geography by the discovery that islands must be isolated. Isolation permits evolutionary progress to be made on separate lines until the differences become of diagnostic utility to the systematist, but that isolation is responsible for the changes which bring about the divergence of characters is a deduction no more logical than that the differences between islands are due to the waters which separate them.

Too narrow zeal in the descriptive task has led many systematists to act on the assumption that the same amount of difference should everywhere receive the same systematic recognition, a method sometimes defended on the ground that all variations of form or structure indicate incipient species budding out from the parent stock, and sure to become separate groups like other now segregated types, a supposition quite unsupported by evidence. Far more rational and more secure would be the progress of systematic biology if recognition as species were limited to groups of individuals separate in nature, regard being given to the *completeness of segregation* rather than to the *amount of difference.*

It is to be admitted, of course, that when specimens from a new locality offer tangible differences from any previously known, the working systematist must describe and name them as representing new species. To crowd them into an old species by 'emending the description' or by calling them a 'variety' is to guess at an integration in advance of knowledge; while to refuse to unite 'species' which have been shown to belong to a continuous series in nature is to prefer technical fiction to biological reality. A coherent group of interbreeding individuals is the unit of evolutionary biology to which the term species finds its most proper application. The tendency of some systematists to refer also to intergrading, unsegregated subdivisions of such groups as 'species' shows how easily conventional taxonomic methods may obscure evolutionary distinctions.

Criteria of Specific Distinctness.

Species differ, of course, in the variability of their characters, but, other things being equal, the uniformity of the individuals of a species might be expressed by a ratio between the range and the facilities for interbreeding. A widespread species of sedentary animals or plants will become locally diversified; more frequent intercommunication permits more uniform progress. A single species may have as great a variety of characters as a dozen related groups which have been segregated. Two species may be quite distinct and yet differ much less than the connected extremes of another. That a species differs in different parts of its range does not necessarily mean that a subdivision will take place; it means merely that characters are originating more rapidly than they spread over the whole species. The integrity of a species is not destroyed by 'inconstancy' of characters, but because geographical or other barriers make a gap in the series.

The failure of the extremes of a widely distributed species to breed when brought together does not prove the attainment of specific distinctness, nor the approach of it, since internal diversity does not weaken the species, but is an evolutionary advantage, and both extremes may continue to cross freely with the connecting forms, which constitute the bulk of the species. Neither does the power to form fertile hybrids prove that two species occupying distinct ranges are one. Faith in such criteria is simply a remnant of the pre-evolutionary theory of the separate creation of species. The only way to ascertain that two groups of organisms are separate species is to find the gap between them. Whether they will breed together or not, and whether the hybrids are fertile and vigorous, or weak, sterile and aberrant, may indicate the period and degree of divergence of the types crossed, but affords absolutely no evidence as to whether the series to which they belong in nature are continuous or interrupted. Specific distinctness is a question much more geographical than evolutionary. Evolution continues whether the species is divided or not; the divergence of the parts is rendered possible by the cessation of the interbreeding which would otherwise maintain the coherence and relative uniformity of the undivided group.

Segregation and Vital Motion.

The systematist 'separates' species because they are 'different,' but the evolutionary significance of species does not appear from formal descriptions of these biological islands; it lies in the fact that isolated groups of organic individuals universally acquire diagnostic differences. Isolation has furnished millions of these tests of the universality of biological motion, but it does not cause the motion. Evolution is independent of isolation, and without it has often brought about great diversity of form and structure, as witness the dissimilar sexes, castes, dimorphic and alternating generations of many species of plants and animals. Without evolutionary progress there would have been no species as we now know them, but the causes of the segregation of species are not causes of evolution; segregation merely permits this universal tendency to become more manifest. If it should be found that evolutionary divergences sometimes assist natural selection or physical barriers in the work of subdividing species, this would mean that evolution sometimes results in segregation, not that segregation results in evolution.

Evolution is a process of change in species; it is the journey of which individual variations are steps. Evolution changes the characters of species, but it does not originate species.

Natural selection may assist geographical and other influences tending to the division of species, but it is not on that account a cause of evolution; it represents the determining aspect of the environment—the factors which influence the direction of the vital motion, but not those which induce the motion. Natural selection may explain differences between two species, but not the becoming different. It is an external incident or influence and not an active principle or agency of organic evolution. Adaptation is possible because there is a vital motion which can be deflected, not because the environment changes the characters of species. The river of evolution flows through the land of environment; the conformation of the valley determines the course of the stream, but the water descends by its own gravity.

In the course of its progress the species explores all the adjacent territory and follows the line of least resistance to the variations it is able to put forth. Changes are necessary to maintain the vitality of the species and also to keep it abreast of its environmental opportunities, and if no adaptive movement can be made it is still unable to remain stationary, but continues to change in characters indifferent to the environment, or even actually detrimental.

The species encounters obstacles and subdivides because it is in motion; the division takes place when variations can no longer spread freely among the individuals of the species, not because the environment introduces new characters.

That species occupy definite regions of distribution has been taken by some to mean that the individuals are similar because they are molded by similar influences, but that this inference is wrong is shown both by the wide diversity of conditions under which some species exist, and by the even wider diversity of form and structure often found among the members of the same species in the same environment. Similarity of conditions may permit plants and animals of different origins to develop similar variations, and to share, finally, the same adaptive characters, but identical conditions do not put an end to individual variations or to evolutionary progress.

The Function of Selection.

By denying that selection has any power to initiate or actuate developmental changes it is not intended to imply that it has not profoundly influenced the course of evolution in many organic groups.

Indeed, it may be claimed that the kinetic theory of evolution affords the first concrete explanation of the workings of natural selection. Vital motion not only makes selective influence possible, but it meets the ancient and hitherto fatal objection to the theory of selection, since it shows how characters may originate and develop to the point of utility or harmfulness, where selection can take effect.

The hypothesis of selection as the active principle or causal agency of evolution became illogical and useless as soon as the inheritance of acquired characters was abandoned. The first idea without the second does not account for adaptations. The 'selection' of Nägeli, Weismann and other believers in a 'determining principle' or 'hereditary mechanism' of evolution is a very weak substitute for the Darwinian idea, able only to eliminate the hopelessly unfit, but quite without means of influencing the survivors. The recognition of a continuous and necessary vital motion permits us to understand that the rejection by the environment of a harmful variation encourages adaptation by accelerating the development of any more adaptive variation which may appear.

All organisms are subject to selective influence in the sense that variations are rejected with a promptness proportional to their harmfulness in the given environment, but generally this leaves a very wide latitude of possible changes in which selection does not interfere. The instances are relatively rare in which existence becomes acutely dependent upon the development of some one characteristic or quality, and such narrow selection does not strengthen the type, but insures and even hastens its extinction.*

The Significance of Species.

The traditional illustration of organic descent by a tree with ever-dividing branches is entirely misleading as a suggestion of the nature of evolutionary processes, because individuals do not follow each other in simple series. Successive generations are connected by endless intergraftings of the lines of descent. A species may be treated systematically or statistically as an aggregation of individuals, and may be described by an averaging of the characters of these; but from an evolutionary point of view it does not exist as a species because of the possession of a certain complex of characters, but because the component individuals breed together; through this alone is the integrity or coherence of the species maintained. For evolutionary purposes we may think of the same species existing thousands of years hence,

* 'Stages of Vital Motion,' POPULAR SCIENCE MONTHLY, LXIII., 16, May, 1903.

and with any or all its characters changed.* It is not necessary even that the individuals of a species remain alike; in many unrelated natural groups extremely diverse sexes, castes and 'forms' remain associated in the same species and travel together on the evolutionary journey, sharing the same environment, but without any tendency to become 'exactly alike.' Moreover, we know that sexual and other diversities inside the species are not casual or accidental, but normal and advantageous, facts quite overlooked in static theories, which have viewed life from a narrowly systematic standpoint and have argued that interbreeding prevents the preservation of new characters and is thus a hindrance to evolution.

The kinetic theory, on the contrary, ascribes the fact that organisms are everywhere bound up into species to a property of fundamental evolutionary importance, and interprets the multitudinous devices for maintaining the coherence of groups of interbreeding organic individuals and the equally general manifestations of sexual and other diversification inside specific lines, as due to the same requirement of protoplasmic organization, an interlacing network of descent. Without cross-fertilization species would not cohere, but would split into numberless independent, diverging lines. This takes place with organisms long propagated asexually, whether artificially or in nature. For example, the genus *Sphagnum,* which very rarely produces spores, offers a multiplicity of varieties nowhere approached among mosses having normal sexual reproduction; but notwithstanding so many differences in minute details *Sphagnum* has remained a very compact, unprogressive group. Cross-fertilization prevents this type of diversification, but it need not on that account be supposed to impede evolutionary progress. Evolution is not merely a progressive diversification, it requires also a progressive synthesis of characters by the interbreeding of the individual members of specific groups.

The Species a Protoplasmic Network.

That sexual reproduction is a substitute or improvement of multiplication by fission is another partial and misleading view which has contributed much towards the concealment of the causes of evolution. The division of cells is the only method of organic increase; conjugation is not multiplication, but serves as a preliminary stimulant to the necessary cell-division. What is growth, for example, among the filamentous algæ composed of chains of cells is reproduction among the unicellular species, where divided cells become separate individuals.

* 'Four Categories of Species,' *American Naturalist,* 33:287, April, 1899. The 'species' into which paleontologists arbitrarily divide geological series of organisms may be explainable by evolutionary progress alone, but the multiplication of the contemporaneous species of a given horizon is a different question.

Only among the simplest organisms, if anywhere, is indefinite reproduction possible without the assistance of conjugation.

The new science of cytology has made us aware that the division of cells is not a passive or a simple process, but is extremely active, complex and varied. Living protoplasm is in motion, and the discovery that cell walls are not hermetically closed, but are perforated by delicate protoplasmic strands, lends strength to the belief of some biologists that protoplasm circulates, not only inside the individual cells, but through the entire organism. Conjugation may signify that such a circulation extends also throughout the species. Or, to vary the analogy, the net-like structure of protoplasm may be thought of as continuous, not only in the individual, but as binding together the whole species by the intercrossing of the lines of individual descent. As individual organisms will in different degrees endure subdivision, and are able to restore or regenerate the lost part, so species may survive a certain amount of segregation, but if too small a group of individuals be cut off it perishes through the reproductive debility long recognized as inherent in inbred or narrowly segregated organisms. For taxonomy the tree notion of descent was sufficient as a means of indicating the history and affinities of species and higher groups, but evolution is a process which must be studied inside the species, and here the diagram of relationship is not dentritic, but reticular.

Symbasis a Cause of Evolution.

If reproduction by means of cell-division is reckoned as an essential property of protoplasm, equally fundamental importance can scarcely be denied to the property called symbasis* which requires this interweaving of numerous lines of descent and this simultaneous movement of organisms in specific groups. As organic complexity increases there is greater necessity for cross-breeding, as evidenced by the accentuation of sexual diversity, and by the decline of asexual propagation and of the power of regenerating lost parts. Organisms which have traveled farthest upon the evolutionary journey are most dependent upon symbasis. Nowhere among the higher animals, including many thousands of species of arthropods and vertebrates, is there known to be a long continued series of nonsexual individuals.† In comparison with the

* POPULAR SCIENCE MONTHLY, May, 1903. Symbasis may be defined further as the property of which sexual diversity and cross-fertilization furnish the phenomena. The word may also be used physiologically to signify a normal and advantageous range of interbreeding among the individuals of organic groups. It is to be distinguished on the one side from wide cross-breeding and on the other from narrow inbreeding, both of which produce inferior offspring and interfere with evolutionary progress.

† Among the bees fertilization may be omitted for a single male generation, and among the plant-lice for several wingless generations, but such instances are admittedly exceptional and specialized.

higher animals plants are but loose and unspecialized aggregations of cells, and yet among them also sexual differentiation has made great progress, and in some orders contrivances to insure cross-fertilization are highly developed.

The extent to which conjugation exists among the lower groups is not yet determined. That it may be omitted for many generations of a simple organism should not be taken to mean that it is entirely absent or has no importance, since among the higher animals, where cross-fertilization is recognized as indispensable, the growth of the body to maturity requires millions of cell-divisions, each of which would mean a new generation in a unicellular species. The supposed absence of sexual reproduction in certain parasitic and saprophytic groups is a confirmatory exception, in view of the obvious degeneration of such organisms.*

To the many speculations on the purpose of sex and cross-fertilization it can do no harm to add the conjecture that the presence of moderately diverse qualities of protoplasm facilitates cell-division. Some have held that the function of sex is to assist evolution by producing variations, and others that it neutralizes variation by maintaining a stable average. From the kinetic point of view it appears that symbasis, as represented by the phenomena of sex and of cross-fertilization, is not an impediment to evolution, nor a device to cause variation, but a means of communicating it. Variations appear without sex, and may even be accumulated, as by the adding of one bud variation to another in plants propagated by grafts or by cuttings, like the breadfruit, apple and banana. Such progress is, however, slow and halting, and is accompanied by a decline in reproductive fertility. Symbasis not only sustains the vitality of organisms already evolved, but it is directly responsible for the upbuilding of the complex structure and vital economy of the higher plants and animals, and it builds the faster when by the differentiation of sexes two sets of variations can be accumulated.

To symbasis is due also the arrangement of organisms in the coherent groups called species, or what may be termed the specific constitution of life. Conjugation is the means of symbasis, as division is of reproduction. Sexual and other dimorphism, and the numerous specializations, devices and instincts by which cross-fertilization is secured, are aids to symbasis, just as the spore-sacs, ovaries and placentæ facilitate reproduction. The phenomena of reproduction and those of sym-

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* There is also the possibility that they secure from their hosts protoplasmic compounds of high complexity which serve as a partial substitute for conjugation. It is further to be observed that under a kinetic theory the existence of sexual reproduction and cross-fertilization in many fungi in which these processes are still unknown may be inferred from the simple fact that the individuals are grouped into well defined species.

basis are combined, perhaps inextricably, but all attempts at assigning them to a single cause or property have failed.

Cross-fertilization is commonly misunderstood to be merely an accessory of reproduction, and a negative factor in evolution, because it is supposed to conduce to the permanence of the specific type by averaging away the new characters which arise as individual variations. There is the amplest experimental evidence that cross-breeding is necessary to maintain the quality and efficiency of the individual, but static theories* require us to believe that evolutionary progress requires conditions unfavorable to the individuals of which species are composed, since under such conditions selection is most effective, and abrupt variations are most striking and numerous. The alternative kinetic theory holds that cross-fertilization, as the active agency of symbasis, is a positive and primary factor of evolution, coordinate with variation itself. Symbasis is, as it were, the multiplier of the evolutionary equation, because it compels the distribution and combination of individual variations into the resultant vital motion of the species. Evolution no longer appears as an abnormal or exceptional phenomenon, and it becomes clear that the conditions under which the species is most prosperous are also those which permit the most rapid evolutionary progress.

The Prepotency of Variations.

The first corollary of the law of symbasis is the prepotency of variations. The combination of variations not only permits the structure of the organism to be strengthened and rendered more efficient, but also gives prepotency, due to the opportunity of vital motion. Variant individuals being thus both vigorous and prepotent, it is easy to understand why diversity, and not uniformity, is the tendency of normally extensive species; changes are necessary and welcome, and the perpetuation of them does not require segregation. Numerous and well authen-

*Static theories, under which species are held to be normally stationary, may be subdivided into two groups, those which look upon evolutionary progress as gradual and actuated or carried along by natural selection, and those which treat the motion as discontinuous or saltatory, and due, not to selection, but to abrupt variation or mutation. Selective theories, again, may hold either that the environment causes the desirable variations or 'acquired characters,' or they may imply the notion of a somewhat constant range of variability in species, which are thought of as growing out farther on one side because selection keeps them pared off on the other. Movement is thus ascribed variously to the direct action of the environment, to selective isolation, to abrupt transformation or mutation, or to some combination of these. The kinetic theory rejects all these supposed factors and interprets vital motion as continuous, gradual and self-caused, or inherent in the species, but the environment is thought of as influencing the direction of organic change. Selective influence is neglected altogether by still other theories, such as that of Naegeli, in which evolution is explained by an internal 'hereditary mechanism,' supposed to carry the species along in a definite direction.

ticated instances of distinctly prepotent variations are known, and such were taken by Mivart and other zoologists to prove that species do not originate by gradual change, but abruptly or by 'extraordinary births,' a view quite similar to the recently published 'Theory of Mutations,' but distinctly more practical because the 'mutations' of plants which are the basis of the inferences of Professor De Vries are not prepotent but 'recessive,' presumably because they do not represent true genetic variations, but are symptoms of what may be described as an evolutionary debility, due to inbreeding. The disappearance of mutative characters when the new variations are crossed with the parent form or with each other is merely the recovery, as it were, of the health of the species when the abnormal condition of inbreeding has been removed, as shown so conclusively in Darwin's well-known experiments with pigeons, and confirmed by an abundance of similar facts.

Though differently interpreted, many other facts supporting this view were collected by Darwin, who summarized the results of his studies of *Ipomea, Digitalis, Origanum, Viola, Bartonia, Canna* and the common cabbage and pea, as follows:

"The most important conclusion at which I have arrived is that the mere act of crossing by itself does no good. The good depends on the individuals which are crossed differing slightly in constitution, owing to their progenitors having been subjected during several generations to slightly different conditions, or to what we call in our ignorance spontaneous variations."*

Differences between the plants of different habitats mean also different lines of descent and attendant variations, and the beneficial results of bringing these together may be explained by reference to symbasis rather than to the 'slightly different conditions.'

While it may not be insisted that species, as described and named by systematists, are never originated by 'extraordinary births,' or from 'mutations,' both suppositions are obviously improbable as general explanations. Mutations are seldom fitted to survive because they are less vigorous and less fertile than the parent type, so that they must be segregated at once in order to be preserved. And even prepotent variations have no necessary connection with the origination of species, since however rapidly the characters of a species might change, it would still be the same species until a subdivision had taken place. The more a species evolves the more different from its relatives it becomes, and the more satisfactory for the purposes of systematic study, but this progressive transformation of the 'type' carries with it no necessity for subdivision, nor any indication that evolution is concerned with the origination of species.

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* Darwin, 'The Effects of Cross and Self Fertilization in the Vegetable Kingdom,' p. 27. New York, 1895.

Summary.

Evolutionary study and thought have been hindered by the confusion of two unrelated biological phenomena, (1) evolutionary progress or vital motion, and (2) the origination or multiplication of species. The 'origin' of a species is not more evolutionary than any other stage in its history. The causes of the subdivision of species are not causes of vital motion; the two processes are quite distinct. The separation of two species is not a focus of the evolutionary problem; it is a mere incident of developmental history.

Segregation is the principle or active cause of the multiplication of species, but the nature and causes of evolutionary progress are not to be ascertained by discovering that species originate by subdivision. Vital motion is continuous, and is neither actuated nor interrupted by the segregation which multiplies species.

Natural selection may assist in the segregation of species, but it is not a factor in evolutionary progress, except as it influences the direction of vital motion. Specific groups become diverse when the component individuals no longer share their variations through interbreeding; not because new characters are induced by external influences. Evolutionary divergence may take place under identical conditions, and in characters which have no relation to the environment and no value to the organism except to permit the necessary vital motion.

A stationary heredity or the continued repetition of an identical structural type exists nowhere in nature; variation is an inherent evolutionary property. Segregation is not necessary for the preservation of variations; genetic variations are prepotent and are more rapidly propagated by crossing with the parent form.

A second evolutionary property of organisms is symbasis, which has built up the complex structure of the higher animals and plants by combining individuals into the interbreeding groups called species. The evolutionary species is not a complex of characters or a mere aggregation of similar plants or animals; it is a protoplasmic network held together by the interbreeding of the component individuals. Symbasis accelerates vital motion, but hinders the multiplication of species.

Species and evolution are different aspects of the same fact; evolution goes forward within specific lines as a manifestation of the same property which necessitates the existence of species; variation and cross-fertilization are not antagonistic phenomena, but two phases of the same creative process.

SOME HISTORICAL ASPECTS OF VEGETARIANISM.

By Dr. LAFAYETTE B. MENDEL,

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VEGETARIANISM, as the term is popularly understood at the present time, is a system of living which teaches that the food of man should be derived directly from the plant world. Considered in the light of its history, however, vegetarianism involves something more than a mere dietetic program. It teaches that the use of animal food is morally wrong, as well as erroneous with respect to the processes of nutrition. The modern critics of the vegetarian propaganda have frequently overlooked the fact that this doctrine has repeatedly, if not always, been the expression of an ethical movement among its expounders; and that its development and transformation ought to be considered with reference to sociological, economic and ethical conditions as well as from the standpoint of physiology.

The use of fruits and vegetables as the appropriate food of mankind has found its advocates from earliest times. Pythagoras (500 B. C.) in particular has frequently been pointed out as the most eminent teacher of vegetarianism among the ancients. It is obvious that a philosophy of life which urged men to lead modest lives, to abstain from indulgences of various kinds, and to seek simplicity in every form, might readily and naturally proclaim the desirability of a simple diet. Abstemiousness in the use of food and asceticism in matters of conduct and religion were brought forth by the same attitude toward the problems of the world, and found expression in vegetarianism as a simple mode of nutrition. For the vegetable foods are as a rule easy to obtain and prepare for dietetic purposes. The praise which the earlier moralists bestowed upon the vegetarian diet and mode of living is merely an aspect of the reaction against the excesses of the period. In Rousseau's 'Return to Nature' likewise we find the advocacy of a simple vegetable diet incidental to the proposed change to primitive conditions of living and the striving for moderation in every feature of society. And even to-day vegetarianism is defended by arguments derived from purely ethical and religious, as well as from economic or hygienic considerations. This peculiar sentiment which defends and prescribes the exclusive use of vegetable foods in the struggle against immorality and the attempt to establish a more virtuous community is expressed by Tolstoi in words illustrating how extensively non-physiological considerations are still drawn upon in justifying vegetarianism. He writes: "The individual who endeavors to exercise abstemiousness will unavoidably be obliged to abide by a fixed rule, the first element in which is abstemiousness in eating—fasting. But if he fasts and strives earnestly and zealously to lead a good life, he must, above all things, abstain from animal foods. For aside from the incitement of the passions which is provoked by these foods, it is decidedly improper to partake of them for the reason that they call for a procedure which is revolting to our moral feelings, namely, the act of putting to death."*

It has frequently been pointed out that the apostles of the non-animal diet have been individuals imbued with unusual views of life and the ways of the world. As in earliest times religious motives were the underlying factors in the prescription of rules of living, so in subsequent periods it has usually been some idealistic conception of the problems of existence which determined the vegetarian doctrine of the time. The political dreamer and the philosophical visionary represent types of men in whom the striving for a new order of doing found expression. No period of history has lacked individuals who fail to find in existing systems the Utopia of their dreams. The traits of mind here referred to are exemplified in the poets Byron and Shelley, both of whom the vegetarians have been proud and eager to include within their ranks. It is needless to refer to the eccentricities or the remarkable genius of either. It is well known of the one that his morbid disposition was not infrequently roused and irritated; of the other it has been said that 'his imagination preponderated over judgment and reason.' Some light is perhaps thrown upon the real attitude of the poet in the subject under discussion by the following lines from Shelley's 'Queen Mab' (VIII.):

Here now the human being stands adorning
This loveliest earth, with taintless body and mind;
Blest from his birth with all bland impulses,
Which gently in his bosom wake
All kindly passions and all pure desires.

. . . .

And man, once fleeting o'er the transient scene
Swift as an unremembered vision, stands
Immortal upon earth. No longer now
He slays the lamb that looks him in the face,
And horribly devours his mangled flesh,
Which still avenging nature's broken law,
Kindled all putrid humours in his frame,
All evil passions, and all vain belief,
Hatred, despair, and loathing in his mind,

* Tolstoi: 'Die erste Stufe,' 1892, quoted from Albu: 'Die vegetarische Diät,' 1902.

The germs of misery, death, disease and crime.
No longer now the winged habitants,
That in the woods their sweet lives sing away,
Flee from the form of man, . . .
. . . .
All things are void of terror; man has lost
His terrible prerogative, and stands
An equal amidst equals. Happiness
And science dawn though late upon the earth;
Peace cheers the mind, health renovates the frame.

Lord Byron evidently believed that flesh eating excites men to war and bloodshed; thus he testifies in 'Don Juan' (Canto II.):

That Pasiphae promoted breeding cattle,
To make the Cretans bloodier in battle.

For we all know that English people are
  Fed upon beef—I won't say much of beer
Because 'tis liquor only, and being far
  From this my subject, has no business here:
We know, too, they are very fond of war,
  A pleasure—like all pleasures—rather dear;
So were the Cretans—from which I infer,
That beef and battles both were owing to her.

The beginning of the modern vegetarian movement is usually dated from the publication of an essay entitled: 'Return to nature, or defence of vegetable régime,' by I. Newton (London, 1811). To the influence of this, the formation of the first vegetarian society by Joseph Simpson in Manchester, England, in 1847, is ascribed; and so far as I am aware the word vegetarian was coined at this time. A similar society is reported to have been formed in the United States in 1850. The use of a vegetable diet had, however, been advocated and practised over a century before, as the following extract from Benjamin Franklin's autobiography testifies. Referring to about the year 1722 he said:

When about sixteen years of age, I happened to meet with a book, written by one Tryon, recommending a vegetable diet. I determined to go into it. My brother, being yet unmarried, did not keep house, but boarded himself and his apprentices in another family. My refusing to eat flesh occasioned an inconvenience, and I was frequently chid for my singularity. I made myself acquainted with Tryon's manner of preparing some of his dishes, such as boiling potatoes or rice, making hasty-pudding and a few others, and then proposed to my brother, that if he would give me weekly half the money he paid for my board, I would board myself. He instantly agreed to it, and I presently found that I could save half what he paid me. This was an additional fund for buying of books; but I had another advantage in it. My brother and the rest going from the printing house to their meals, I remained there alone, and, dispatching presently my light repast (which was often no more than a biscuit, or a slice of bread, a handful of raisins, or a tart from the pastry cook's, and a glass of water), had the rest of the time till their return for study; in which I made the greater progress from that greater clearness of head and quicker apprehension, which generally attend temperance in eating and drink-ing. Now it was, that, being on some occasion made ashamed of my ignorance in figures, which I had twice failed learning when at school, I took Crocker's book on Arithmetic, and went through the whole by myself with the greatest ease. (Sparks's 'Life of Franklin,' p. 19).

The early literature of the vegetarian movement in this country indicates a greater tendency toward the substitution of arguments based on scientific observation in place of purely sentimental considerations than do the trans-Atlantic publications of similar date. It must not be inferred from this statement, however, that visionary and unscientific doctrines were wanting. Evidence to the contrary is readily available. In 1833 the Boylston Medical Committee of Harvard University offered a prize for the best dissertation on the following question: 'What diet can be selected which will ensure the greatest probable health and strength to the laborer in the climate of New England? quantity and quality, and the time and manner of taking it, to be considered.' The prize was awarded to Dr. Luther V. Bell, whose essay (1836) may still be read with interest. The status of the propaganda against flesh-eating as summarized by him is quoted here, since it indicates how similar have been the personal characteristics and motives of the vegetarian advocates in the most widely separated localities. Bell wrote:

Some extraordinary, and to the unprofessional class, doubtless novel, views in regard to diet were broached and have since been pressed upon attention, and that too by at least some men of scientific reputation, ingenious lecturers and individuals who from weight of personal character, or their position before the public, possess no limited influence. They have persuaded themselves, and labored hard to proselyte to their own faith, that the use of animal food in all its forms and varieties, is a custom, unnatural, injurious to bodily health, and even prejudicial to intellectual and moral sanity;—a custom at once unnecessary and inexpedient. How far, or how durably, they may have impressed the public with their views, time only can show; at present it need only be said, that such effect has at least been produced, as to raise a laudable curiosity and wish for the truth, in the minds of many, deserving to be gratified.

Bell adds the following interesting remarks:

Their views are by no means new or original. They date their origin at least as far back as the ancients, and they have been received in every century from the time of Pythagoras to the days of the philosopher of Geneva (Rousseau). "It is not intended to deny the right of ingenious men to propose innovations, and it is a fortunate circumstance that the public is as much too slow in coming into a practical acknowledgment of new truths, as men of erratic and visionary genius are too sanguine in promulgating and inculcating new hypotheses. It is dangerous to unsettle long established truth, for it is difficult to limit the extent of error. The gratification of a morbid desire to be distinguished as the propagator of new principles in philosophy, or as the head of a new sect, is not the only result to be expected from such heresies. New opinions or doctrines, whether true or false, will have admirers and followers, and will lead to practical results, and the errors of one man may lead thousands into the same vortex." (Bell, 'A dissertation on the Boylston prize question for 1835,' pp. 6–7.)

The conclusions to which Bell's study led him are worthy of brief mention. He summarized as follows:

1. A diet of *both* animal and vegetable food is adapted to the condition of the New England laborer.

2. No grand errors exist in his present system of diet, and no radical change is demanded to ensure a greater amount of health and strength, though many minor, but still important errors exist.

3. The proportion of animal food usually customary is too great, and a considerable reduction would be expedient and advantageous, though it is impracticable to make a precise statement of the extent to which this is required, which must depend upon circumstances, as amount of labor performed, climate, season, bodily constitution, habits of life, etc. A general statement of this fact can alone be made.

4. The amount of food in general, customarily used, is more than is necessary for the maximum of health and strength, though a more specific statement of this abuse is also impossible. It must be left for each individual to attempt to reduce his quantity of food to that point at which he finds his mental and bodily powers most energetic. In searching for this point the New Englander may be almost certain that he must look for it in descending ratio.

5. The great principle in regulating diet is to regard quantity rather than kind.

Most students of dietetics will, I think, readily admit the validity of the majority of these statements, even in their application at the present day. In contrasting the conditions during colonial days with those prevailing in our own times it is entertaining, if nothing more, to recall some ideas regarding the diet of the people of the United States at the end of the eighteenth century which were published by the French traveler Volney.* A grain of truth may doubtless be gathered from his vivid observations, even though they can not be taken too seriously. Thus he writes:

I will venture to say that if a prize were proposed for the scheme of a regimen most calculated to injure the stomach, the teeth, and the health in general, no better could be invented than that of Americans. In the morning at breakfast, they deluge their stomach with a quart of hot water, impregnated with tea, or slightly so with coffee; that is, mere colored water, and they swallow, almost without chewing, hot bread, half baked toast soaked in butter, cheese of the fattest kind, slices of salt or hung beef, ham, etc., all of which are nearly insoluble. At dinner, they have boiled pastes under the name of puddings, and the fattest are esteemed the most delicious; all their sauces, even for roasted beef, are melted butter; their turnips and potatoes swim in lard, butter or fat; under the name of pie or pumpkin (pumpkin pie?) their pastry is nothing but a greasy paste, never sufficiently baked; to digest these substances they take tea almost instantly after dinner, making it so strong that it is absolutely bitter to the taste, in which state it affects the nerves so powerfully that even the English find it brings on more obstinate restlessness than coffee. Supper again introduces salt meats or oysters: as Chastelux says, the whole day passes in heaping indigestions on one another; and to give tone to the poor relaxed and wearied stomach, they drink Madeira rum, French

* 'View of the climate and soil of the U. S. of America,' by C. F. Volney.

brandy, gin or malt spirits, which complete the ruin of the nervous system. (Quoted by Bell, pp. 23–24.)

The vegetable diet found an enthusiastic champion in America in the person of Dr. W. A. Alcott, who published a small volume on the subject in 1838. In the preface he tells us: "When I commenced putting together the materials of this little treatise on diet it was my intention simply to show the SAFETY of a vegetable and fruit diet, both for those who are afflicted with many forms of chronic disease, and for the healthy. But I soon became convinced that I ought to go farther, and prove its SUPERIORITY over every other." This the author attempted to do by an appeal to contemporary medical men and by a compilation of the 'anatomical, the physiological, the medical, the political, the economical, the experimental and the moral arguments' then prevalent. But the individual who probably did more than any other in this country to reduce the subject of vegetable dietetics to a system was Sylvester Graham. This eccentric reformer, remembered to-day in connection with the bread which familiarly bears his name, was an enthusiastic temperance advocate, who insisted that the craving for drink can only be combated by the use of a judicious diet in connection with correct habits of living. His belief that 'an exclusively farinaceous and fruit diet is best adapted to the development and improvement of all powers of body, mind and soul' was set forth for many years both in public lectures and in writings, among which the 'Graham Lectures on the Science of Human Life' (2 vols., 1839) were perhaps most widely quoted in vegetarian literature. About 1837 there was formed an American Physiological Society of two hundred members, nearly all of whom, as well as their families, abstained from animal food. (Cf. Alcott, 'Vegetable Diet,' p. 219.)

The characteristic features of the vegetarian movement in England are set forth in the 'Constitution of the Vegetarian Society of Manchester,' to which reference has already been made. The objects were:

To induce habits of Abstinence from the Flesh of Animals as Food, by the dissemination of information upon the subject, by means of tracts, essays and lectures, proving the many advantages of a physical, intellectual and moral character, resulting from *Vegetarian habits of Diet;* and thus, to secure, through the association, example and efforts of its members, the adoption of a principle which will tend essentially to true civilization, to universal brotherhood, and to the increase of human happiness generally.

As early as 1829 there existed in England a 'Society of Bible Christians,' of which a member wrote as follows:

The Society of Bible Christians abstain from animal food, not only in obedience to the Divine command, but because it is an observance which, if more generally adopted, would prevent much cruelty, luxury and disease, besides many other evils which cause misery in Society. It would be productive of much good, by promoting health, long life, and happiness, and thus be a most effectual means of reforming mankind. It would entirely abolish that greatest of curses, *war;* for those who are so conscientious as not to kill animals, will never murder human beings. On all these accounts the system can not be too much recommended. The practice of abstaining can not be wrong; it must therefore be some consolation to be on the side of duty. If we err, we err on the sure side: it is innocent; it is infinitely better authorized and more nearly associated with religion, virtue and humanity than the contrary practice. (Cf. Alcott, pp. 214–215.)

One more quotation must suffice to indicate the spirit of the early modern vegetarian literature. Its author was J. A. Gleïzès, an eccentric writer of several volumes, who became a favorite of the Vegetarian Society. In the preface to 'Thalysie, ou la nouvelle existence' (3 vols., 1840–1842) he wrote:

Je me propose d'y démonstrer:

1°. Que l'homme n'est point animal de proie; qu'il est, au contraire, par sa nature, la plus douce de toutes les créatures, ainsi que devait l'être la dernière et la plus noble expression d'un Dieu grand, bon et juste.

2°. Que le meurtre des animaux est la principale source de ses erreurs et de ses crimes, comme l'usage de se nourrir de leur chair est la cause prochaine de sa laideur, de ses maladies, et de la court durée de son existence.

3°. Que cet état d'égarement est dans une opposition directe avec sa destinée ultérieure dans le sens communément attaché à ce mot, autrement dit, la vie hors de la terre; tandis que la privation de cet acte, ou, pour parler positif, le régime des herbes, développe en lui la beauté l'intelligence, la vertu, et le fruit immortel qui en est le dernier résultat.

It is unnecessary to multiply examples in order to emphasize how diverse have been the actuating impulses of the vegetarians of history. Like England and America, Germany has had its vegetarian movement which developed particularly under the leadership of Ed. Baltzer. The first German vegetarian society was founded by him in 1869. Here, as elsewhere, the system proposed has never received broad recognition among the masses of the people, but has rather been confined to small bands of enthusiasts. Even among the latter there is no unanimity of plan. The most radical reformers have abstained not alone from all food of animal origin, but also from tubers and underground roots, eating only fruits and vegetables grown in the sunlight; others again reject the cereals and live on fruits, nuts and milk; while the most conservative exclude only fish, flesh and fowl from their diet. Among the latter groups may be arranged the so-called fruitarians who abstain from all food obtained by infliction of pain. The student of the psychology of the vegetarian faith can not fail to be impressed by the diversity of the elements which have convinced its expounders. Physiological and anatomical arguments based on the comparative structure and functions of the digestive organs have vied with considerations of economy, morality and religion. From the standpoint of hygiene, the dangers of disease lurking in animal flesh have been pointed out; to other persons the encouragement of horticulture and the racial improvement incidental to an active agricultural life have offered an attractive theme. The vegetable kingdom can satisfy all. "If any vegetarians be extravagant in milk and eggs, it is not from any craving of their stomachs, but from excess in zeal or ignorance in their cooks." (Newman, *Frazer's Magazine*, February, 1875.) Finally the Bible itself has been drawn upon to furnish lasting proof: "Behold, I have given you every herb bearing seed, which is upon the face of all the earth, and every tree, in the which is the fruit of a tree yielding seed; to you it shall be for meat." (Genesis, i., 29.)

The advocates of the vegetarian diet at the present day are no less ready to draw upon the diverse types of argument already discussed than were their predecessors of fifty years ago. In a recent volume, entitled 'The Living Temple' (1903), Dr. J. H. Kellogg, urging the use of non-meat diet, has presented the ethics of flesh-eating in the following light:

> The basis for the ethical argument against flesh-eating is to be found in the fact that the lower animals are, in common with man, sentient creatures. We have somehow become accustomed to think of our inferior brethren, the members of the lower orders of the animal kingdom, as things; . . . We are wrong in this; they are not things, but *beings*. . . . A horse or a cow can learn, remember, love, hate, mourn, rejoice, and suffer, as human beings do. Its sphere of life is certainly not so great as man's, but life is not the less real and not the less precious to it; and the fact that the quadruped has little is not a good and sufficient reason why the biped, who has much, should deprive his brother of the little that he hath. For the most part it must be said that the lower animals have adhered far more closely to the divine order established for them than has man.
>
> The divine order, as clearly shown by nature as well as by revelation, and by the traditions of the ancient world, and illustrated by the present practice of a great part of the human race makes the vegetable world the means of gathering and storing energy and making it into forms usable by the sentient beings that compose the animal world, the one gathering and storing that the other may expend. When animal eats vegetable, there is no pain, no sorrow, no sadness, no robbery, no deprivation of happiness. No eyes forever shut to the sunlight they were made to see, no ears closed to the sweet melodies they were made to hear, no simple delights denied to the beings that God made to enjoy life—the same life that He gave to his human children. (Pp. 184–185.)

On the other hand, we may recall Robert Louis Stevenson's apparent defense of cannibalism among some of the peoples inhabiting the South Sea Islands. He writes:

> How shall we account for the universality of the practice over so vast an area, among people of such varying civilization, and, with whatever intermixture, of such different blood? What circumstance is common to them all, but that they lived on islands destitute, or very nearly so, of animal food? I can never find it in my appetite that man was meant to live on vegetables only. When our stores ran low among the islands, I grew too weary for the recurrent day when economy allowed us to open another tin of miserable mutton. And in at least one ocean language, a particular word denotes that a man is

'hungry for fish,' having reached that stage when vegetables can no longer satisfy, and his soul, like those of the Hebrews in the desert, begins to lust after the flesh-pots. ('In the South Seas,' Chapter XI.)

How differently the experiences of mankind appeal to different individuals! We oppress the living, yet shrink from barbarities toward the dead; we condemn in others the very practises which at times have applied to ourselves. Individual bias is so common among the great masses of people that it is rare to find impersonal judgments in things ethical or religious. But ideas which claim exemption from scientific control can never demand recognition by force of argument alone. 'There is no short cut to truth except through the gateway of scientific method.' The doctrines of the vegetarians have not escaped the attacks of scientific criticism; with what success they have met, this paper is not intended to proclaim. It has aimed merely to point out some little known historical aspects of a movement which is unique, if not progressive. A position so long and stubbornly held can not be entirely devoid of some resources, and may well offer an occasional helpful suggestion for the improvement of our plans of nutrition. By the physician and hygienist especially is real progress in dietetics to be welcomed. *Qui bene nutruit, optime medebitur.*

TOKYO TEIKOKU DAIGAKU (IMPERIAL UNIVERSITY OF TOKYO).

By NAOHIDÉ YATSU, RIGAKUSHI,
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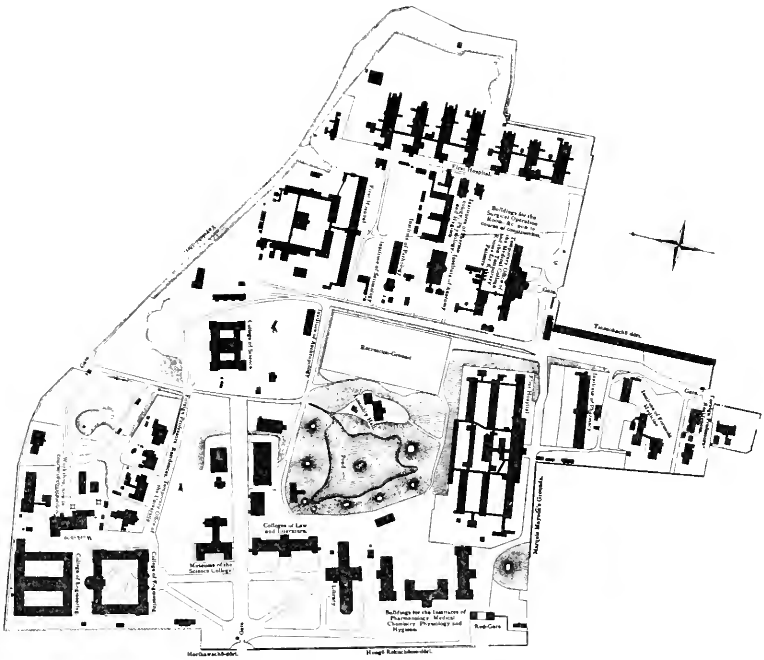
IN the recent outburst of literature upon Japan and things Japanese, one can not help feeling as he surveys the field that the European has but a scanty idea of the opportunities which the young Japanese enjoys for securing a thorough grounding in the learning of western nations. The average American or European is apt to think, that, aside from military and naval matters, the Japanese education of to-day is largely, if not exclusively, an Asiatic one. It may, therefore, be of interest to refer to the organization of the higher education

AKAMON, (ENTRANCE GATE TO IMPERIAL UNIVERSITY) TOKYO.

in Japan as it is being carried out at the present day. In this connection, I think, I may safely say that few foreigners realize the anxious care with which during the past score of years the emperor and his advisers have established the higher education of Japan on a basis as broad as that of the European universities, and at the same time, have aimed to mold in it the best elements of learning of both the west and east. And if this is not understood, still fewer foreigners realize, I think, the extent and character of the less modern form of education in Japan. Indeed, on the other hand, according to some recent writer, one might even fancy that Japan had no true learning before the advent of the 'black ships' of Commodore Perry. It may be of interest, therefore, to some, to learn that in so remote a time as in the eighth century a university had already been established in Japan that included such modern divisions as schools of medicine, ethics, mathematics, history, and that some of the text-books employed at that remote period dealt with such subjects as the diseases of women, *materia*



GROUND PLAN OF THE UNIVERSITY.

medica and veterinary surgery, types of text-books which appear to have been unknown in European countries until about one thousand years later.

Japanese higher education at the present day includes: (1) *high schools,* of somewhat higher scope than the American high schools, (2) *higher normal schools* for both sexes, (3) *colleges of peers and peeresses,* (4) *military and naval colleges* at Tokyo and Etajima, (5) a series of *schools of technology and arts,* including an *academy of music,* (6) *colleges of law, politics and literature* in Tokyo and Kyoto, (7) *girls' university of Tokyo* and (8) *Imperial Universities* of Tokyo and of Kyoto.

As the universities stand at the head of the educational system of Japan, it may be well to describe their organization in some detail. And I shall refer especially to the Tokyo Imperial University since the second one is only recently founded (1897).

The university is strictly governmental and is under the control of the Department of Education, one of the main divisions of the imperial administration. It includes six colleges—law, medicine, engineering, literature, science and agriculture. In general, its students are the graduates of high schools and are enrolled in a three-year course, medicine and law requiring, however, four years. It may be safely said that the grade of the regular work of the university is higher than that of the American colleges, for I find that the courses which are set down in the curricula of many colleges for freshmen and sophomore classes are given in the Japanese high school. One may further note that in the interest of general higher education the university courses are practically free. And as evidence of the democracy of learning one may sometimes note a young noble sitting shoulder to

COLLEGES OF LAW & LITERATURE, TOKYO.

shoulder with the son of a peasant. It goes almost without saying that every university student is expected to understand lectures when given in one of the European languages.

With this introduction we may briefly refer to the development of our university. Between the end of the sixteenth century and the beginning of the eighteenth century young Japanese who had been thirsting for western learning began their study of medicine, astronomy, physics, chemistry, gunnery, fortification, by the aid of textbooks, mainly written in Dutch, which they had obtained, often in spite of much local disfavor, from the trading station at Nagasaki. Succeeding in their western studies, some of these Japanese workers opened schools at several places for the dissemination of their hard-earned knowledge. And one of these schools, named *Bansho-shirabejo* (the place for the examination of the writings of the barbarians).

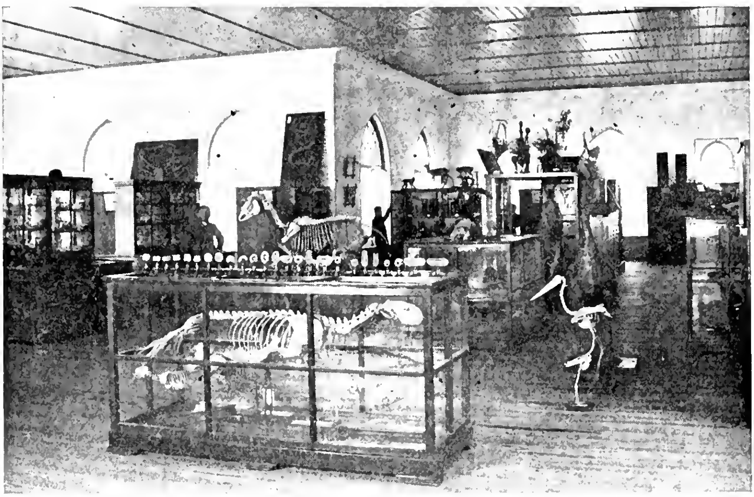
was the embryo of our university. After the Restoration of 1868 this school, through many changes, became *Kaisei-gakko*. And to this was later added the medical college (1877), the law college (1885) and the college of engineering (1886). It was not, however, until March 1, 1886, that the university came actually into existence, a day which has come to be celebrated every year as 'foundation day.' In 1884–85 the colleges moved to their present site. To this end the university was ceded a park, three square miles in extent, located on a side of Hongo hill, in the northwestern part of Tokyo. The site, moreover, was of considerable historic interest, since it was the Kaga-Yashiki, or the palace grounds of Kagasama, one of the most powerful daimyos of feudal days, whose imposing processions of two-sworded retainers,

INSTITUTES OF PHYSICS AND CHEMISTRY.

gold-laquered palanquins, and splendid horses are remembered to the present day. Indeed, the present red gate of the university is a relic of his feudal sway, his wedding gift, it is said, from the Prince of Satsuma. In contrast with former pageants one sees here to-day only a stream of students plain in uniform and with square caps, hurrying to and fro among the lecture halls. When the colleges first moved to the present site, wooden buildings were used for lecture-room and laboratories. But as time passed these were replaced by the brick buildings, which are shown in the adjacent pictures. The college of agriculture is situated in a suburb six miles away from the university. The Botanical Institute is in the Botanical Garden, situated in another daimyo's park, about a mile and a half away from the university.

The entire staff of the six colleges numbers about 270, of these 120 hold the rank of professor. It is significant of the progress of the Japanese in western learning that even in special branches of work few foreign instructors are now required. In earlier days the majority of the professors were foreigners, to-day their number has been reduced

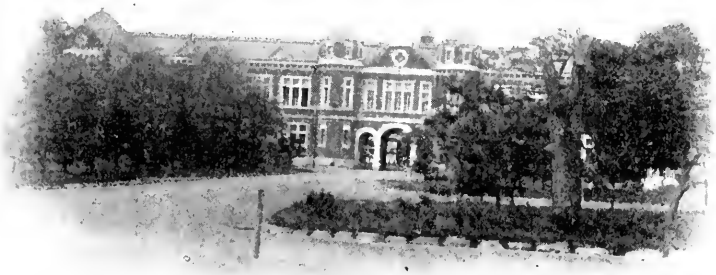
Institutes of Zoology and Geology.



Interior of the Zoological Museum.

to fourteen, and this number bids fair to be reduced as soon as able graduates return from their foreign studies to take their places. It follows, accordingly, that lectures are more and more frequently given in the Japanese language. It may be noted that in the science college there remain no foreign professors.

The present catalogue shows an enrolment of 3,121 students, and of these about 350 are post-graduates in the 'University Hall.' Every student must wear a square cap with golden badge of the university. And the 'square caps,' as they are called, are entitled to special consideration from the general public. The graduates are termed 'Gakushi,' to which title is added the prefix of their college, as Ho-



Tokyo, COLLEGE OF ENGINEERING

gakushi (law), Bun-gakushi (literature), I-gakushi (medicine), Rigakushi (science), etc.

The title 'Hakushi,' corresponding somewhat with Ph.D., is given to those who have been in the 'University Hall' (post-graduate) and passed prescribed examination, or to those who have attained similar distinction, especially in research.

The commencement usually takes place on July 11. It may be of interest to describe the ceremony, since it differs somewhat from that of American colleges. The large reading hall of the library is simply decorated; purple and white silk drape the walls, and in the place of honor hang portraits of the emperor and empress. The room is closely filled, students standing massed in military order in the middle of the room, professors and guests standing at the sides. Then the ceremony commences by the president's recital of the words of the emperor on the principles of ethics and on the education of his subjects. Then follows a brief address by the emperor, or by one of the imperial family. And after this has been made the emperor's gracious presents, about twenty in all, are given to the best graduates. Then the president gives an address. The national anthem 'kimigayo' is then sung three times, followed by the cries of 'Tokyo-Teikoku Daigaku Banzai.' The entire ceremony is a simple one, but it is notably solemn and impressive.

Even athletics are not wanting in this eastern university. The athletic club consists of seven sections—rowing, track athletics, baseball, football, lawn tennis, swimming, Judo (a kind of wrestling), fencing and archery. In the spring, when the rosy cloud of cherry blossoms covers the bank of the River Sumida, the rowing club holds a regatta. In the autumn the athletic section holds a meeting in the recreation ground of the university. Running, jumping, hurdle races, etc., last the whole afternoon, and the scene is as animated as even a Yale-Princeton 'rooter' could wish; the sloping hillside of the arena-like ground is filled with cheering crowds, and the mingling of costumes, colors and gestures add to the animation of the scene. In the matter of supplemental athletics, we may note that swimming is given a conspicuous place; a teacher even takes volunteer students under his charge during the summer vacation.

As a special development in the research work of the university one might briefly mention the laboratory for the study of earthquakes, which occur so frequently, and often, indeed, with dangerous results. And it was with the aim of studying these phenomena, from standpoints both of applied and of pure science, that the seismological observatory was founded in 1880. It has since been in charge of Professors Sekiya and Omoiri. In fact it is due to the researches of these scientists that the horizontal pendulum and the vertical motion seismographs were designed. By means of these delicate instruments it is possible to measure earthquakes and other earth movements of different grades of magnitude, ranging from microscopic tremors and pulsations up to destructive earthquakes. The instruments are so sensitive that an earthquake in England can be recorded in Japan, and from this the rate of traveling of seismic waves has been calculated. There has also been set up recently a horizontal pendulum for continuous registrations. These are an interesting collection, showing the development of seismographs from crude Chinese devices to the most elaborate and modern apparatus.

In the zoological museum there are the splendid collections of the glassy sponges. Hundreds of valuable specimens have been collected through Professor Ijima's constant and earnest exploration of the Sagami Bay. They are so fragile that they might easily be crumbled into pieces by the fisherman's rough hands. One may easily conceive how still is the abyss of 200 fathoms. The first two parts of beautiful monographs have come from the hands of Professor Ijima, who has been working on these delicate creatures for over ten years. Besides this collection, there are hundreds of curious creatures peculiar to Japan, rare specimens which arouse the enthusiasm and possibly even the envy of our foreign confrères. Indeed, every year forms which are new to science come to the museum. In connection with the science college, I should also mention a marine biological station at Misaki. At this point, about thirty miles south of Tokyo, the warm 'black current' comes frequently close to the land and brings to the station interesting pelagic forms, especially the minute floating 'plankton.'

In anthropological lines Professor Tsuboi and his assistant have been many years engaging in the study of the Japanese races, past and present, including the exploration of Ainu, Formosan aborigines and the investigations of the prehistoric Japanese race. And in connection with his laboratory we may mention the rich anthropological cabinet.

In summary, accordingly, I think that it can safely be claimed that Japan has made studies not less in higher education than in matters of military, naval or practical importance, and that its work is progressing satisfactorily in quantity, no less than in quality. The Tokyo Imperial University, as we have seen, is not more than twenty-five years old, yet it has become the largest educational institution of the far east. Its graduates already number about 6,000, and of these alumni many are now filling posts of importance as professors, scientists, jurists, physicians, statesmen, diplomats, and one can predict with reasonable certainty that many of the best supporters of the future Greater Nippon and its emperor will have worn the square cap as they passed under the red gate of our alma mater.

THE PROGRESS OF SCIENCE.

IMMANUEL KANT.

The centenary of the death of Kant was commemorated on February 12. There was a special celebration at Königsberg, where the philosopher spent his whole life; a monument is planned for Berlin, and a Kant Society has been formed in Germany. It would probably be difficult for most readers of a scientific journal to explain why Kant is one of the great men of the world, and next to Aristotle the most honored philosopher. In the preface to his 'Kritik der reinen Vernunft' Kant expressed his own view of the service he hoped to accomplish in the following words: "In metaphysical speculation it has always been assumed that all our knowledge must conform to objects; but all attempts from this point of view to extend our knowledge of objects *a priori* by means of conception have ended in failure. It is well to ask, therefore, whether greater progress may not be made by supposing that objects must conform to our knowledge. This would clearly agree better with the desired possibility of such an *a priori* knowledge of objects that could establish something about them before they are presented. Our suggestion is similar to that of Copernicus in astronomy, who, finding it impossible to explain the movements of the heavenly bodies on the supposition that they turned round the spectator, tried whether he might not succeed better by supposing the spectator to revolve and the stars to remain at rest. Let us make a similar experiment in metaphysics with perception."

Kant's rather remarkable lack of appreciation of the work of his predecessors led him to emphasize unduly the novelty of his own point of view. Yet subsequent philosophers have tended quite generally to regard him as its most representative exponent. And he forced the issue with such energy as to make himself the most prominent figure in the philosophy of the last century. He asserted repeatedly that we do possess knowledge of objects which is universal and necessary, and he asserted with no less frequency that in all such cases our knowledge has not conformed to objects, but objects have conformed to the necessities of thought. Just because we find that we *must* think of objects in a certain way, we must admit that this necessity springs from thought itself. In spite of the fact that this assumption is far from self-evident, Kant succeeded in imposing it upon his time with remarkable success. The philosophy of the nineteenth century witnessed as a result many noteworthy attempts to determine what reality must be by reference to the necessities of thought alone. The absurdities of Schelling and the subtleties of Hegel mark, perhaps, the extremes of this tendency.

But the significance of Kant is not seen only in this new inspiration given to the attempt to determine, not what reality is, but what it *must* be. For his philosophy had its negative side, which contained an equally important emphasis. Just because what we must think is due to the necessities of thought, we have no right, he urged, to extend the results of such thinking beyond thought itself and so pass to things as they are. Exterior to thought, beyond its controlling influence, they escape us utterly. The significance of this important limitation Kant exhibited most crucially when he criticized all attempts of speculative thinking to establish the existence of God, freedom and immortality, the three things with which, as he viewed it, metaphysics is most concerned. Here thought finds itself completely baffled and confronted by contradictory possibilities for which there appears equally valid evidence. Thus metaphysics would appear to be an impossible science—a result in strange contrast with the successive systems of metaphysics which the positive aspect of his work called into being. Kant remained stubbornly true to his conviction that the necessities of thought set their own impassable limits. Agnosticism has thus found him an able support, and Heine could say of the 'Kritik,' 'This book is the sword with which, in Germany, theism was decapitated.'

IMMANUEL KANT.

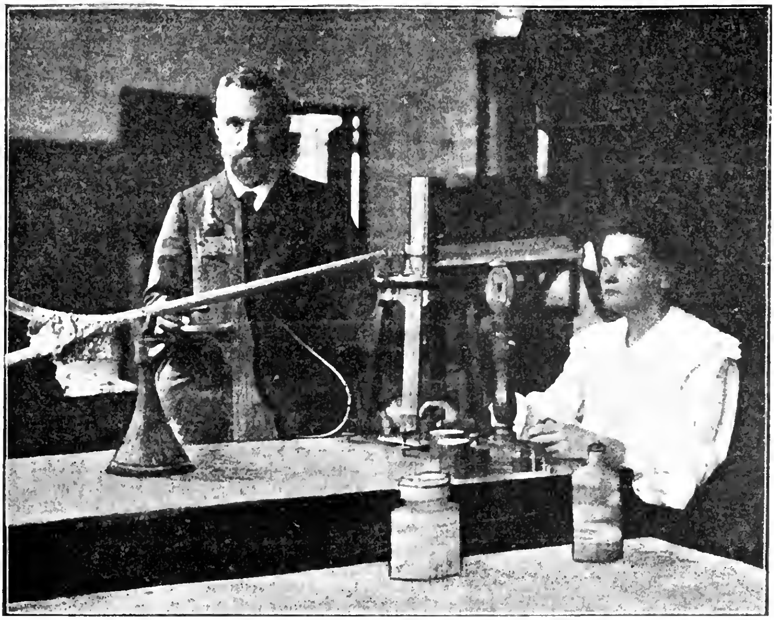
Kant, however, would find in practical life and particularly in moral life a way of transcending the limits of speculative thinking. In his writings on morality and religion he claims that the necessities of practise have also a determining influence on the content of philosophy. Man's morality presupposes as conditions necessary to its existence the very things—God, freedom and immortality—which man's reason can not attain, and the existence of morality itself becomes, therefore, the guarantee of their existence. Practise thus gives what speculation fails to give. So after all the theologian could take courage from the Kantian philosophy, and the pragmatism of to-day could find a basis in the searching criticism of the Königsberg professor.

The significance of Kant for modern philosophy has thus been wide and varied. He has been at once an inspiration and a check to free speculation, and also a source of renewed progress in moral and religious inquiry. Yet, it must be admitted that his importance has waned considerably in recent years. His central idea that there are necessities of thought and practise which of themselves significantly determine the content of our knowledge and belief has come to lack its authoritative tone. This has been brought about not so much by direct refutation as by the steady advance in stability of scientific knowledge, which insists that we can be really compelled only by the exigencies of the things with which we deal. Kant in his early years was no mean scientist. Indeed he thought that his philosophy could give to science its only stable basis and its only correct interpretation. The result is in striking contrast with his conviction.

RECENT PROGRESS IN THE STUDY OF RADIOACTIVITY.

The dream of the alchemists had without doubt a strong philosophical foundation, and although the desire to accomplish transmutations of the elements has lost all power as an incentive to the study of natural phenomena, one can not help noticing the small amount of reverence modern physics has for the identity of the atom of a chemical element. The electronic theory of matter, well set forth by Sir Oliver Lodge in his Romanes lecture at Oxford, which was published in this magazine last August, holds that there is no more difference between the atoms of the different elements than between houses of different shapes and sizes, but built of the same kind of bricks, the little electrons being the bricks of which the atoms are built, although the structure of an atom is more like that of a planetary system than that of a house. Confidence in the stability of this structure in the case of ordinary atoms has not been shown to be misplaced, but in the case of the radioactive substances—elements they are by the usual tests—evidence of atomic disintegration continues to accumulate. Their radiations consist chiefly of projected particles, far smaller than the atoms of the radioactive elements, and, as Professor Rutherford and Mr. Soddy have shown, the radioactive matter passes successively through a series of unstable forms. The final product of this atomic disintegration must be stable and therefore not radioactive, and since the gas helium is found in all radioactive minerals it is suggested that helium is one of the stable residues left by the heavy and unstable radioactive atoms.

During the past summer Professor Ramsay, the discoverer of terrestrial helium, and Mr. Soddy followed up this suggestion with experiments and came to the conclusion that helium is continuously produced by radium. The experiments consisted in examining in a spark tube the spectrum of the radioactive gas, or emanation, given on dissolving in water fifty milligrams of nearly pure radium bromide that had been in the solid state for some time. This radioactive gas is not stable, but decays in a geometrical progression with the time, the rate being about half in four days. Of course the most careful precautions were taken to free the spark tube from foreign gases, especially hydrogen, oxygen and carbon dioxide. When first prepared the tube gave a new and hitherto unknown spectrum, probably that of the radioactive gas. After four days the lines of the helium spectrum began to appear, growing brighter for several days, while the new spectrum observed at first disappeared. The supposition is that the helium is the product of the atomic decomposition of the radioactive gas. It may be argued that the experiments only prove that radium is not an element, but only a compound of staple elements. On the other hand, the production of this radioactive gas is not influenced by changes of temperature, which is true of no chemical process, and is accompanied by radioactivity, which is not a phenomenon of chemical changes.

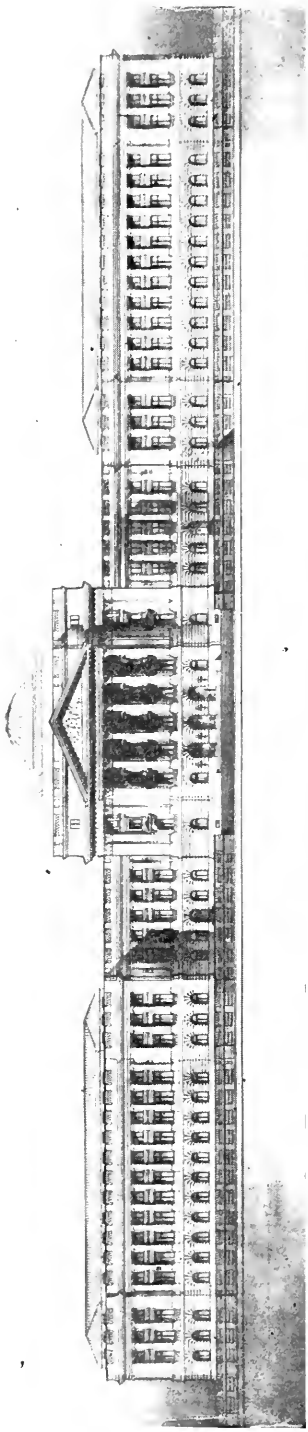


M. AND MME. CURIE IN THEIR LABORATORY.

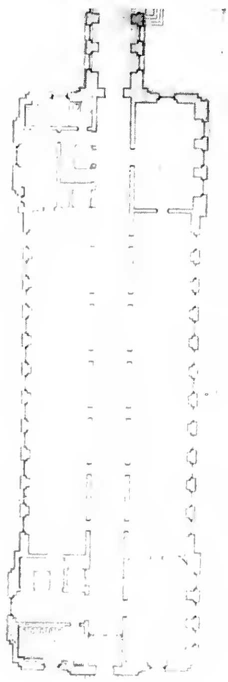
The wide distribution of radioactive matter has been brought to light by the work of Professors Elster and Geitel in Germany on the radioactivity of the atmosphere and soils, and by a number of observers under the leadership of Professor J. J. Thomson on the presence of a radioactive gas in many spring and well waters. Elster and Geitel discovered that clay is much more active than other soils, apparently from the presence of a trace of radium, though much depends on the locality. A certain clay which they examined contained one eleven-hundredth as much radium as pitchblende, the ore from which radium is extracted. Radium salts are found to give off heat at a very considerable rate. M. Curie estimates that radium can melt its weight of ice in an hour. A more exact investigation by Rutherford and Barnes shows that the radioactive gas and the secondary activity are the chief sources of the heating effect.

The treatment of certain diseases, particularly of cancer and lupus, by means of radium radiation continues to attract much attention from physicians both in this country and in Europe. A committee appointed by the Vienna Academy of Science to investigate the results of the treatment of cancer with radium reported that in nine cases in which the treatment was used abatement in the cancerous swelling resulted and in two of these cases the swelling had not reappeared after five months' time. A case of cancer of the palate was much improved by the treatment. The use of radium is not recommended when an operation is practicable. Numerous other cases of the beneficial results of the radium treatment have been reported in this country and England.

More exact measurements by other observers corroborate the conclusion of Rutherford that the radiations from radium which are the least penetrating of the three types present, but represent the greater part of the energy, consist of positively charged particles of about twice the mass of the hydrogen atom, and moving with a velocity about one tenth that of light.

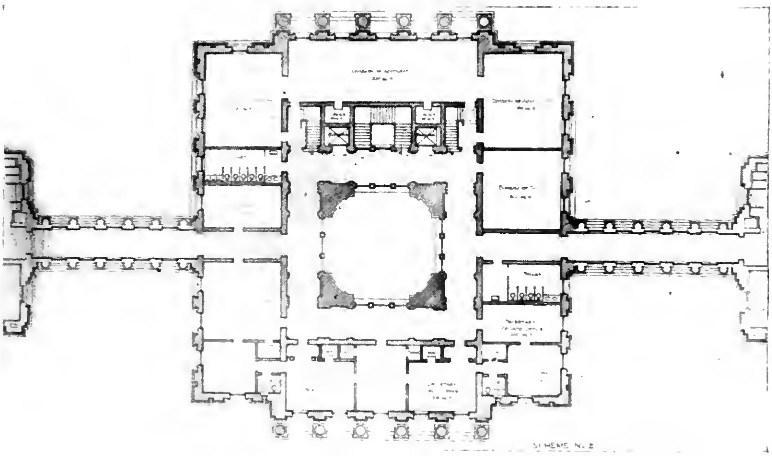


New Building of the U. S. Department of Agriculture, South Elevation, Facing on Proposed Mall.



Laboratories, Plan of First Floor.

The supply of radium on the market is very uncertain. All of it is imported from France or Germany, and the price has recently been going higher. Many efforts are being made to extract radium in this country from carnotite, an ore of uranium that is found in considerable abundance in Colorado and



ADMINISTRATION BUILDING. PLAN OF SECOND FLOOR.

Utah. These efforts have met with some degree of success, but radium from carnotite is not yet on the market.

NEW BUILDINGS FOR THE DEPARTMENT OF AGRICULTURE AT WASHINGTON.

The plans for the new buildings for the National Department of Agriculture contemplate a group of ten buildings, arranged in the form of a quadrangle, with an administration building as the central feature. The nine laboratory buildings will be units, and will be connected with the administration building by covered corridors. They will be 60 by 200 feet each in size and 4 stories in height above a high, well-lighted basement. The administration building will be about 135 by 160 feet and 5 stories high. The latter, with a laboratory building on either side, will present an imposing front of 700 feet, which will face south on the broad parkway planned to extend from the Capitol to the Washington Monument.

The appropriation of $1,500,000 made by congress will provide for the erection of three laboratory buildings, leaving the administration building and the others to be provided for later. As the new site is some distance removed from the site of the present buildings, the latter can remain in use in the meantime. The three new buildings will provide accommodations for the laboratories and offices of the department now occupying rented buildings, as was directed by congress.

The buildings will be classic in design and will probably be built of marble. The construction will be of the most substantial character, with thick walls carrying heating and ventilating flues. The interior space will be divided into units 20 by 20 feet, and each unit will have access to a conduit furnishing water, steam, gas, electricity, air pressure and exhaust. The actual arrangement of the laboratories has not yet been settled, nor has it been definitely decided which three of the laboratory buildings will be erected now.

The department is now occupying very inadequate and in many cases temporary quarters, and is paying an annual rental of about $25,000 for buildings located outside the department grounds. Its main building was long since condemned and is in no sense a modern structure. The staff of the department at the time it was erected included less than 100 persons; the present enrollment is about 4,200 persons. A group of buildings in keeping with the dignity and importance of agriculture in our national economy and significant of the service of the Department of Agriculture to the country at large, is greatly to be desired. A year from now congress will probably be asked to provide further funds, so that the administration building (estimated to cost $1,000,000) and possibly other laboratory buildings may be erected.

SCIENTIFIC ITEMS.

We regret to announce the deaths of Dr. Charles Emerson Beecher, professor of historical geology at Yale University and a member of the governing board of the Sheffield Scientific School; of Dr. Emil Alexander de Schweinitz, chief of the Biochemic Division, U. S. Department of Agriculture; of Arthur William Palmer, D.Sc. (Harvard), head of the Department of Chemistry of the University of Illinois, and of Miss Anna Winlock, computer and assistant in the Harvard College Observatory.

Dr. David Duncan, having been entrusted by the late Mr. Herbert Spencer with the writing of his biography, will be obliged to persons who may possess letters from him of value if they will kindly lend them for the purpose of such biograpny. All letters addressed to Dr. D. Duncan, care of H. R. Tedder, Esq., secretary, the Athenæum, Pall-mall, London, S. W., will be carefully preserved and returned in due course to their owners. Mr. Spencer's autobiography will be published by Messrs. D. Appleton & Co., on March 25.

The steamship *Princess Irene*, bringing the remains of James Smithson, arrived in New York on January 20. These were transferred to the *Dolphin* of the U. S. Navy and taken to Washington. They have been deposited in the Smithsonian Institution until arrangements can be made for suitable burial in the grounds of the institution and the erection of a monument. The remains were brought to this country by Dr. A. Graham Bell, at whose instance the regents arranged for the removal, owing to the fact that the English cemetery at Genoa in which Smithson was buried was to be abandoned.

At the annual meeting of the Royal Astronomical Society on February 12, Ambassador Choate received the society's gold medal on behalf of Professor George E. Hale, of the Yerkes Observatory.—The Lalande prize in astronomy has been conferred upon Director W. W. Campbell, of the Lick Observatory, by the Paris Academy of Sciences.—The French minister of public instruction and fine arts has conferred the degree of officer of public instruction upon Dr. Lester F. Ward for his scientific and sociological works.

THE POPULAR SCIENCE MONTHLY.

APRIL, 1904.

RECENT DISCOVERIES IN RADIATION AND THEIR SIGNIFICANCE.

BY PROFESSOR R. A. MILLIKAN,
UNIVERSITY OF CHICAGO.

THERE are times when the atmosphere seems to be fairly saturated with the spirit of scientific discovery. Such a time existed during the opening years of the nineteenth century when John Dalton was putting the atomic theory of matter upon an experimental rather than upon the purely speculative foundation upon which it had previously rested; when Count Rumford, an American by birth, was laying the corner-stone of the modern mechanical theory of heat, in accordance with which heat consists in the vibratory motion of the particles of which matter is composed; when Thomas Young was forging the final links in the chain of proof that light consists in the wave motion of some all-pervading medium, the ether.

It is not a little interesting that the opening years of the twentieth century have also been marked in no less a degree than those of its predecessor by epoch-making discoveries in physics. Most of this new activity has been grouped about the general subject of radiation, discoveries of new rays having followed one another in such rapid succession that it is difficult even for a physicist to keep posted about them all. As a result of these discoveries important progress has been made toward the solution of one of the most fundamental questions with which science has to deal, viz., the question as to the nature and the constitution of matter.

The Discovery of X-rays.

The discovery of X-rays is to be regarded as the starting point of this epoch of investigation upon radiation. It was in the Christmas season of 1895 that Professor Röntgen of Wurzburg, Germany, exhibited to the Physical Society of Berlin the first X-ray photographs. These photographs showed that from a vacuum bulb in which an electrical discharge was passing some sort of radiation was emitted, which was like light in that it produced an effect upon the photographic plate, but was unlike light, first, in that it was wholly invisible, and, second, in that it was able to pass easily through many substances which are perfectly opaque to ordinary light, such, for example, as cardboard, wood, leather and, notably, the flesh of the human hand. This discovery would probably have attracted little attention outside of scientific circles had it not been for this last-mentioned remarkable property, but the idea of obtaining photographs of the skeleton of a living being was so startling, so uncanny, at that time, to the average mind, that the discovery took to itself wings and within two weeks had set the whole world agog. Scores of scientists in all countries dropped at once their pending researches and began to experiment upon these strange new rays which Röntgen had named X-rays because they were such a completely unknown quantity. A surprisingly small amount of new knowledge concerning the nature of X-rays themselves resulted from all this research. The X-rays are almost as much of an unknown quantity to-day as they were when Röntgen made his first announcement. As is so often the case, it was in unexpected directions that this wave of experimentation upon X-rays bore fruit. The discovery of radio-activity was not the least important result of this activity. It came about in this way.

The Discovery of Radio-activity.

It was noticed that an exhausted bulb which is emitting X-rays under the influence of electrical discharges is always aglow with a peculiar greenish-yellow light which is commonly known as fluorescent light. Now it had long been known that there are some natural substances, notably the mineral uranium and its compounds, which possess a similar property of emitting this yellowish-green light not only when they are in a vacuum tube through which electrical discharges are passing, but also when they are exposed to the invisible radiation from the sun, that is, to the so-called actinic or ultra-violet rays which are chiefly responsible for the effects which sunlight produces upon photographic plates. It accordingly very naturally occurred to some scientists that the X-rays might perhaps be due to this fluorescent light which came from a vacuum bulb, rather than to any immediate influence of the electrical discharge, and, if so, that they ought to be emitted not simply by a vacuum tube, but also by uranium when exposed to sunlight. It was in 1896, within a year of the discovery of X-rays, that Henri Becquerel, the fourth illustrious possessor of that illustrious name, devised some experiments to test this inference. His method was to expose uranium to strong sunlight for a long time, and then to notice whether a photographic plate, which was wrapped up carefully in perfectly opaque paper and placed beneath the uranium, received any impression from it. He found that it did; but he further found that the exposure of the uranium to sunlight was altogether unnecessary; that the uranium itself in a perfectly dark room would affect, in the course of ten or twenty days, a photographic plate from which it was separated both by opaque black paper and by a thin sheet of metal. In fact he obtained in this way a radiograph of a metallic object similar in all respects to the pictures which Röntgen had obtained with X-rays. This showed, in the first place, that the fluorescent light had nothing whatever to do with the production of the photograph, but it showed also something much more important than this, namely, that *the mineral uranium is all the time spontaneously emitting rays of some sort, which are capable of penetrating opaque objects in just the way the X-rays do.*

This discovery, which has been one of the most fruitful in the history of science, is immediately due to the accident of a few cloudy days in Paris, during which Becquerel, since he could not expose his uranium to sunlight, set away his plate with the uranium on the top of it, to wait for fair weather. When the fair weather returned and he was ready to continue his experiments, it fortunately occurred to him that it might be worth while to develop the plate upon which the uranium had rested to see if anything had happened to it. The discovery of radio-activity was the result. Those who recall the story of the discovery of photography will remember that it was made quite as accidentally and under quite similar circumstances.

Becquerel further found that the rays emitted by uranium are also emitted by all uranium compounds. He therefore named them *uranium rays.* Another property which he found that the rays possessed, in addition to that of affecting a photographic plate, was the important property of rendering a gas through which they pass a conductor of electricity, or, to state the same thing in another way, the property of discharging any electrified body which is brought into their neighborhood.

The Discovery of Radium.

It was but a few months after this that Madame Curie, one of the few women who has attained eminence in the pursuit of science, and who together with her husband, with whom most of her work has been done, deserves a large share of the credit for our present knowledge of radium, set about investigating all the then known elements to see if any of the rest of them possessed this remarkable property which Becquerel discovered in uranium. She found that one, and but one, of the remainder of the elements, namely, thorium, the element which is one of the chief constituents of Welsbach mantles, was capable of producing precisely the same effects which Becquerel had discovered with uranium. After this discovery the rays from all this class of substances began to be called *Becquerel rays,* in honor of Becquerel, and all substances which emitted such rays were called *radio-active* substances.

But in connection with this investigation, Madame Curie noticed something which appeared to her very noteworthy. It was that pitchblend, which is the crude ore from which uranium is extracted and which consists chiefly of uranium oxide, would produce an effect upon a photographic plate, or would discharge an electrified body, in about one fourth the time in which the same weight of a pure uranium salt would produce the same effect. She inferred, therefore, that the activity of pitchblend in emitting rays could not be due solely to the uranium contained in it: that, on the contrary, pitchblend must contain some hitherto unknown element which had the property of emitting Becquerel rays more powerfully than uranium itself. She therefore immediately set about the task of separating as carefully as possible the dozen or so of substances which are contained in pitchblend, such for example, as uranium, barium, lead, copper, arsenic, antimony, and so on, and after each separation, testing the two portions separated to find which part carried with it the activity, that is, the ability to affect a photographic plate or to discharge an electrically charged body. The methods employed were the ordinary ones used in qualitative chemical analysis. The search was a long and difficult one, but ended triumphantly in the separation from several tons of pitchblend of two or three grains of the new element which has now become one of the wonders of the world.

The successive steps in this discovery were as follows: Madame Curie found, first, that in this process of separation of the constituents of pitchblend, the reagent which separated the barium out of the solution also brought down in the barium precipitate a large part of the activity. The barium chloride precipitate obtained in this way had about sixty times the activity of pure uranium chloride. She next found that when alcohol was added to a solution of this barium chloride, the first precipitate which was thus formed was more active than that which came down later. By retaining only this first precipitate and discarding the rest, and again redissolving and repeating the process over and over again (this process is called fractional precipitation) she succeeded in obtaining a sample of barium chloride which was 4,000 times as active as uranium chloride. Further, since the weight of the barium chloride for a given weight of contained chlorine was greater in the ratio 140 to 137 than the weight of ordinary inactive barium chloride for the same weight of contained chlorine, she concluded that the apparent activity of the barium chloride could not be due to barium at all, but must be due to this unknown element which was mixed with the barium in the precipitate. She therefore announced definitely the discovery of a new substance which she named radium.

There is a second process, which is now more commonly used than the above, for separating this active substance, that is, the radium, from the barium with which it is always found. It is called the process of fractional crystallization, and consists simply in retaining the first crystals which crystallize out from an active barium chloride solution and then redissolving these crystals and allowing some of them to crystallize out again, and so on. With each new crystallization the activity of the crystals per unit of weight increases. In this way the Curies have recently obtained samples of radium which are as much as 1,800,000 times as active as uranium, the activity being measured by comparing the rates at which equal weights of radium and uranium will discharge an electrified body.

Having followed in this way the processes by which radium was discovered as early as 1898, let us turn to some of the other results which followed close upon the discovery of the X-rays, and which it is necessary to understand something about before we can intelligently discuss the nature of the radiation from radium and other radio-active substances.

The Nature of Cathode Rays.

I have said that X-rays are emitted by an exhausted bulb in which an electrical discharge is passing, but the very existence of X-rays is found to depend upon another kind of rays which are also connected with the electrical discharge from an exhausted tube. These are called the *cathode rays* because they originate in the negative electrode or cathode, see Fig. 1, of a discharge tube when it is put into connection

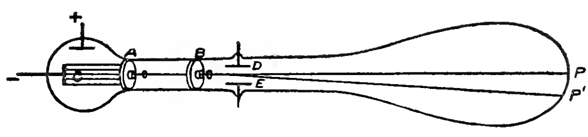


FIG. 1. ILLUSTRATING DEFLECTION OF CATHODE RAYS BY AN ELECTROSTATIC FIELD.

with an induction coil or static machine. These cathode rays were discovered long before X-rays. Fig. 1 will give some idea of how they manifest themselves. If *A* and *B* are two diaphragms, in the middle of which are two horizontal slits, then, when an induction coil is connected to the points marked + and — and set into operation, a small spot of greenish-yellow light will appear on the glass at *P*, just as though some sort of rays were emitted in straight lines from *C*, and, passing through the two openings *O*, fell upon the point *P*. There are a great many substances which, if placed anywhere in the line *OP* so that these cathode rays from *C* can strike upon them, will light up with a characteristic glow. For example, if a screen coated with zinc sulphide is placed within a discharge tube in the manner shown in Fig. 2, the cathode rays which pass through the slit in the mica diaphragm just opposite the cathode, light it up brilliantly in the parts along which they graze, and thus trace a distinct outline of their path from one end of the tube to the other.

The nature of these rays was the subject of much dispute between the years 1880, when they first began to be studied, and 1898. Some thought them to be streams of minute negatively charged particles shot off with enormous velocities from the cathode *C*, while others maintained that they did not consist of particles at all, but were waves in the ether, just like light waves. The dispute was finally ended by two very conclusive experiments performed, the first by Perrin, a Frenchman, and the other by J. J. Thomson, professor of physics in Cambridge University, England. Perrin's experiment consisted in proving that under all circumstances a body which was placed along the path *OP*, so that the cathode rays could fall upon it, became charged with negative electricity, just as would be expected if the cathode rays consisted of negatively charged particles. J. J. Thomson's experiment consisted in showing that if a charge of positive electricity were placed upon the plate *E* (see Fig. 1), and a charge of negative electricity upon the plate *D*, the rays were deflected out of the line *OP* and into the path *OP'*. This, too, was to have been expected if the rays consist of negatively charged particles, for these particles would be repelled by the negative electricity upon *D* and attracted by the positive electricity upon *E*.

Fig. 2. Showing Beam of Cathode Rays.

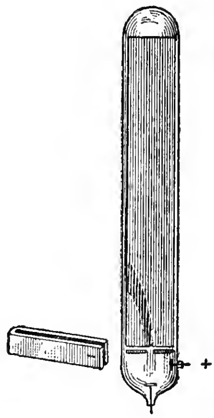


Fig. 3. Showing Deflection of Cathode Rays by a Magnet.

There is a further property of the rays, which, although it had long been known, adds powerful support to the projected particle theory. It is that when a magnet is brought near the cathode beam in the manner shown in Fig. 3, the beam is deflected by it also, just as would be expected if it consisted of a stream of negatively charged particles. These three experiments settled the question in favor of the projected particle theory, so that physicists are now all agreed in regarding the cathode rays as streams of minute, negatively charged corpuscles shot off in straight lines from the surface of the negative electrode and in a direction at right angles to this surface.

Cathode Ray Particles Much Smaller than the Smallest Known Atom.

But the most remarkable result of experiments upon cathode rays is the conclusion that while they consist of rapidly moving particles, these particles are not ordinary atoms or molecules, but are instead bodies whose mass is only about one one-thousandth of the mass of the smallest atom known, namely, the atom of hydrogen. The calculation by which this conclusion is obtained is based upon a comparison of the amount of deflection which is imparted to the rays by a magnet of known strength, and the amount of deflection which is produced by electric charges of known size on *D* and *E*. It can also be based upon other experiments which will not here be described. Suffice it to say that more than a dozen well-known physicists have made the observations and the calculations upon which they are based, and that, although they have worked by as many as three different methods, the results are all in substantial agreement.

A New Theory as to the Constitution of Matter.

Furthermore, since experiments of the kind mentioned above always lead to the same value for the mass of the cathode ray particle, no matter what be the nature of the gas which is used in the bulb and no matter what be the nature of the metal constituting the cathode *C*, physicists have found it necessary to conclude that these minute particles are constituents of each and every one of the different metallic elements at least, and probably of all the other elements also. In view of these discoveries, the suggestion has been put forward by several of the greatest living physicists, that these cathode particles are themselves the primordial atoms out of which the 70 odd atoms known to ordinary chemistry are built up. According to this suggestion, the chief difference between the different atoms of chemistry would consist simply in differences in the number of the primordial atoms which enter into them. Thus the hydrogen atom would be composed of about a thousand of these minute corpuscles, or electrons, as they have been called, the oxygen atom of 16,000, the mercury atom of 200,000, and so on. It is necessary to assume, however, that these electrons are half plus and half minus, for otherwise we can not account for the uncharged condition of ordinary atoms. Since, however, no evidence has as yet appeared to show that positively charged electrons ever become detached from atoms, J. J. Thomson has brought forward the hypothesis that perhaps the positive charges constitute the nucleus of the atom, while the negative electrons are on the outside and are therefore more easily detachable. It is too early to assert this theory as correct; it is introduced here merely as a profoundly interesting speculation brought forward by men high in authority in the scientific world. It differs radically from most other speculations of the same general nature, in that it is based upon a certain amount of experimental evidence. However, the experiments can not be said to have gone so far as to render its correctness even probable. This much, however, it is safe to say: the experiments upon cathode rays have *proved conclusively that under some circumstances particles do exist which are smaller than the ordinary atoms of chemistry.* It was the study of cathode rays, then, which first sounded the death-knell of the *indivisible* atom of our earlier chemistry and prepared the way for the discoveries, which were soon to follow, of subatomic transmutations which involve the liberation of stored-up energies, the very existence of which had never before been dreamed of .

The Nature of X-rays.

I have already said that cathode rays are very intimately connected with X-rays, for both are associated with the discharge of electricity in exhausted tubes. In fact, at the time of Röntgen's discovery, many physicists thought that the X-rays were nothing more nor less than cathode rays which had passed through the walls of the tube into the outside air. But Professor Röntgen demonstrated that the X-rays are wholly different from the cathode rays in these two important respects, namely: (1) they are not deflected in the slightest degree, either by a magnet or by bodies charged with static electricity; (2) they do not impart negative charges to objects upon which they fall. X-rays are therefore not cathode rays. They originate at the point at which the cathode rays strike against the walls of the tube, or against any object placed in their path inside the tube. In the ordinary X-ray tube a little plate of platinum is commonly placed in the middle of the tube, just opposite the cathode, for the purpose of receiving the stream of cathode rays. It thus becomes the source from which the X-rays proceed. This is about all that we know with certainty concerning X-rays. Most physicists, however, now believe them to be ethereal rather than material in their nature, that is, they believe them to be some sort of waves or pulses in the ether, not very dissimilar from light waves.

Radio-active Substances emit Cathode Rays.

We are now in a position to understand the experiments which were performed with radio-active substances, namely, uranium, thorium and radium, in order to discover the nature of their radiation. It was at first suspected that these rays were similar to X-rays, because, like them, they possessed the power of penetrating opaque objects and of affecting photographic plates. But as soon as the test which distinguished X-rays from cathode rays was applied, that is, as soon as a magnet was placed so that it could distort the photograph produced with the aid of Becquerel rays, in case these rays like cathode rays were deflected by it, it was found indeed that these photographs did indicate such deflection. It was further found that they could be bent out of their course by electric charges just like the cathode rays, and, lastly, that, also like them, they imparted negative charges of electricity to objects upon which they fell. Further, when the mass of these particles was calculated by comparing the amount of deflection produced by a magnet with that produced by an electric charge, it proved to be, strangely enough, the same as that of the cathode ray particles. It seems certain, therefore, *that radio-active substances spontaneously emit rays which are identical in all respects with the cathode rays, i. e.,* which consist of minute negatively charged particles of about one one-thousandth the size of the hydrogen atom. The velocity with which these minute particles are shot off from the radio-active substances is found to be even more enormous than the velocity of the same particles in the cathode rays. The latter were found to move with a velocity which is sometimes as high as 20,000 miles per second. Now, the velocity with which light travels from the sun to the earth or from star to star is 186,000 miles per second. Hence, the cathode ray particles sometimes move with a tenth the velocity of light. But the velocity of the particles shot off from radio-active substances is still more surprising, for it sometimes reaches the stupendous figure of 175,000 miles per second, only a trifle less than that of light.

Other Radiations from Radio-active Substances.

But it was discovered in 1899 by Rutherford, of McGill University, Canada, that uranium, thorium and radium all emit other rays besides cathode rays, which are distinguishable from them, first by their very much smaller penetrating power and, second, by the fact that they are not ordinarily deviated either by a magnet or by an electrically charged body. He named these rays the *alpha* rays, while he designated the cathode rays emitted by radio-active substances as the *beta* rays. In order to separate the *alpha* from the *beta* rays, it was only necessary to lay over the radio-active substance, that is, the uranium, the thorium or the radium, a very thin sheet of aluminum; for example, a sheet .005 centimeter thick. This opposed almost no obstruction to the passage of the *beta* rays, but it cut off entirely the *alpha* rays. Another mark of difference between the two kinds of rays was that, while the *beta* rays were very much more effective than the *alpha* rays in penetrating opaque objects and in affecting a photographic plate, their influence in rendering a gas electrically conducting was very small in comparison with that of the *alpha* rays; so that if the thin sheet of aluminum were taken away, the gas above the radio-active substance became a hundred times as good a conductor as when the *alpha* rays were screened off.

There is also a third kind of ray given off by radio-active substances, which has been given the name of *gamma* rays. These are very much more penetrating even than the *beta* rays; but, so far, little is known about their nature. Since, however, the energy carried by them is very insignificant as compared with that in the *alpha* and *beta* rays, we can leave them entirely out of account in most of the computations which we make upon the energy of radiations of radio-active substances. It is now conjectured that the *gamma* rays are ethereal pulses like the X-rays.

The Nature of the Alpha Rays.

It was at first conjectured that possibly the *alpha* rays might be X-rays, since, like them, they are not deflected by a magnet, and since, also like them, they are very effective in rendering a gas electrically conducting. But only last year Professor Rutherford contrived a very ingenious experiment by which he showed conclusively that the *alpha* rays are deflected very slightly by a magnet if the magnet is sufficiently powerful. He also succeeded in showing that they are deflected by a very strong electrical field. But in both of these cases the direction of the deflection is opposite to that obtained under the same conditions with *beta* rays. These results of Professor Rutherford's are of the utmost importance, and they have been recently confirmed both by Becquerel in Paris, and by a German physicist by the name of Des Coudres. The only possible interpretation which can be put upon them is that the *alpha* rays also consist of particles of matter shot off from the radio-active substances, but that, while the *beta* ray particles carry charges of *negative* electricity, the *alpha* ray particles carry charges of *positive* electricity.

Further, when from the amounts of the deflections produced by the magnet and by the electric charge, the size and velocity of the *alpha* particles are calculated, the results are again most interesting. For these particles are found to have a mass not one one-thousandth that of the hydrogen atom, like the cathode rays, but approximately twice as great as that of the hydrogen atom, or about the size of the atom of helium. (The atomic weight of helium is 4.) They are therefore about 2,000 times as heavy as the cathode ray particles. This explains why they do not pass through ordinary matter as readily as do the smaller *beta* particles. But despite this comparatively great mass, their velocity is found to be as much as 20,000 miles per second, more than a tenth that of the smaller particles. It will be seen, therefore, that the energy of the blows which they strike against the bodies upon which they fall is much greater than that of the *beta* particles. This explains why they knock the gas to pieces, or dissociate it and thus render it conducting, so much more energetically than do the *beta* particles.

The Crookes Spinthariscope.

We have attempted to follow, thus far, the evidence upon which we base the conclusion that the radiations from radioactive substances consist, largely at least, of projected particles of matter expelled with enormous velocities from the active substance. But no amount of reasoning of the sort thus far given will be found half as convincing to the ordinary mind as the sight of a bit of radium at work. Radium itself, in the dark, glows with a light which resembles that of a glow-worm, and when placed near certain substances like willemite (zinc silicate) or zinc sulphide, it causes them to light up with a glow which is more or less brilliant according to the amount of the radium at hand. Last spring Sir William Crookes first exhibited the following most beautiful and wonderful experiment at the soirée of the Royal Society in London. A small bit of radium is placed about a millimeter above a zinc sulphide screen, and the latter is then viewed through a microscope of from ten to twenty diameters magnification. The continuous soft glow of the screen, which is all that one sees with the naked eye, is resolved by the microscope into a thousand tiny flashes of light. It is as though one were viewing a swamp full of fire flies, or, better still, a sky full of shooting stars. The appearance is as though the screen were being fiercely bombarded by an incessant rain of projectiles, each impact being marked by a flash of light, just as sparks fly off from an iron when it is struck with a hammer. Becquerel has recently brought forward evidence to show that the spark is due to a cleavage produced in the zinc sulphide crystal by the impact of the *alpha* particles. This explains why the effect is not observable with all kinds of screens.

The Continuous Emission of Light and Heat by Radio-active Substances.

After learning that the radio-active substances uranium, thorium and radium are, for some reason or other, continuously projecting with enormous velocities two kinds of particles, the *alpha* and the *beta* particles, one is not surprised to find that these substances maintain a temperature above the temperature of the surrounding atmosphere. This has been proved experimentally only for radium, which was found last year by M. Curie and M. Laborde to remain permanently at a temperature between one and two degrees centigrade above that of its surroundings, and to give out for each gram of weight enough heat per hour to raise a hundred grams of water through one degree. Since radium radiates more than a million times more actively than either of the other substances, it is not likely that any one will ever be able to show experimentally that uranium and thorium also maintain a temperature above that of their surroundings. Nevertheless, the same causes which operate to hold up the temperature of radium, operate also to hold up the temperature of both the other radio-active substances, the only difference being one of degree. Hence it is probable that all radio-active substances are continuously emitting, in a greater or less degree, heat energy. This is not surprising in view of the conclusion that such substances are continually projecting particles with enormous velocities, for if these particles are projected from all the molecules of the active substance, it would be expected that the temperature of the mass of the substance would rise under this unceasing internal bombardment. But whence comes this energy which is represented in the projected particles, and of which this heat and light are the ultimate manifestation?

Radio-activity a Manifestation of Subatomic Energy.

The answer to this last question has not yet been fully given. This much, however, can be said, that, thanks to the splendid work of Rutherford and Soddy, of McGill University, of Sir William Crookes, of the Curies and Becquerel in Paris, and of one or two German physicists, a fairly satisfactory answer is at least in sight. Whatever be the cause of this ceaseless emission of particles by radio-active substances, it is certain that it is not due to any ordinary chemical reactions, such as those with which we have heretofore been familiar; for Madame Curie showed, when she originally discovered the activity of thorium, that the activity of all the active substances is proportional simply to the amount of the active element present and has nothing whatever to do with the nature of the chemical compound in which that element is found. Thus, thorium may be changed from a nitrate to a chloride, or from a chloride to a sulphide, or it may undergo any sort of a chemical change, without any change whatever being noticeable in its activity. Furthermore, radio-activity has been found to be absolutely independent of all changes in physical as well as chemical condition. A radio-active substance may be subjected to the lowest temperatures known, or to the highest temperature obtainable, without showing in either case any alteration whatever in the amount of its activity. Radio-activity seems therefore to be as unalterable a property of the atom of the radio-active substances as is weight itself. It is certainly something which is entirely beyond the range of ordinary molecular forces. This is strong evidence in favor of the view that radio-active change, *i. e.*, the change, whatever it be, which is responsible for the expulsion of the *alpha* and *beta* particles, involves a change in the nature of the atom itself. This is the first time in the history of science that any *subatomic* store of energy has been tapped by man, although, as stated above, the possibility of breaking up the atom was first proved by the study of cathode rays.

The Production of Uranium X.

The view that radio-activity consists in some change going on in the nature of the atom has received powerful support from a series of discoveries which were started in 1900 by an experiment performed by Sir William Crookes. He found that if uranium nitrate were precipitated by ammonium carbonate and then enough of the ammonium carbonate added to redissolve the uranium nitrate, there remained behind an undissolved precipitate which contained a large part of the original activity which had been possessed by the uranium nitrate. He called this undissolved precipitate (or better, the portion of it which was responsible for the activity, for when chemically tested, it showed nothing but iron, aluminum and other impurities) uranium X. But he soon afterward discovered that the uranium nitrate, which had partially lost its activity through the separation from it of this unknown substance, uranium X, in the course of a few months had regained completely its original activity, while the uranium X had lost its power to radiate.

A little more than a year ago Rutherford tried the same experiment with thorium and found quite similar results. But more important still, he found that in both cases the rate of loss of activity of the separated substance, that is, of the uranium X or the thorium X, was equal to the rate of recovery of the uranium or the thorium from which the new substance had been extracted. To state this result in a slightly different way, he found that if all the uranium X were removed from a sample of uranium by this process, so that further precipitation by ammonium carbonate would bring down no more uranium X, and if the uranium were then allowed to stand till it had recovered one half of the lost activity, and if then the uranium X was again removed, the amount of this uranium X which could be obtained was now just one half as much as the amount obtained at first. If the uranium had regained three fourths of its original activity, just three fourths as much uranium X could be obtained from it as at first. This result seems capable of but one possible interpretation, namely, this: the uranium is continually producing, by some change which goes on within itself, some radio-active substance uranium X, which, however, is formed in such minute quantities that it can be detected and measured only by means of its radio-activity. Further, this uranium X itself is unstable, for it undergoes a change by which it loses its activity. Rutherford further found that in this separation of uranium X from uranium the part of the activity which was left behind in the uranium consisted entirely of the *alpha* type of radiation, while the part which was separated out in the uranium X consisted wholly of the *beta* type. This seems to show that the first step in the process of radio-active change consists in the expulsion from the uranium atom of the big *alpha* particles, while the *beta* particles are expelled only from some product which is formed by the disintegration of the uranium atom.

In all these particulars Rutherford found that thorium and uranium acted essentially alike, the chief difference being that while the uranium X loses one half of its activity in about twenty-two days, it requires but four days for the activity of the thorium X to decay to half its initial value.

The Emanation from Radium.

The examination of radium revealed a behavior exactly similar to that of uranium, for it too was found to be continually producing a radio-active substance which, when separated from the radium, slowly lost its activity, while the radium from which it was separated slowly regained its original radiating power. In the case of radium this new substance, unlike the uranium X and the thorium X, could be distinguished by other physical properties besides its activity. Thus Rutherford found it to be of the nature of a gas. It could be separated from radium by heating the latter, or by dissolving it in water. The radium which had been so treated lost for the time being all but one fourth of its original radiating power, the other three fourths being found in the gas, or emanation, as Rutherford called it. This gas could be carried by means of air currents through long tubes to considerable distances from the radium itself, its path through the tubes being easily traced by the fluorescence which it imparted to the glass walls of the tubes. It could be set away in bottles and the change in its activity watched from day to day. In this way it was found to lose about half its activity in a period of four days, while in the same period the radium from which it had been separated regained one half of its lost radiating power. By passing this gas or emanation through a tube immersed in liquid air, Rutherford found that it condensed at about —150° C. Ramsay has recently found that it appears to have a characteristic spectrum, as have all the elements. This gas, therefore, seems to be a substance of very definite physical qualities which is produced by the disintegration of the atom of radium in just the same way as the uranium X and thorium X are produced by the disintegration of the atoms of uranium and thorium. But this gas, like the uranium X and the thorium X, has but a transitory existence, for the fact that it gradually loses its activity shows that it passes on into something else.

Induced Radio-activity.

Nor did physicists have long to look in order to discover this substance into which the emanation from radium is transformed. The Curies found as early as 1899 that when this gas comes into contact with a solid object, the object becomes coated with a film of radio-active matter which can be dissolved with hydrochloric or sulphuric acid, and which is left in the dish when the acid is evaporated. Or which may be rubbed off with leather and found, by means of the property of activity which it possesses, in the ash of the leather after the leather has been burned. This radio-active matter is so infinitesimal in amount that in no case is it detected in any other way than by its radio-activity. It might, at first, look as though it were nothing but the active gas itself condensed on the surface of the solid object, but since the rate at which it loses its activity is altogether different from the rate at which the activity of the emanation decays; and, more important still, since it is found to emit both *alpha* and *beta* rays while the emanation emits only *alpha* rays, it seems necessary to conclude that this film of active matter is a product of the emanation rather than the emanation itself. In fact it appears to bear in all respects the same relation to the emanation which the emanation does to radium. That is, *it is the result of the disintegration of the atom of the emanation, just as the emanation is the result of the disintegration of the atom of radium.*

In the case of thorium this continuous change from one radio-active substance into another has been followed with certainty through as many as four different stages, thus; first, thorium produces thorium X; second, thorium X produces an active gas or emanation which is very like the radium emanation; third, the thorium emanation gives rise to a radio-active substance which is responsible for the induced radio-activity which is observable whenever the emanation comes in contact with a solid object; fourth, this induced radio-active matter due to the thorium emanation gradually loses its radiating power, and hence must undergo at least one further change into some other substance.

The Disintegration of the Atom of Radio-active Substances.

We have endeavored to follow step by step the discoveries which have led up to our present knowledge of the nature of radio-activity. These discoveries have seemed to prove conclusively that the atoms of radio-active substances are slowly undergoing a process of disintegration, this disintegration being indicated, first by the fact that there is a continuous projection from them of particles of matter, the *alpha* and *beta* rays; and second, by the fact that we are able to detect the presence of new and unstable types of matter accompanying the phenomena of radio-activity. Just why these atoms are disintegrating and just how these new types of matter are formed must of course be largely a matter of speculation. Nevertheless, discovery has gone far enough to enable us to form a reasonably plausible hypothesis as to the probable mechanism of radio-active change. In presenting this hypothesis the first remarkable fact to be noted is that the three permanently radio-active substances thus far discovered, the only ones which can with certainty be classed as elements, namely uranium, thorium and radium,* are the substances whose atoms are the three heaviest

* There are two other substances which must perhaps be added to this list, viz., polonium and actinium. But neither of these has as yet been found to show a distinct spectrum or to show any of the other characteristics of elements; furthermore, the activity of one of them and possibly of both of them slowly decays. Hence it is possible that they, like uranium X and thorium X and the radium emanation, are only stages in the disintegration of radio-active elements. The present indications, however, seem to be that actinium is, like radium, a new and very powerful radio-active element.

atoms known. Thus the atomic weight of uranium is 240, that of thorium 232, that of radium 225 or, according to a recent spectroscopic test, by Runge, 256. There is no other property in which these three substances are at all alike. In their chemical characteristics they are extremely different. Now, according to our modern mechanical theory of heat, the atoms of all substances are in extremely rapid rotation. It appears, therefore, that these rapidly rotating systems of heavy atoms, such as characterize radio-active substances, not infrequently become unstable and project off a part of their mass. These particles which are first projected were found to be the *alpha* particles, and this process of projecting the *alpha* particles is the first stage of radio-activity. The mass which is left behind, namely, the uranium X, the thorium X, or the emanation, according as the original atom was uranium, thorium or radium, is itself unstable, and projects still other particles. The remainder, at least in the case of thorium and radium, is still unstable, and another particle is projected. Thus we were able to follow the disintegration of the atoms through at least four (according to Rutherford, five) successive stages. How many more stages there may be no one can tell, but as soon as the stable condition is reached and no more particles are projected the product is of course no longer radio-active, and its presence can no longer be detected by the delicate test of radio-activity. It is then only after it has accumulated in sufficient quantity to be capable of detection by the ordinary methods, namely, by spectroscopic or chemical analysis, that it could be expected to be found.

The Birth of Helium.

More than two years ago Rutherford, with this picture of the mechanism of radio-activity in mind, made a prediction which has recently been most remarkably verified. The history of science scarcely affords a more striking instance of the fulfilment of scientific prophecy. Since 'helium' (the element which was first discovered in the sun, by means of a line in the solar spectrum which did not agree with the lines of any of our known elements, and which was discovered on the earth only a few years ago by Lord Rayleigh and Professor Ramsay) is found in nature only in connection with radio-active minerals, *i. e.*, in connection with those minerals which contain uranium, thorium or radium, Rutherford predicted that helium would one day be found to be one of the ultimate products of the disintegration of the radio-active elements. A year later, it may be remembered, Rutherford himself found that the *alpha* particle, which is certainly one of the products of radio-active change, had about the same mass as the helium atom. This pointed still more strongly to the confirmation of his original prophesy. Last July Professor Ramsay and Mr. Soddy actually saw the spectrum of helium grow out of the emanation of radium. They collected the emanation from fifty milligrams of radium bromide and, examining it in the spectroscope, found that it was characterized by a wholly new spectrum, probably the characteristic spectrum of the emanation. But after watching this spectrum for three days they saw the characteristic lines of helium beginning to appear. This seemed to prove with certainty that helium was being continually formed by the disintegration of radium.

The Life of Radium.

It appears, therefore, that all the three heaviest atoms known are slowly disintegrating into simpler atoms. The process is, however, extremely slow. Despite the incessant projection of particles from radium, so strikingly shown by the Crookes spinthariscope, no one has as yet been able to detect with certainty any loss whatever in its weight, nor any diminution in its activity. Yet we may be certain that in fact it is both losing weight and diminishing in activity; for otherwise the principle of the conservation of energy, the corner-stone of modern science, would be violated. From a knowledge of the amount of heat energy given off by radium per hour, viz., 100 calories, and a knowledge of energy represented by each projected particle (this knowledge we possess, since we know the mass and velocity of the *alpha* particles, the energy contained in the *beta* particles being wholly negligible in comparison), we can easily estimate certain limits within which we may expect all the radium now in existence to pass out of existence as radium. In the first place we obtain the number of *alpha* particles projected per second from one gram weight of radium atoms by dividing the 100 gram-calories by the kinetic energy of each *alpha* particle. The result of this calculation is 200,000,000,000 ($= 2 \times 10^{11}$). Now there are 3×10^{21} atoms of radium in a gram of radium chloride. Hence if each atom of radium which becomes unstable threw off but one *alpha* particle, then the fractional part of any given number of radium atoms which become unstable per second would be simply 2×10^{11} divided by 3×10^{21}. This amounts to but one in fifteen thousand million. On the other hand, if each atom of radium which becomes unstable produces the maximum possible number of *alpha* particles, viz., 225/2, 225 being the atomic weight of radium and two the atomic weight of the *alpha* particles, then only one atom in sixteen hundred thousand million would become unstable per second. These two numbers represent then respectively the maximum and minimum possible rates at which the atoms of radium are becoming unstable. At the first rate radium would lose about one one-hundredth of its activity in five years, ninety-nine one-hundredths in 2,200 years and in 9,000 years it would possess no more than one hundred-millionth part of its present activity, *i. e.,* it would no longer be measurably active. Since we have brought forward good evidence in the foregoing paragraphs that each atom of radium which becomes unstable throws off at least as many as four alpha particles before it again reaches a condition of stability, it is probable that the above lowest possible limit to the life of radium, viz., 9,000 years, should be replaced by 36,000. At the second or minimum rate radium would lose one-hundredth of its activity in about 500 years and in 900,000 years would be no longer measurably active. It appears then that within a period of a million years at most all the radium now in existence will have ceased to be radio-active, *i. e.,* will have ceased to be radium. The life of uranium and thorium would be from one to two million times as much, since they are radiating only about a millionth as actively.

The Transmutation of the Elements.

The discoveries which we have attempted to describe in the preceding pages have seemed to lead to the startling conclusion that in the case of certain elements at least, the dreams of the ancient alchemists are true, for the radio-active elements all appear to be slowly but spontaneously transmuting themselves into other elements. The present indications seem to be that this transmutation which is going on in nature is a change from the heavier atoms to the lighter ones. Whether any other heavy atoms besides those of uranium, thorium and radium are thus slowly disintegrating, we can not say, but probably actinium must be added to the list. If any of the other known heavy elements, like gold, lead, barium, bismuth, mercury, are undergoing such a change, it is too slow to be detected even by the delicate test of radio-activity. But it is interesting to note that the only changes of this kind which have thus far been discovered to be going on among the atoms are in some respects similar to the changes which are going on in the organic world among the molecules. By the ordinary process of decay, all organic compounds, which represent very complex molecular structures, are continually disintegrating into simpler ones, and in so doing are setting free the energy which was put into them when the processes of life built them up into complex forms. Similarly, the studies of the last eight years upon radiation seem to indicate that in the atomic world also, at least *some* of the heaviest and most complex atomic structures are tending to disintegrate into simpler atoms. The analogy suggests the profoundly interesting question, as to whether or not there is any natural process which does, among the atoms, what the life process does among the molecules, *i. e.,* which takes the simpler forms and builds them up again into more complex ones. It would be rash to attempt to give any positive answer to such a query, yet the fact that radium now exists on the earth, taken in connection with the fact that the life of radium is short in comparison with the ages in which the earth has been in existence, certainly seems to point to an affirmative answer. The only other alternative is to assume that radium is itself a product of the disintegration of some heavier element which has been undergoing this process of decay since the world began.

Subatomic Energies.

The energy which would be required to produce such changes from the simpler to the heavier atoms, and the equivalent energies which are set free when the heavier atoms disintegrate into simpler ones, are enormously greater than those involved in the changes which take place in the constitution of molecules in the ordinary chemical transformations with which we have thus far been familiar. The disintegration of a gram of uranium, or thorium, or radium, sets free at least a million times as much energy as that which is represented in any known chemical change taking place within a gram weight of any known compound substance. The experiments of the last eight years have then marked a remarkable advance in science in that they have proved the existence of an immense store of subatomic energy. It seems highly improbable, however, that this energy can ever be utilized on the earth to serve man's economic needs, for thus far we know of but three substances which are disengaging it and these are changing so slowly that the rate of evolution of energy is almost infinitesimal. Radium may possibly prove to be of some practical value in the cure of disease, although it is too early yet to assert even this with certainty. But even if no practical application of these discoveries should be found, radio-activity will nevertheless have served one of the most useful of all ends, namely, that of enlarging man's knowledge of the ways of nature and of deepening his insight into the constitution of matter.

EVOLUTION OF THE HUMAN FORM.

By CHARLES MORRIS,
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THAT men, or thinking beings akin to man, exist only on that minute fragment of the universe we call the earth is a conception so highly improbable, in view of the vast multitude of planets which we may logically conceive to exist, that it seems as if no reasoning being could entertain it. It is true, indeed, that in our own solar system perhaps only two or three of the planets, perhaps only the earth, are in a condition suitable for human habitation, and that the earth has been so for a comparatively brief period. It may well be, therefore, that only a very small percentage of the planets of space are in a similar condition. But in view of the vast multitude of planets that presumably exist, the number of those that possess reasoning beings is probably great. If we deal with this question from the point of view of actual evidence, the fact that the only planet whose conditions we know is inhabited by man is a strong argument in favor of his wide-spread existence. On the other hand, the fact that man's existence upon the earth is dependent upon a certain limited range of temperature, of brief duration in the earth's total history, is an argument on the opposite side, and goes far to narrow the possible domain of life in the universe. Yet if we extend our view to embrace the past and the future as well as the present, we can not avoid the conclusion that the realm of life and thought in the universe is an immense one.

To this question of the existence of thinking beings appertains another, that of their form or physical character. Are we to suppose that these beings, wherever placed, resemble man, or that each planet develops a type of its own, and that, if we could bring together a collection of the *men* of different sections of the universe, we should have a diversified museum of animal forms, with but one characteristic in common, that of the faculty of abstract thought? This is the conception usually entertained by those who have indulged in speculation or fiction concerning the inhabitants of Venus, Mars and other planets of our system. Yet it is one that may be questioned. A study of the development of life upon the earth seems to lead to the opposite conclusion, and yields warrant for the theory that thinking beings, wherever they may dwell, resemble man in body as well as in mind In other words, we have reason to conclude that, if we were capable of traversing the universe, we should find beings akin to ourselves in many a remote corner of space.

On the earth, indeed, life exists under conditions which may be widely departed from in many other planets. Here the extreme range of favoring temperature is that between the freezing and the boiling points of water, the practical range being much smaller. Special conditions of surface material and formation, atmosphere, chemical action, etc., are also necessary. It is far from certain that the same conditions are necessary everywhere. Life may perhaps flourish on other planets under quite different conditions of temperature, gravitation and chemical action. It is true that, if all the spheres of space are made up of essentially the same chemical elements, as spectrum analysis seems to show, the range of life conditions can not greatly vary. Yet if the more abundant and active elements in any sphere differ from those of the earth, the consequent life conditions might vary accordingly and life exist under relations of temperature and chemical action unknown to us. The one thing essential, in every case, is an environment favoring organic chemism.

All this, however, is a side issue. It has no necessary bearing upon the question of animal form. If human beings could exist on some planets at 1000° instead of 100° F., and be made up of a protoplasm of quite different chemical composition, their forms and modes of action might still be closely the same. For the external forms of animals are due to physical, not to chemical, conditions. They are mainly results of the struggle for existence, and the effort to gain the most effective formation for the incessant battle of life. This must go on wherever life appears and develops, wherever the temperature or the active chemical elements may be. Much the same may be said of internal development. It seems to us that in any advanced stage of life the energy of animal motion must be a consequence of chemical change, due to something equivalent to oxidation of the tissues. There must also be an efficient agency for the supply of fresh nutriment to the wasting tissues, nerves for sensation and muscles for action, excretive and reproductive organs, etc., in short, organic conditions analogous to those which exist in our own bodies.

In truth, the minuteness of the earth as a planet, and the seeming insignificance of its life story as compared with that of all spheres and all periods, are apt to give us a false impression of the real significance of the development of life upon our place of abode. Though the process of organic evolution here may seem to us a minor one, a review of its history will serve to show that it has been a major one. And its final outcome in man can hardly be looked upon as a fortuitous result, but seems rather the inevitable consequence of an innumerable series of experimental variations. The life period upon the earth has been a very extended one, stretching through many millions of years, and living matter has passed through an extraordinary diversity of forms, from microscopic specks of primeval jelly to the highly organized form of man. Of any planet upon which thinking beings have appeared, doubtless much the same may be said. The beginning must have been at the same low level; the gradations must have been similar in general character; the ultimate may perhaps have been widely different, though there are what seem good reasons for believing that it was closely accordant.

The final result of organic evolution depends largely upon external relations, the environment; largely upon the relations of organic matter to the chemical conditions of this environment. In certain particulars this has remained persistent throughout. The presence of water and air and the active oxidation of organic substance have been essential conditions of plant and animal existence through all the earth's life era. In other particulars the environment has varied immensely. At first physical only, it soon became in large measure vital. Organic beings, at first struggling for existence against adverse inorganic conditions, soon had to add to this a struggle against one another. As life grew more complex and diversified, so did the vital environment. The hurtful or helpful effects of heat and cold, storm and calm, poisonous and nutritious food, and other inorganic agencies, became of minor importance as agents in evolution in comparison with the intense competition for the food supply between living forms. The development of the carnivorous appetite in animals, with the subsequent necessity of methods of escape or defense in food forms, has been the most prominent selective agency in organic evolution, and the one to which we mainly owe the great diversity of advanced forms now existing. The struggle has been not alone between higher assailants and lower fugitives. It has also taken the form of the assault of lower upon higher forms. And it is of great interest to find that man, the highest of all, finds his most dangerous organic foes in the disease-producing microbes, among the lowest forms of life.

Life, then, in its progress upward, has moved in a somewhat narrow lane, whose borders it could not cross without encountering death. And in dealing with earthly evolution, we are in great measure dealing with evolution everywhere; since, whatever the organic conditions and the inorganic environment, the vital struggle for existence must have been much the same in all life-containing spheres. Nature may be held to have tried a great experiment upon the earth, carried on through a vast stretch of time, as if with intent to discover what ultimate result would arise from this long-continued action of inorganic and organic forces upon living forms.

This experiment has not lacked a sufficiency of material. During unknown millions of years it has had to do with forms innumerable, a great battle going on in which myriads of unlike combatants were pitted against one another, each species being produced in such multitudes as to give it the fullest opportunity to sustain itself if capable. At every stage of the conflict the best adapted forms crowded down or annihilated their inferior competitors; themselves to be similarly dealt with when some new and superior combatant appeared. One needs only to look down the long record of paleontology, and consider that this represents only unit survivors of untold myriads, to recognize that nature has dealt with a superabundance of material, and to conceive that the final result may have been inevitable rather than fortuitous.

If we attempt to review the course of organic evolution upon the earth, we find ourselves confronted with so many types of life, so great a diversity of forms, such varied methods of motion and degrees of activity, that it is quite out of the question to deal with the subject adequately in a brief space. We can simply glance at it here, as an attempt to follow the whole line of progress would lead us too far afield.

Taking organic evolution as a process of colloid cell development—in distinction to the inorganic crystal development—we meet with a probably very long period of pristine evolution in which a single cell composed the whole organism. From this period examples indicating perhaps nearly the whole process of evolution still survive. The possibilities of progress in this direction were apparently very fully tried before organisms composed of a number of cells appeared. But when these came they quickly showed their superiority to the single-celled type alike in size and in complexity of organization.

From the basic generalized condition of living substance two great organic kingdoms arose, the fixed and the moving forms, plants and animals, the one living upon inorganic, the other upon organic material. Between these two inevitable resultants of the nutrient conditions the question of comparative rank is self-evident, the animal takes precedence of the plant. But the development of the latter was only in a minor degree due to inorganic influences. In water, where the animal assault on plants is not great nor varied, their evolution has been small. On land, where it has been severe and diversified, plant evolution has been large. But in no instance has it advanced from the purely physical to the conscious stage.

It is to the metazoa that we must go for the higher stages of evolution. Of the varied phases of this type of life, we can refer only to those of general character. No matter upon what planet life may have originated, we can not well avoid the conclusion that it must have had the organic cell as its unit, and that everywhere in its upward progress the many-celled self-moving form, feeding upon organic nutriment, must have been reached, as a stage superior to the minute single-celled animal, or the immobile plant, fed with inorganic nutriment.

If we may then accept it as inevitable that organic evolution everywhere, if sufficiently advanced, must have reached the stage of the metazoon animal, this may be taken as the necessary basis of higher progress in any life-bearing planet. In the metazoon we have a creature consuming organic food, which it is necessary to seek, and thus needing powers of self-motion, either of the body as a whole or of its members. And in any planet in which beings equivalent to man appeared the faculty of consciousness must have been equally necessary at an early stage, as a highly advantageous aid in the struggle for existence.

This type of life once attained, it formed a fertile field for the operation of the principle of natural selection. Upon the earth, and presumably everywhere, it developed into innumerable forms, each adapted to some passing or permanent condition of the environment. Assuming that the agencies of internal organic activity were everywhere much the same—including active chemical change, due to oxidation or something similar, vascular organs for the conveyance of nutriment to the wasting tissues, apparatus for sensation and motion, and the like—and that these led to the development of specialized organs equivalent to the lungs, the heart, the brain, etc., we shall confine ourselves here to the subject of variation in outward form and condition.

Even in this there are a multitude of relations to consider, and we can deal here only with those of general character. A main one is that of activity as contrasted with inactivity. Many of the new forms became sessile animals, their only active parts being tentacles or other organs of offense and defense. Others became free-moving animals. Of the two types the latter was evidently the best adapted to high development, both physical and mental, its free motion greatly diversifying its environment and bringing it into much more varied relations than could be enjoyed by the plant-like sessile forms. The more active the animal, the more diversified its powers of motion, the more acute and varied its organs of sense, the more alert its powers of consciousness, the higher seemingly would be its position in the ranks of life and the superior its opportunities for upward progress. And this rule must have prevailed not only on the earth, but throughout the universe.

This being the case, not alone the sessile, but the sluggish, forms were at a disadvantage as compared with the active. Anything, then, likely to prevent rapidity and diversity of motion must have acted as a check to progress. Activity is essential to the most effective offensive powers, and upon these the higher stages of development depend;

but various types of animals became defensive rather than offensive in habit. These include the armored classes, of which the mollusks are the most marked example. To these may be added the forms that seek concealment, either by burrowing or otherwise. These creatures are necessarily sluggish, either from the weight of their armor or their lurking habits. They live upon inactive food, their environment is limited, their contact with nature narrow, their powers of sensation and consciousness little developed. The conditions of their life definitely take them out of the line of the higher progress, in which they can not compete with the more active forms.

In considering then the classes of animals adapted to advanced development, it seems necessary to confine ourselves to the free-moving, agile forms. And among the inhabitants of the ocean—in which life had its origin and its lower stages of development—these are not to be sought among the crawling and burrowing, but among the swimming species. With these the highest activity is dependent upon the most suitable formation of body and the most capable organs of motion.

If we may pursue our fable of nature's experiment in evolution, it can be said that very numerous trials in form were made. There seem possible to colloid substance only two general types of form, the circular or radial and the elongated. Both these were produced in numerous varieties, the circular type embracing two large classes of animals, the cœlenterata and the echinodermata, all of them sluggish, many of them sessile, their general shape and radiated limbs being very ill adapted to active motion. In this respect they were at a great disadvantage as compared with the bilateral, elongated type.

We thus seem to find the experiment of organic evolution, after millions of years of incessant effort, reaching the type which in its simpler stages is popularly designated as the worm, as the form best adapted for advanced evolution. The pristine worm was not in itself a promising creature. Its organs of motion were inefficient and its movements sluggish. Probably several worm-like types appeared, simply organized elongated animals of varied formation, to which we owe, in their final development, the three classes of animals known as the mollusca, the arthropoda, and the vertebrata. This development of an elongated, bilateral animal would seem to have been an inevitable stage in the evolution of animal life, sure to appear in any planet where life had sufficiently progressed, and capable of unfolding into a number of different types. In addition to the great types named, several of minor importance appeared upon the earth, and different ones may well have arisen elsewhere.

Yet if we seek for the highest class of form likely to arise from the worm-like unit, our field of search is restricted. If activity and flexibility of body are advantageous, we must seek these in the swimming rather than in the crawling forms; in the naked rather than in the armored; in those of simple rather than in those of multiple organization—like the arthropods; in those with lateral rather than in those with oral limbs—like the mollusks; and finally in those with the smallest available number and most efficient character of limbs and other organs. This leads us to the vertebrates for the highest type that appeared in the waters of the earth, as the outcome of forms almost numberless in variety. In this we have an oval-shaped elongated animal, its organs of motion much the most effective of the many that had appeared in the progress of life, its vital organs unified and simplified to the greatest extent possible, its skeleton internal instead of external, used solely as a support, in no sense as an armor.

If we consider the fish in its most primitive varieties, we certainly seem led to the conclusion that it is the form to which the evolution of life would lead in any planet, as the basis of the higher development. In *Amphioxus,* for instance, we find the elongated bilateral animal simplified to an extraordinary degree; without external armor of any sort, with the simplest vital organs, with only the beginning of an internal skeleton, and with merely the suspicion of a fin, virtually a flattening of the skin. In this form we have the vertebrate reduced to its lowest terms, or the worm advanced to its highest. In the hag we find again a boneless and scaleless creature, with a sheath of cartilage to represent the backbone and with no organs of motion other than a fin-like flattening around the tail. Much the same may be said of the lamprey. From forms like these the fish seems to have developed, with all its subsequent variations.

The fish remains the highest form of water-developed life. It has made comparatively slight steps of progress during the immense interval since the paleozoic age. The limitations of its habitat seem to have checked the development of organic form at this stage. It can not be said that the evolution of life in the water has been in any sense restricted by deficiency of time or narrowness of variation. The variety of forms that have appeared is surprising when we consider the uniformity of conditions in the water, and are only to be accounted for as the result of a very active vital struggle. We find its simplest and least specialized higher result in *Amphioxus,* of which the ultimate result is the fish, beyond which, during millions of years, no progress has been made. And a full consideration of what has taken place on the earth strongly suggests that the oceanic evolution of life in any planet must have ended at some not dissimilar stage. Mentally it stands at a low level; and the whale, a mammal which has returned to the fish-form, is as low as the fish in mental powers.

Life in water was the basis of life on the land. It could not originate there *de novo,* land conditions being unadapted to the early life stages. Land life was therefore handicapped by its origin. It had to start with what the ocean had to offer, and to begin with physical conditions which afterward could, at the best, only be modified. These conditions have left ineradicable traces even in man, the most removed of all from the original types. Of water animals only the elongated forms sent representatives to people the land—the worm, mollusk, arthropod and vertebrate. And of these, the latter two alone seemed well adapted to their new habitat, the arthropod developing into an extraordinary multitude of species, though its inferiority of organization removed it, at the start, from any competition with the vertebrate as a basis for the higher evolution. We find in the bee and the ant the ultimate development of the insect intellect, and the insect form is decidedly restricted by its characteristic condition.

Despite the immense variation that has taken place in land vertebrates, their marked departures from the fish type have not been numerous. One of the most important of these was the development of the fin into the limb, yielding the quadruped. Another was the replacement of the gill by the lung. But varieties of partially air-breathing and four-paddled fishes still exist, as if to serve us as object lessons in these stages of development.

Land animals were exposed to much more varied natural conditions than water animals and the struggle for existence between different forms was quite as acute. Yet, though a vast number of differing forms appeared, they were all built on the original lines of structure, the type of organization of the fish strictly limiting that of the land vertebrate. A development takes place, but it is on the lines already laid down. The internal organs vary and become more effective in action, the cold-blooded is succeeded by the warm-blooded, the egg-bearing by the young-bearing, etc. There is much change in external form. Animals became adapted to running, to flying, to swimming, to crawling, to burrowing. There are many variations in the feet and limbs, and in some cases these vanish, as in the serpent and the whale. Some animals are clothed in scales or bony armor, some in hair or feathers. But no new type appears, and though the mental powers increase, ages pass with little indication of the coming of any animal possessed of advanced powers of thought. Mentally the higher land vertebrate progresses far beyond its highest water kindred, but its powers of thought, after gaining a certain development, remain in great measure dormant, and there is nothing to indicate that the quadruped could ever progress in thought beyond a certain low level. If so on the earth, probably so everywhere: the influences acting on the quadruped do not seem calculated to produce any advanced thinking powers.

We have, in the foregoing pages, followed in its general features the evolution of animal life upon the earth. In view of the immense period over which this evolution has extended, the extraordinary variety of forms which have appeared, and the strict limitations of the problem by natural influences, chemical, meteorological and vital, it is not easy to perceive how the final result could have deviated widely from that which we have before us. If the process were gone over again upon the earth, the great probability is that it would end once more in the mammalian quadruped. On other planets different chemical and physical conditions might affect the result, though the general principles of vital action could not greatly deviate and the evolution of the organs would doubtless pursue much the same course. As regards external form, the struggle for existence must operate in the same way and probably to the same effect.

Let us, for example, take the head of the quadruped, with its facility of motion, its apparatus for mastication, its sense organs, its nerve center. Can any one suggest an improvement upon the general arrangement of these organs, the ultimate outcome from a myriad of experimental efforts? The nasal openings stand above the mouth, in the best position to give warning of dangerous odors from food. The eyes are placed at the highest altitude and in the frontal position, the best location for their special duty. The ears are situated to catch sounds from the rear and the front, but preferably the latter. The brain is situated in the immediate vicinity of these organs of special sense, as if to favor quickness of sensation. All the organs of the head, indeed, seem remarkably well placed and adapted to their particular duty, and when we consider the varied positions which these organs have occupied in lower forms of life, we may justly look upon those in the quadruped as the final 'posts of vantage' resulting from a multitude of trials. Similar deductions might be made from other sections of the body, internal and external.

But we have not yet reached the evolution of a thinking being, an animal dependent much more upon its mental than upon its physical powers. In each advanced type of animal some mental progress was made; largest of all in the quadruped mammal; yet even in the latter it ended at a low stage. This is evident if we compare the quadruped with man, the former dependent very largely upon its physical, the latter mainly upon his mental powers. Evidently, in any planet, some step of progress beyond the quadruped was necessary for this result. On the earth this step was towards the form of man, the only true biped. May it not have been different in other planets, yielding human beings widely diverse in form and general bodily relations?

The answer to this query depends upon that special characteristic to which man—wherever found—owes his superiority. His physical difference from the lower animals is by no means great. It consists principally in an adoption of the upright attitude, a reduction of the organs of locomotion from four to two and the development of a hand with grasping powers. But in this physical deviation lies the secret of the whole mental deviation. The species of animals below man are obliged to depend upon their personal organs, being incapable of availing themselves of natural objects. The elephant, with its grasping trunk, and the apes, with their partly freed hands, are nearly the sole exceptions to this rule. Man, on the contrary, by the freeing of his fore limbs from duty in locomotion and the grasping power of his hands, became able to add to his own powers those of nature, to employ weapons and tools fashioned from non-living matter, and thus to initiate a new cycle of evolution that was scarcely touched upon in the world below him.

The employment of tools and weapons separate from those provided by nature in the body is a condition demanding the active exercise of the mental powers, and at once gave man an incitement to the development of the mind which did not exist in the lower animals. We need not pursue this subject farther. The new process of evolution thus begun,—that of the exercise of the faculty of thought in making use of the powers of nature— it went on until it yielded man as he now exists, a being in whom the intellect controls not only his own bodily actions but largely all nature below him.

If now, we may justly conjecture that animals resembling our quadrupeds in general organization appeared on other planets, and if a thinking being analogous to man also appeared on any of these planets, it is very difficult to conceive how he could have arisen in any widely different way. It certainly seems as if the evolution of the higher intelligence in any planet must have depended upon some means of making use of the forces of nature, and the first step towards this, starting from the quadruped, would seem necessarily to be in the direction of the biped, with free arms and grasping hands.

There is thus considerable reason to believe that the beings which answer to man upon any of the planets of the universe must at least approach man somewhat closely in physical configuration. They may differ in minor details of organization, in many cases they may have escaped the special organic weaknesses of man, but it certainly seems as if a human traveler, if he could make a tour of the universe, would find beings whom he could hail as kindred upon a thousand spheres.

THE AREQUIPA STATION OF THE HARVARD OBSERVATORY.

By Professor SOLON I. BAILEY,

DIRECTOR OF THE AREQUIPA STATION.

THE same restless energy which impelled the American people to become a world-power has led their men of science to extend the range of their researches. The possibilities of a nation's influence are bounded only by the whole earth; and in a similar way the field of astronomy is limited only by the whole sky. At the latitude of Cambridge, Mass., an observer can never see more than three fourths of the sky. In order to observe the remaining fourth, which lies about the south pole of the heavens, he must seek some station below the equator. A complete study of all the stars in the sky is imperatively demanded for the solution of many of the great questions which the astronomy of the future must answer. Only by bringing such completeness into astronomical research will the construction of the universe and the true place of our solar system become known.

The Arequipa Station of the Harvard College Observatory owes its foundation to the far-sighted policy of its present director, Professor Edward C. Pickering. Under his direction, in 1889, the writer of this article visited South America in order to make the preliminary studies necessary to the selection of a station for the observation of the southern sky. The west coast of South America was chosen for this purpose, since it offered the possibility of great altitude, in addition to a dry climate and a clear atmosphere. The funds for this enterprise had been bequeathed for such a purpose by Uriah A. Boyden, a Boston engineer.

From the best information which could be obtained in the United States, it was thought that the valley of the River Rimac, near Lima, Peru, would furnish conditions favorable for the proposed station. The valley itself, however, did not offer a sufficiently free horizon, being shut in everywhere by mountains. There was a wide range for choice in regard to elevation. The hills near Lima are only a few hundred feet in height, while the great mountains forming the western Andes rise eighteen thousand feet above sea level. The primary conditions were an open horizon and a clear sky. To obtain a free horizon it was only necessary to climb one of the steep and barren summits near the valley; but to determine where the sky was clearest was a more difficult problem. At this latitude the western Cordillera extends nearly parallel to the coast at a distance of perhaps sixty or seventy miles in an air line. The amount of cloudiness at different distances from the coast varies enormously. A different cloud system prevails on the coast from that in the mountains. The rainy season in the mountains is from November or December to March or April, more or less in different years. Toward the coast the rainfall grows less, while, in general, little or no rain falls within thirty or forty miles of the ocean. In Lima there is no rainy season, but there is an extremely cloudy season. This is due to the low cloud which is found more or less along the whole coast. This coast cloud is most prevalent from May to November. Throughout a large part of the year, however, the coast region of Peru, though almost rainless, is very cloudy. It seemed, therefore, that while the lofty clouds which cause the rainy season in the interior are gradually dissipated many miles from the coast, and the dense coast cloud never extends far away from the ocean, a situation chosen between these two, if such were possible, might, perhaps, escape both. With these ideas in mind a site was selected on an isolated summit, at a distance of about twenty-five miles from the coast, and at an elevation of six thousand five hundred feet.

The provisional station thus selected was at a distance of about eight miles from the village and hotel of Chosica, in the Rimac Valley, from which all supplies, of both food and water, were obtained. The residents of the hotel were our nearest neighbors, with the exception of occasional wandering herdsmen. In many ways it was an ideal location. It was named Mount Harvard, and became well known in Peru. The outlook was superb. To the east the ranges rose ever higher and higher to the Great Andes; to the west they fell away in numberless crests and wavy lines to the Pacific. Five miles away in a straight line a glimpse of green indicated the valley of the Rimac. The rest was hidden by mountains. In every direction nothing but barren mountains was to be seen. Where the buildings stood the soil was a hard sand, covered here and there with huge bowlders and with many varieties of cacti. To the north and south we looked down into gloomy ravines thousands of feet deep. To the east and west the slopes were more gradual, and there were charming little valleys needing only water to make them spots of beauty.

The buildings on Mount Harvard were portable structures, carried for the most part from the United States. They were made of a light framework of wood, covered with canvas and heavy paper. These houses and the instruments were conveyed from Chosica on muleback over a trail constructed for the purpose.

Life on Mount Harvard was somewhat lonely and monotonous, especially for Mrs. Bailey, who seldom enjoyed the society of any woman, except that of our amiable half-breed cook. Perhaps the most unique feature was its situation between two clouds. Below us to the west was the coast cloud, which reached a varying distance inland according to the topography. Up the Rimac Valley it flowed like a great river; occasionally it filled not only the valley, but the barren ravines that branched from it north and south, rising till it covered even the ridges at our feet and, flowing around us, formed islands of Mount Harvard and the other more lofty points. The upper surface of this cloud was very sharply defined, but of wave-like form, so that its resemblance to water was at times so perfect that we could with difficulty persuade ourselves that far beneath its under surface all the varied activities of ordinary life were going on cheerfully. If from this view of 'clouds wrong side up' we turned our eyes upward, we at times saw another cloud system far above us; so that frequently we were between two clouds in a wide but shallow world, ourselves, perhaps, the sole inhabitants.

Fortunately for our work, the clouds above us appeared but seldom during the first months of our residence on Mount Harvard. During this time the extension of the Harvard photometry to the southern sky was begun. This is a determination of the brightness of all stars visible to the naked eye, a work begun by Professor Pickering in 1879. Photographic work was also carried on. The climatic conditions from April to September were excellent, but later clouds became troublesome. This condition of the sky growing worse as the cloudy season approached, it was decided to devote the following months to a meteorological study of different localities along the coast, and incidentally to extend the work of the meridian photometer in some region more free from clouds. Of the clearness and steadiness of the atmosphere in these different localities there was no certain knowledge, and the only way was to investigate it for ourselves. We left the Mount Harvard Station early in November in charge of a Peruvian assistant. During the next four months a personal examination was made by Dr. M. H. Bailey and myself of what appeared to be the most desirable localities along the coast, including Arequipa, the region about Lake Titicaca, both in Peru and in Bolivia, the Desert of Atacama, Valparaiso, Santiago and various other places in Chili. Perhaps no spot in all America offers a clearer sky than the Desert of Atacama. More than a month was passed at Pampa Central, near the center of this desert, and a study was made of the meteorological conditions, while the work of the meridian photometer was rapidly extended. There is a striking difference during the Peruvian cloudy season, between the cloudiness at Mount Harvard or at Arequipa, where the conditions are similar, and that on the Desert of Atacama. This is well shown in the following brief table, where *A* represents a perfectly clear sky during the whole night; *B,* a clear sky for a portion of the night; *C,* sky partially cloudy all night, and *D,* sky completely cloudy all night.

			A	B	C	D	Total.
1890.	January.	Pampa Central	21	7	0	1	29
"	"	Mount Harvard	0	2	2	27	31
"	February.	Pampa Central	12	12	1	3	28
"	"	Mount Harvard	0	0	0	28	28

A record of the cloudiness was kept not only at Mount Harvard, but at Arequipa and Pampa Central for some time after our residence in Chili. The cloudy season at Mount Harvard and Arequipa is in the southern summer, that of Pampa Central in the southern winter. By changing from one to the other of these localities one could keep in a region of clear sky nearly the whole time.

THE TEMPORARY STATION ON MOUNT HARVARD.

As a result of the investigations thus made the director selected Arequipa for the site of the permanent station, and the equipment on Mount Harvard was removed to that city in October, 1890. In January of the following year Professor W. H. Pickering arrived in Arequipa, bringing with him the thirteen-inch Boyden telescope and other smaller instruments. Under his direction a residence for the astronomer in charge and his family was erected, and two additional buildings were received from the United States. One of these was designed for a laboratory and the other for the use of the Boyden telescope. During his two years' residence in Arequipa, Professor Pickering, assisted by Mr. Douglass, made a large number of observations of Mars, and of the satellites of Jupiter and Saturn, as well as of the lunar surface, all of which attracted wide attention. The steadiness of the atmosphere at Arequipa makes it an especially favorable spot

THE AREQUIPA STATION OF THE HARVARD OBSERVATORY.

for the use of higher powers, and for the study of faint and difficult planetary details. For double star work also the conditions are extremely good, and a large number of new and interesting double stars have been discovered by Professor Pickering, Mr. H. C. Bailey and the other members of the observatory.

At the present time the equipment of the Arequipa Station of the observatory consists of the following instruments: the thirteen-inch Boyden telescope, an instrument so constructed that, by a change in the position of the lenses, it may be used either for visual or for photographic work; the twenty-four-inch Bruce photographic telescope, the most powerful instrument of its class in the world, a gift of the late Miss Catherine Bruce, of New York; the eight-inch Bache photographic telescope; a five-inch refractor, and several smaller instruments of different kinds.

In general the work carried on in Arequipa is the extension to the southern sky of that previously begun in Cambridge. This is well illustrated by the Harvard photometry. With the large meridian photometer alone more than a million light comparisons have been made. The greater part of this work was done in Cambridge by the director and his assistants, but about two hundred thousand observations have been made by the writer in Arequipa and elsewhere in South America. This work, planned and begun by Professor Pickering a quarter of a century ago, now furnishes not only precise determinations of the magnitudes of all the brighter stars in the sky, but also the magnitudes of certain zones of fainter stars, by which the estimated magnitudes of the stars included in the various great catalogues can be reduced to the photometric scale.

With another Pickering photometer, during the last year, several thousand light comparisons of Eros were made by the writer. Eros is that remarkably interesting little planet which at times comes so near the earth as to be our nearest celestial neighbor. Eros is a variable planet, undergoing striking changes in light. The above observations showed that during the year 1903 the complete light-cycle was only $2^h\ 38^m\ 6^s.1$. If these changes are due to the rotation of the planet, the true period may be that given above, or, more probably, twice that amount, $5^h\ 16^m\ 12^s.2$.

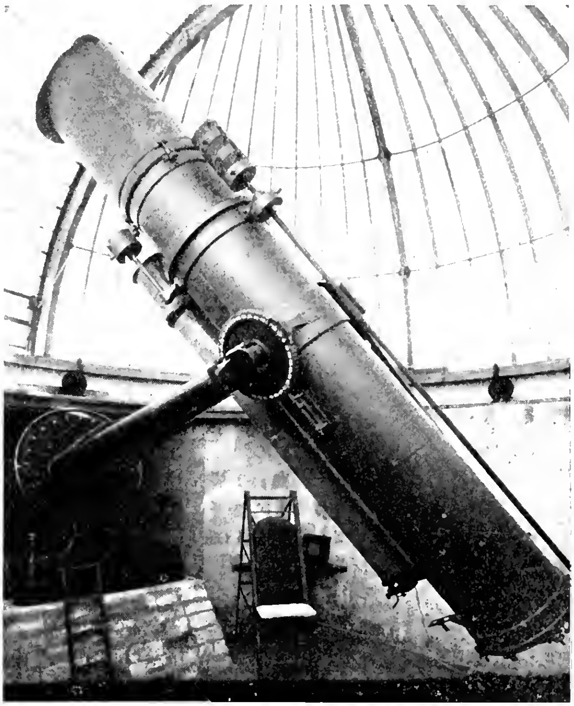
Visual observations of variable stars have been regularly carried on since the establishment of the station, although the results have not yet been published. These observations are now made by Messrs. Manson and Wyeth. A determination of the longitude and latitude of the station was made in 1897 by Professor Winslow Upton, of Brown University. The result was, longitude $4^h\ 46^m\ 12^s$ west of Greenwich. The latitude is south $16°\ 22'\ 28''$. The longitude of the observatory in Cambridge is $4^h\ 44^m\ 31^s$. It follows, therefore, that Arequipa is about thirty miles west and four thousand miles south of Cambridge.

Photographic work has always occupied a large share of the time at Arequipa. Several photographic instruments are kept employed throughout the whole of every clear night. The photographs thus made are usually examined in Cambridge, where a number of assistants are employed for the purpose. Only in exceptional cases is more than a preliminary examination made in Arequipa.

The largest instrument in the observatory is the twenty-four-inch Bruce telescope. This telescope is a doublet, that is, it has a combination of four lenses, giving good definition over a large field. The scale is the same as that of the instrument used in the international photographic survey of the sky, but the region covered by each plate is six times as great, so that the work of covering the whole sky is much less. With such instruments the work of making a photographic *Durchmusterung* of the stars to any desired magnitude would be comparatively simple, since a pair of these telescopes, one in the northern, and the other in the southern, hemisphere could furnish all the plates needed within two or three years. The Bruce telescope, after a year's trial in Cambridge, was mounted in Arequipa, in 1895, by the writer. Nearly the whole sky has been photographed with exposures of ten minutes, showing stars to about the eleventh magnitude. Good progress has also been made on plates having exposures of sixty minutes, which show stars to about the fifteenth magnitude. A set of plates has also been begun, having exposures of four hours. These can only be made on moonless nights, and a number of years will be required to cover the whole sky. The approximate number of stars has been determined on some of these plates. The number varies, in general, from one thousand to ten thousand stars per square degree. Four hundred thousand stars have been photographed on a single plate. The whole number of stars which will be recorded in this splendid set when completed will probably approach one hundred millions. In addition to such vast numbers of stars, these plates will also contain numerous star clusters and nebulæ, together with occasional asteroids, comets and meteors. This set of plates alone would furnish two or three astronomers with materials for a lifetime of study. A large part of the plates thus far obtained with this instrument have been made by Dr. Stewart and Mr. Frost.

An instrument, which has been in constant use since the beginning of Professor Pickering's photographic researches in 1886 is the Bache telescope, which has an aperture of eight inches, and a focal length of four feet. It was employed for several years in Cambridge, then for a year and a half on Mount Harvard, and since that time in Arequipa. Altogether, more than thirty thousand photographs of the stars have been made with this instrument. By its use with an objective prism photographs of the spectra of all stars to about the eighth magnitude have been made. A study and classification of these spectra have been carried out by Professor Pickering as a memorial to the late Dr. Henry

Draper. The funds for this research were furnished by Mrs. Draper. From a study of the spectral peculiarities of the stars thus photographed, Mrs. Fleming has discovered a large number of variable stars and several new stars. Charts of the southern sky are made with this instrument each year. This work is in extension of that done in Cambridge for the northern sky. This collection is now of great value in tracing the history of any newly discovered celestial object.



THE BRUCE PHOTOGRAPHIC TELESCOPE.

A similar but more frequent photographic survey of the sky is also made by means of a Cooke lens with an aperture of about one inch. Photographs are made each month with this instrument of the available sky. An exposure of one hour shows stars to about the eleventh magnitude, and a plate eight inches by ten covers a region more than thirty degrees square, or about one fortieth part of the whole sky.

The thirteen-inch Boyden telescope has been used photographically for the detailed study of the spectra of the brighter stars, and for charts of special regions. The power of this instrument is such that, by the use of a battery of two or three prisms, spectra of the bright stars are obtained several inches in length, which show hundreds of lines. By an examination of these spectra several spectroscopic binaries have been discovered. As the objective prisms employed do not permit the use of a comparison spectrum, the binary character is apparent only when both the components are bright. In such cases the lines of the spectrum are alternately single and double. A study of the spectra of the southern stars photographed with this telescope has been made by Miss Cannon as a part of the Henry Draper Memorial.

The focal length of this telescope is about sixteen feet, so that an arc a degree in length in the sky is represented on the photographic plate by a line more than three inches long. The scale of the instrument is thus very suitable for the details of nebulæ, and for nearly everything except the centers of the densest clusters. For long exposures on difficult objects, such as globular clusters, the telescope must follow the stars in their diurnal motion with great precision. This can only be accomplished with such an instrument by watching a star visually and keeping it constantly bisected by the lines of a reticle. Formerly, a secondary telescope was used for this purpose, but, due to the flexure between the two tubes, and perhaps for other causes, really fine photographs were not obtained with this telescope until a lens for following was inserted into the field of the main instrument, so that the other telescope was dispensed with. In all cases the mean movement of the telescope is provided for by carefully devised and well-constructed clockwork; and in the case of small and rigid instruments this alone serves fairly well, unless the exposure is more than an hour.

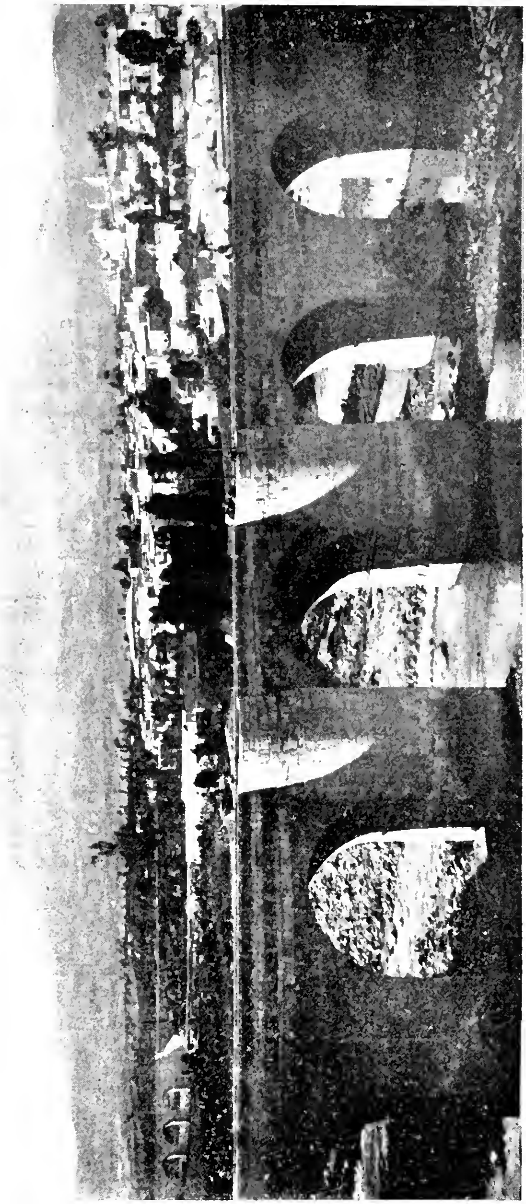
More than five hundred variable stars have been discovered by the writer in the globular clusters, by means of charts made with this instrument. These constitute nearly one half of all the variable stars known, but they all occur in only one thirty-thousandth part of the sky. At the centers of some of these clusters, the stars are packed together so densely that there are one hundred stars to the square minute. If the stars were equally dense over the whole sky, their number would exceed ten billions, and the sky would be so luminous that there would be no real night. In one of these clusters, Messier 3, one hundred and thirty-two variables were found. These are all situated within a circle whose area is one fourth of a square degree, or only one one-hundred-and-sixty-thousandth part of the sky. In this cluster one star in seven is variable. The photographs used for this investigation must be made with the greatest care, and must then be enlarged, or else examined by a microscope, since the images of the stars on the original plates resemble thickly scattered grains of dust.

The duration of exposure employed varies enormously, according to the instrument and the object to be attained. They have been made from one second up to twenty-four hours. With the great Bruce lens, an exposure of one second is sufficient for the brightest stars, while an exposure of four hours, or more than fourteen thousand times as long, fails to record stars which will appear when an exposure of five or six hours is used. For the comparatively bright stars, the number increases approximately by the ratio three for each magnitude. For example, there are about three times as many stars of the second magnitude as of the first, and three times as many of the third magnitude as of the second. There are indications, however, that this ratio is not kept up for the fainter stars, that is, there are not three times as many stars of the sixteenth as of the fifteenth magnitude. No limit to the universe has yet been reached, however. With the Bruce telescope stars can be photographed too faint for vision in the greatest

THE METEOROLOGICAL STATION ON EL MISTI. 19,000 FT.

telescopes of our day; but increase in exposure always brings out new and fainter stars, until the practical limit of the exposure is reached in the fogging of the plate by the diffused light of the sky. The longest exposure yet made in this observatory was with the Cooke lens, an exposure of twenty-four hours, on four different nights. Such an exposure in such an instrument brings out with great perfection the wonderful beauty of the cloud-forms of the Milky Way.

Since the establishment of the Peruvian station, meteorology has formed an important, though subordinate, part of the work. For about ten years a line of auxiliary stations was maintained, reaching from the Pacific across the Andes to the low country on the upper waters of the Amazon. The culmination of this series was the station on the summit of El Misti, at an elevation of nineteen thousand feet. The conditions for reaching great altitudes are exceptionally good in



The City of Arequipa.

this part of Peru, but even here it was found impossible, with the funds available for this purpose, to keep observers at the summit, in order to obtain systematic personal observations. It was necessary to depend chiefly on the self-recording instruments of Richard Frères. The station was established by the writer in 1893, and was visited later by different members of the observatory, or by some person engaged especially for the purpose. At such visits the observer rewound the self-recording instruments and made personal observations. This station was continued for about seven years. The records were broken, and not always of the highest accuracy, but it is believed that they will be of service to meteorology. Personal observations of the highest precision at this station are much to be desired, but a special gift for this purpose would be necessary. Few persons could live, even for a few days, at such an altitude. Nearly every one suffers from mountain sickness, and sometimes very severely. Nevertheless, there are sufficiently well educated persons, born in Peru at a high altitude, who could be engaged for a reasonable sum to pass alternate weeks at the summit. In this way, for a few thousand dollars, complete records of great precision and value to science might be obtained. There are also problems in astronomy and physics, which could be investigated at a well-equipped station at such an altitude, which perhaps can never be solved at sea-level.

Arequipa is a city of about thirty thousand inhabitants. It lies on the western slope of the Cordillera at an elevation of seven thousand five hundred feet. No more beautiful view can well be imagined than that which is seen as one approaches Arequipa from the coast. It is built of a soft white volcanic stone, and in the distance appears to be a city of marble. It is surrounded by wide-spreading green fields of wheat, corn and alfalfa. It is in a region of volcanoes and earthquakes, but the danger from these is slight, either to observers or to instruments. The observatory is situated on rising ground, about two miles north of the city, at an elevation of eight thousand feet above sea-level. To the north rises the great range Chachani, about twenty thousand feet in elevation; to the northeast El Misti, a volcanic cone nineteen thousand feet high; and to the east Pichu-Pichu, over seventeen thousand feet high.

The climate of Arequipa is superb for those who do not object to a somewhat rarefied and dry atmosphere. There is scarcely any seasonal change in temperature during the year, though the diurnal range is fairly large. The mean maximum and minimum temperatures for the year 1902 were 68° and 49°. In the observatory residence, which is built of stone, the temperature without artificial heat ranges between 60° and 65° Fahrenheit. The rainfall is slight, amounting to only two or three inches during the year. Agricultural pursuits are possible only by means of irrigation. Around the fertile fields, in whose center lies the city, extend endless barren pampas. All the waters of the Chili River, however, are now well utilized, and there is no other convenient supply.

The people of Peru, and especially of Arequipa, have always taken great interest in the observatory, and have extended to it many favors and constant good-will. There is a university in the city of Arequipa which is supported by the Peruvian government. There is no lack of educated and refined Peruvian society, and in addition there are American, English and German colonies. The laboring and servant classes are half-breeds, usually illiterate and careless, but kindly and contented. Besides these, especially in the interior, are large numbers of civilized Indians. In the low lands lying about the head waters of the Amazon are also numerous groups of savages, but they are never seen near Arequipa, and are slowly becoming half-civilized or disappearing. Revolutions have been numerous in the past history of Peru, and one occurred since the establishment of the station in Arequipa, but not the slightest indignity was offered to the observatory or its members. The common people of Peru, even in time of revolution, are not dangerous, and those who are not actually engaged in warfare are seldom molested. It is a game of politics, carried on by bullets instead of ballots, and without permanent hatreds. For several years past no revolution of importance has occurred, and there are strong indications that Peru has at last entered on a career of peace and prosperity. Such, at least, is the earnest wish of her best citizens.

THE ROYAL PRUSSIAN ACADEMY OF SCIENCE AND THE FINE ARTS. BERLIN.

BY EDWARD F. WILLIAMS,

CHICAGO, ILL.

II.

History of the Royal Prussian Academy of Science and the Fine Arts from its reorganization under Frederick the Great till his death in 1786.

UNDER the patronage of the new king, which was continued with increasing sympathy during the forty-six years of his reign, the academy in Berlin acquired world-wide influence. The Literary Society of Berlin, which had been a serious rival, was united with it, and the new organization was named The Royal Prussian Academy of Science and the Fine Arts. The king had intended, it is thought, that Voltaire should be its president, but for some reason, greatly to the mortification of the Frenchman, Francis Algaratti, of Paris, was given that honor. But he did not retain it long.

The king was anxious to have Wolff, the philosopher, in the academy as a representative of the thought of the new time, and Maupertuis, of Paris, as a representative of the attainments and the spirit of Sir Isaac Newton. Wolff did not care to leave his professorship in Halle, and though Maupertuis was made one of 'The Immortals' of the French Academy in 1743, he came to Berlin in 1741, and at the king's wish, assumed control of the academy and continued at its head till his death on July 17, 1759. In 1743 the last volume of the Berlin 'Miscellanies' was issued. The academy now entered thoroughly into an era of reorganization. Its publications became cosmopolitan in character. Even if expenses increased the income grew. Men of distinction began to think favorably of Berlin as a home, and of membership in the academy as desirable. New societies for the study of natural history and literature, for which the inefficiency of the academy had furnished an excuse, were united with it on the broad plan of Leibniz. In the reorganized institution there were to be classes for the study of physics, mathematics, philosophy and philology, with a director at the head of each class. There were to be 24 members, and these were to be selected by the king from lists of names placed in his hand. The members of the old academy were all retained, but new men of the highest standing only were granted membership in the new institution.

FRÉDÉRIC II.

Each class had the privilege of choosing its own secretary or director, but in addition there was to be a general secretary entrusted with the business and general interests of the academy. A treasurer was also appointed and provision made for two public meetings every year, one on the king's birthday. In later years one of these public meetings has been held on what is called 'Leibniz day,' July 11. Sessions were held weekly on Thursday afternoons. New members were nominated by the class they were expected to join, but the nomination had to be approved by the directory of the academy, which was made up of five secretaries and other officers, then by a general meeting of the academy and last of all by the king. It was decided that prizes should be offered every year and that papers of foreigners, if worthy, should be printed in the proceedings, as well as those by the active or honorary members of the academy. By the king's order the sessions of the reorganized academy were held in the castle. They began on January 24, 1743.

It is difficult to give a full history of the academy while Maupertuis was at its head. He preserved few papers. Although the roll of officers was full, he was really the academy. It was through his influence that men of distinction abroad became corresponding or honorary members, and some, at his solicitation, even came to Berlin that they might work in it and through it.

Deeply interested in the academy and writing papers to be read in its literary department, the king attended neither its private nor its public sessions. Nor till toward the end of his reign did he bid any of its members, save Maupertuis, to his palace. Even Formey, the famous secretary, was not called to Sans Souci till the king had been thirty-eight years on the throne. The social circles in Berlin and Potsdam were not quite the same. Maupertuis made the academy French in its thought and its aims. Under his guidance and that of his successors it was composed of a group of French scholars residing on German soil. Maupertuis was one of the most gifted men of his generation. He had great learning, was a diligent student of natural history and possessed rare powers of conversation. But his influence was lessened by his egotism and his pessimism. Still he did his best for the academy. Its 'Memoires' were sought for in every learned circle in Europe. Membership in it was regarded by scholars as the highest honor they could receive. Its atmosphere was tolerant. There were no limits put upon research or upon free speech. Though German was not absolutely excluded, the discussions carried on in the academy were in French and the 'Memoires' were printed in French. There were more French-speaking Swiss in the academy prior to the death of Maupertuis than native-born Frenchmen or Germans. Switzerland was producing more learned men than she could sustain, and was willing they should go to Berlin or wherever else they might employ their talents to advantage.

The academy suffered from the seven years' war (1756–1763), but its regular work continued, though few new members were added during this period. From 1760 to 1764 no 'Memoires' were published. While Maupertuis was absent on account of the wars and in search of health, Euler acted as president, and proved himself well qualified for the duties of that office. But the king had no intention of filling it with a German. The man he wanted was d'Alembert, of Paris, to whom he offered a large salary, rooms in the palace and a seat at the royal table if he would come to Berlin. But d'Alembert belonged to the French Academy and did not care to leave Paris. Yet, through his correspondence with the king, in which during these years the best history of the academy is found, he directed the work of the German academy and determined its membership. Virtually he was its president, though the king as its protector may be said to have assumed that office himself. In these conditions the academy became more French in its spirit than ever. In spite of the fact that the forty-six years of Frederick's academy were years of the first importance for the development of science and literature in Germany, neither the king nor his French presidents took any notice of the new spirit which had arisen among the German people, and had begun to show itself in the academy. Euler, disappointed at the turn matters had taken, after twenty-five years of hard work in Berlin, asked leave to return to St. Petersburg. For a time the king declined to grant the request, but its renewal finally secured his assent, though without any recognition of the fame Euler's attainments and publications had brought the academy and Berlin. Ten years later, on accepting honorary membership in the St. Petersburg Academy, at that time a rival of the Berlin Academy, the king wrote Euler a letter accepting the honor secured for him, and in it made something like an atonement for former neglect. La Grange, of Turin, second only to Euler as a mathematician, was elected to the vacancy Euler's departure had made, and about the same time J. Heinrich Lambert, another mathematician of note, came into the academy. Prior to d'Alembert's connection with it the Eulers, father and son, Pott, Marggraff, Gleditsch, Merian, Sulzer and Suessmilch had given it fame. Other men of rare ability had been persuaded to come to Berlin with the promise of membership in it, but with the understanding that they were to teach in the Ritterakademie, an institution in which the king took much pride and which he founded.

Not many changes in the academy took place during the last sixteen years of Frederick's reign. Between 1766 and 1770 two volumes of 'Memoires,' which the war had prevented from appearing, were published. With the next issue a new series of 'Memoires' was begun, greatly improved in binding and paper. Each of these new volumes contained a brief history of the work of the year.

D'Alembert died on October 29, 1783, sincerely mourned by the king. He had rendered the academy as good service as any one could, living in Paris. He and the king had not always agreed in their policy. D'Alembert not only desired the utmost freedom of research, he wanted the whole truth as it appeared to be at any particular time

PIERRE-LOUIS MOREAU DE MAUPERTUIS.

given to the people. To this the king would not consent. He often quoted Fontenelle's saying, 'If I had my hands full of the truth I would not open them to give it to the people. It would not pay for the trouble.' Harnack says the chief aim of the king was the welfare of his subjects, and that, free thinker as he was, he was no atheist and would not accept the opinions either of Hume or Holbach. He loved

the truth, and did not mean to withhold it from the people forever. But he believed in preparing them to receive it before giving it to them. Hence in part his interest in education, and an explanation of the famous rescript of September 5, 1774, which, as carried out by Minister von Zeidlitz, became the foundation of the improved methods in Prussian teaching. Logic, the king wrote, must be taught effectively after the manner of Locke and Quintilian, and Latin and Greek in such a way as to bring young men into their atmosphere.

The sincerity with which the king held his opinion as to the proper treatment of the people is seen in the fact that he directed the academy to offer a prize for the best answer to the question, 'Is it lawful, *i. e.*, right, to deceive the people?' At the time of d'Alembert's death the philosophical class in the academy had shrunk to three members. Again turning to a Frenchman for help the king asked Condorcet, permanent secretary of the French Academy, to take d'Alembert's place in directing the work of the Berlin

IMMANUEL KANT.

Academy. Condorcet consented, but the new relation lasted only sixteen months.

It had at length become evident to all German scholars that their academy needed new blood. Its men of fame were growing old. They had done their work and had lost in a measure their ambition. The king was growing old also. The changes so necessary and so greatly desired came, but not till after a new king was on the throne. When Frederick died, only five Germans belonged to the academy—Gleditsch, Gerhardt, Roloff, Walter and Schulze—and they had little influence in its councils. It is not surprising that many felt that it was a discredit to Germany that Germans should have so small a part in determining the character and directing the work of one of their representative institutions. It was time, men said, that Germans should be at the head of a German academy of science. It had been ruled long enough by absentees. Even Leibniz had resided in Hannover during his presidency, though he had visited Berlin as occasion demanded and, being a German, had sought to develop the German spirit. This had not been the case with Maupertuis, or d'Alembert, or Condorcet. Hence the demand for such a reorganization of the academy as would make it thoroughly German and representative of German intellectual life. The change, so uniformly desired, was brought about by one of its members, Minister von Hertzberg, who was made its curator by Frederick William II. at the very beginning of his reign.

Before passing to consider the history of the academy under the successors of Frederick the Great, who died on August 17, 1786, and in its distinctively German period, something should be said concerning the contributions to learning and the new thought which its members had made. There can be no question that the papers written by the king, for the department of fine arts, and read by some one whom he designated, are among the most valuable possessions of the academy. This is one of the reasons which has led the academy within recent years to prepare and publish a complete and worthy edition of his writings.

From the beginning the academy sought to advance science and encourage sound learning in Germany. That this was so long done under the direction of Frenchmen did not really affect the result. But much as members of the academy were enabled to do for science and literature through the publications and reports of the academy, they did far more as individuals, and by private publications. Early in his reign Frederick the Great expressed a wish that the members of the academy would give the results of their studies and experiments to the public in the shape of lectures, and, though this was not generally done, lectures were given by Gleditsch, the botanist and the founder of the botanic garden of Berlin, to the medical students, and, at the same time, other members of the academy made their discoveries known to the people. Thus Gerhard lectured on mineralogy, metallurgy and the theory of mining, and Achard on chemistry, experimental physics and electricity, so that by 1780 there was a university in Berlin in everything save name and organization.

After 1744, through the subjects proposed for prizes, the academy became a sort of guide in study and research for some of the best minds in Europe. Small as the prizes were, fifty ducats at first and after 1747 a gold medal, they were contended for by the most eminent scholars and thinkers of the day. Such men as Euler, La Grange, d'Alembert, Kant, Rousseau, Herder, Lessing and Moses Mendelssohn entered the lists for them. In general, the themes proposed required a thorough knowledge of an entire discipline and a discussion of its fundamental principles. For the prize of 1780 forty-two papers were sent in. During the forty-six years of Frederick's reign 26 German works were crowned, and 10 French. One written in Italian received the prize. Of 45 themes treated, 20 were medical or physical in their character, and 25 philosophical, philological or literary. It is a fact worthy of note as indicating the intellectual attainments of the ministry of the period, that ten of thirty-eight works winning the prize were written by ministers of the Reformed or Lutheran church. In the twenty years following this period the average was even higher.

The eighteenth century was not favorable to exact historical study. It was fortunate, therefore, that the academy continued to offer prizes for the discussion of historical themes. The spirit of the time was philosophical rather than scientific or historical. The successful didactic poet was in most circles thought to have realized the highest ideal of life. The writings of Rousseau, Kant and the German idealists were the means of extending the range of thought, giving it a new direction, and of introducing a series of questions which demanded immediate and thorough answer. Advocates of the Leibniz-Wolff philosophy were opposed by the followers of Newton and the French school. For a number of years themes were presented by the academy which seemed to have for their object the overthrow of the philosophy of Leibniz, and the substitution of that of Newton in its place. But these were not the only subjects discussed. J. D. Michaelis, the orientalist, won the prize for 1759 by pointing out, in the best way possible at the time, the reciprocal influence of the people on their language, and of language upon opinion. In 1763 Moses Mendelssohn answered, in a manner which satisfied the academy, the question, 'Is metaphysical knowledge susceptible of the same evidence as mathematical?' and received the prize, though he had no less a rival than Immanuel Kant. Yet the rejected essay of Kant gave the death blow to the philosophy of Wolff. Cochius, court preacher at Potsdam, received the prize in 1768 for an essay on the topic, 'Is it possible to destroy natural inclination, and how may one strengthen the good and weaken the bad?', but even here it was Kant who stated the problem so effectively as to overthrow the philosophy of the *Aufklärung* and to establish ethics upon a new and firmer basis. The origin of language was discussed in 31 treatises in 1769, and the prize awarded to Herder, who took the ground that it is neither divine in its origin nor an invention of men, but a gradual growth springing out of the necessities of human nature and therefore imperfect and incomplete.

One hundred years later this essay received the approval of Jacob Grimm. In 1775 Herder won a second prize by an essay on 'The degeneration of taste in various peoples,' and in 1780 on the theme, 'What has been the influence of government on letters among the nations where they have flourished, and what influence have they had on government?' These essays were epoch-making for historical study. In 1784 the theme was, 'What has made the French language the universal language of Europe, or by what means did it win this prominence? Can we believe that this prominence will be permanent?'

Lambert, a man whom Kant regarded as the greatest genius of his time and in whose judgment as a critic he had complete confidence, died in 1773, after a membership in the academy of thirteen years. While he lived he read all that Kant wrote before it was given to the world. He composed essays for three of the four classes into which the members of the academy were divided, published in addition to these papers, fifty-two treatises, perhaps one hundred pamphlets, and ten very large works. Not a little was accomplished by the academy during these years for geology and mineralogy, as well as for astronomy and mathematics. Pott made the academy famous in chemistry, but Marggraff and Achard were large contributors to the science. Walter succeeded Meckel, the anatomist, in 1773, and laid the foundation by his splendid achievements of the anatomical museum of the University of Berlin. Neutral as the academy was in its philosophy, it yet prepared the way for Kant and the general acceptance of his opinions in Germany. It was equally neutral in religion, and in morals it sympathized with the king, who admired, and probably made his own, the opinions of Marcus Aurelius and the Stoics. The academy, through Maupertuis, Euler and La Grange, made the works of Newton known to Germany, and in this way, as well as in many other ways, stimulated and directed the scientific movement among all the German-speaking peoples.

Some idea of the industry of the members of the academy may be formed if we observe the number of works credited to them in its catalogue. The secretary, Formey, leads with 140 titles. John Gottfried Gleditsch has 36 titles. To Gerhard, the geologist, there are given 21 titles, while the younger Kirch, the astronomer, has 27 titles. Euler, in the quarter of a century he lived in Berlin and worked in the academy, published in its transactions 121 complete treatises, through other channels at least 700 more, and, in addition, was the author of 32 quarto and 13 octavo volumes. La Grange, his successor, the discoverer of the calculus of variations, during the thirteen years of his life in Berlin published 52 important treatises, about 100 pamphlets and 10 large works. From 1746, when the era of publication really began, to 1771, 25 volumes of 'Transactions' appeared and 65 volumes of what are called historical writings. The publications were even more important between 1771 and 1786. The income of the academy at the death of the king was nearly $18,000, devoted, it was supposed, entirely to the discovery and extension of knowledge, and yet, as a matter of fact, expended to such an extent for buildings and the payment of salaries at the order of the king as to leave comparatively little for the support of original investigators, or for costly experiment and research. In fact the management of the academy, even under Frederick the Great, was so unsatisfactory as to furnish excuse for the formation of many learned societies in Berlin, in some of which members of the academy took a leading part. Thus in the philosophical society, which flourished from 1773 to 1798, men like Mendelssohn, whom the king would not have in the academy, Nicolai, Teller and Engel were prominent, and a society of naturalists was formed during this period by the aid of Gleditsch, the botanist, one of the famous men in the academy. Yet with all its failures, and the fact that it was so completely under French influence, there can be no doubt that the Prussian Academy of Science and Fine Arts at the death of Frederick the Great had become the center of the scientific and critical movement in Germany, and was regarded all over Europe as a worthy rival of the Royal Society of Great Britain and of the French Academy in Paris.

THE INFLUENCE OF LIEBIG ON THE DEVELOPMENT OF CHEMICAL INDUSTRIES.*

By Dr. CARL DUISBERG,

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THE chemical industry is a child of the nineteenth century. The inorganic branch, the so-called industry of heavy chemicals, such as the manufacture of sulphuric acid in lead chambers, the manufacture of nitric acid, of hydrochloric acid, of sulphate, the manufacture of soda according to Le Blanc's process, the manufacture of chlorine and bleaching powder according to the processes of Deacon and Weldon, was already in operation in the first part of the nineteenth century, while the organic branch of the industry, the manufacture of coal-tar products, of the organic intermediary products, of the aniline and alizarine dyestuffs, pharmaceutical and photographic preparations, the artificial sweeteners and artificial perfumes, and the whole crowned by the synthesis and manufacture of indigo on a large scale, became known only in the latter part of the last century.

As Liebig's influence on the education of chemists and on the chemical industries was chiefly exercised during the time he lived in Giessen, that is until about 1860, and as this influence became of course perceptible only very gradually and slowly, it is evident that the *organic* chemical industries owe most of their progress to Liebig, and therefore I shall devote my remarks chiefly to a description of this influence.

As every branch of industry is originally the result of empirical research, it is very rare for men of great scientific knowledge to become the founders of any new industry. We find that almost invariably energetic and enterprising merchants, who possess some technical skill, are at the head of such undertakings; and thus we find at the beginning merchants as managers of the factories of the organic chemical industries. Scientific research pointed out the direction in which the gold fields were to be discovered, and enterprising and energetic men marched on the road indicated to the unknown regions, provided with the simplest tools, to uncover the golden treasures and to free them from the gangue which hid them from the view of mankind.

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* An address delivered before a joint meeting of the New York Sections of the Society of Chemical Industry, the American Chemical Society, the Verein Deutschen Chemiker and the Chemists Club, held in celebration of the one hundredth anniversary of the birth of Justus von Liebig.

This was the case with the first works for the distillation of tar, as well as with the coal-tar color factories. Tar was *not* distilled and split up into its various component parts according to principles which were founded on rational and exact chemical research, the different hydrocarbons thus obtained were *not* nitrated, reduced, sulphonated, condensed, etc., in order to be converted into intermediary products and dyestuffs by processes discovered by the scientific investigator. These operations were executed by the rule of thumb, by men who had been engaged in kindred industries, in metallurgical works, in dye-houses, or in pharmacies or drug houses. These men worked in mere sheds, with vessels which for the most part were taken from the kitchen. There were no chemists; there were no laboratories. If it became necessary to analyze the inorganic crude materials which were used in the manufacture, it was done in a remote dark corner of the factory by so-called chemists, who were only educated in analytical schools. Instant dismissal was the penalty at that time imposed upon any chemist who dared to enter any of the rooms where the manufacturing was going on, to try to familiarize himself with the processes for the preparation of various products. The supervision was exercised by so-called practical men, who were ignorant even of the simplest principles of scientific chemistry, who derived their methods for the manufacture from mechanical experiments and who kept the formulæ a deep secret, just as the alchemists concealed their receipts for the art of making gold.

Meanwhile Liebig had shown by his work in the laboratory in the quiet and far-away Giessen, by lectures and publications, what important treasures could be found in all branches of agriculture and industry by scientifically educated chemists well trained in laboratory methods, in analyses and syntheses of chemical bodies. He had shown that a knowledge of general chemistry and of its scientific principles and practical methods enabled men to advance all branches of the industries.

Liebig's staff of excellent pupils made their way to all quarters of the globe to disseminate his ideas and to assist agriculture and the industries. The light of scientific research kindled by Liebig penetrated all branches of industry. It pierced into the darkest factory rooms which were guarded with many secret locks, and more and more the truth of Liebig's teaching became recognized, that agriculture and the industries would accomplish undreamed of results, if scientifically educated chemists were employed in all branches and were permitted to exercise control of all methods.

In consequence thereof we now see that these large factories, devoted to the chemical industries which have drawn into their circle the manufacture of all the heavy chemicals, the production of the intermediary products from the distillation of wood and coal-tar, the finished materials being aniline and alizarine dye-stuffs, indigo, pharmaceutical and photographic products, artificial sweeteners and artificial perfumes, are managed exclusively by scientific chemists. The practical man was forced to yield to the well-educated theoretical man.

Laboratories in which are to be found all the modern apparatus and implements of science and technique have taken the place of the dark cellars in which chemists were formerly imprisoned; magnificent libraries are at the disposal of the investigating chemist of the works, and everywhere Liebig's spirit rules and everywhere Liebig's methods are practised.

How much importance the German chemical industry attaches to the exclusive employment of scientific men, how these are educated at the universities and polytechnics, and what means are employed to maintain the scientific standard of the chemist, all that I had the honor of pointing out in a lecture, delivered seven years ago during my first visit to the United States before the New York Section of the Society of Chemical Industry. Meanwhile the number of chemists employed in our German factories has not only increased considerably, but we have also raised the requirements in the education of chemists whom we employ in our factories and laboratories. Where seven years ago, as I then stated, our factory, the Farbenfabriken vorm. Friedr. Bayer & Co. at Elberfeld, had only one hundred chemists, educated at German universities or high schools, we have now over 160 in our employ.

A systematic organization, founded on a scientific basis, encircles our works. No effort is omitted to bring to the notice of all the chemists every advance of science, so that they may utilize it for the benefit of our factory, and every new technical method is at once thoroughly investigated in order thus to gain new knowledge and create new products.

The details of such an organization are most interesting. The control of all raw materials, delivered at the works by water or rail and of all the intermediary products, are carried out by a central laboratory, which is devoted to analytical chemistry exclusively. In this laboratory a large force of analytical specialists is employed. Here are analyzed not only products which are bought by us, but also intermediary products which are furnished by one department of our works to another, and the exchange of goods within our factory is carried out by contracts which are concluded between the various departments. The analytical methods which are to be used and the conditions of the contracts are perhaps more stringent than if the material had been purchased from outside factories. When no analytical methods exist, as is frequently the case with new products, it is the task of the analytical laboratory to devise such methods, and the work demanded of our analysts is just as important and difficult as the task of any other chemist in our employ. Our analytical chemists must have the same scientific education as the others, and we consider them in position and rank on a par with any other chemist.

The manufacturing is of course in the hands of first-class chemists. The factory is divided into different departments. At the head of each department one of the most experienced chemists is placed as department chief, and he manages his section as a factory in itself. Thus our works are divided into the inorganic department, the departments for intermediary organic products, for aniline colors, for alizarine colors and the pharmaceutical department.

Each of these departments consists of a number of separate divisions which are again under the management of chemists, all of whom we have trained ourselves. The chemists of the different divisions belonging to one department have a joint laboratory whence they conduct the various manufactures, their main object being economical production and good yields. Each step of the reaction is continually watched analytically, and thousands upon thousands of experiments are constantly carried out to improve the processes and above all the quality of the manufactured products. These chemists have also charge of the machinery used in their departments, and a scientific engineer acts in conjunction with them.

Commercially educated employees control the consumption of chemicals of all kinds in each department, and based on their figures, and the figures of the consumption of water, gas, steam, ice, compressed and rarified air, etc., used in the processes, exact calculations are made for each product monthly. Furthermore, there are scientific laboratories, one for inorganic chemistry, another for coal-tar colors of the benzine and naphthaline series, a third for those of the alizarine and anthraquinone groups, another for pharmaceutical and photographic products. In these laboratories all reactions which seem to be of technical importance and which have been described in scientific and technical journals are tested as to the value. All the patents, issued in the various countries, are studied and their processes executed on a small scale. The new products which appear in the market are analyzed and investigated in order to determine their constitution and their practical value and to ascertain whether they can be utilized in the manufacture of any new products. It is further the duty of the heads of these scientific laboratories to inform not only the chemists who are working under them, but also the other works chemists, of everything new in chemistry, scientific as well as technical, and regular meetings are held, where reports are made on all new discoveries and publications.

The finished products of each department, both the coloring matters and the pharmaceutical and photographic products, are tested as to their efficiency in laboratories especially equipped for the purpose. The controlling laboratory for coloring matters is provided with all the machinery and apparatus used in first-class print works and dye houses. Here the coloring matters are practically applied, and it is ascertained whether they come up to the requirements or not, and only when their standard has been determined are they permitted to leave the factory. A very important part of the work of these control or testing laboratories consists in examining the many new products which are the results of the investigations of the scientific laboratories, as to their usefulness, and to find new methods of application for the older products.

As the colors are tested in the dye laboratory, so the pharmaceutical products are investigated in the pharmacological laboratory, at the head of which we have at our Elberfeld works a prominent representative of this science, who was a teacher of pharmacology and physiology at the University of Göttingen. His assistants comprise four physicians and two bacteriologists who are constantly carrying out animal experiments on frogs, rabbits, cats, dogs, etc.

It will be seen therefore that scientific and systematic research has in Germany taken the place of empirical experiments. Although every chemist is a specialist in his own branch, he is enabled to find his way in any other special line of chemistry on account of his thorough general education and the constant accessions to his knowledge.

We should never have reached and would surely not have been able to maintain the high standing which the German chemical industry holds in the world now-a-days, unless this scientific bent of mind, which seems to be a particular quality of the German national character, had governed our work.

As I did seven years ago, so I have this time taken a four weeks' trip through this beautiful country, and have seen many of the American industries. Owing to the extraordinary hospitality and courtesy of the inhabitants of all the cities visited, we have been allowed to inspect almost all the great branches of American industry. Aside from the various and magnificent textile works of the south and the east, we have seen the largest steel works and iron foundries, refineries of petroleum, glass factories, factories for all kinds of electrical appliances and machinery; and of the chemical factories we have visited some of those engaged in the production of heavy chemicals, factories of the organic chemical industry and especially those of the electro-chemical industry.

It may perhaps be of interest to learn what impression your industries made on a fellow chemist, not only at his first visit, but also during the present one, and I shall not hesitate to give frankly my impartial opinion.

At first sight it alarms us Germans when we observe what tremendous natural resources this country possesses—the wealth of lumber in your forests, the fertility of your soil, the mountains, the extent of the plains and valleys—all natural storehouses of great riches. If a hole is drilled or a drift is made in the mountains in some of the states, natural gas or petroleum is found; in another the finest of anthracite coal or soft coal, which furnishes the best material for coking and distillation; in a third state we find ores of every description; in a fourth salt, or sulphur; in a fifth, deposits of phosphates which are of so much importance in agriculture, while in some of them we find a collection of nearly all these products.

This is not the case in Germany. We are not blessed with natural gas or petroleum; anthracite coal is very rare. We have immense soft coal fields, but we must go down to a depth of two to three thousand feet, whereas in America it is at the surface, or in the very worst cases a depth of only three hundred feet must be penetrated. We have minerals, but not in such masses as here, and above all they are not of that purity which facilitates metallurgical processes. Only of salt have we as much as you, and more as far as potash salts are concerned, of which we have immense fields in Stassfurt. While with us the water in rivers flows gently and softly, and even for navigation our rivers need to be constantly dredged, you have in your grand country natural water courses such as are found in no other land in this world. In addition to this, your rivers rush down high mountains, so that every stream can be made a tributary to the industries. The millions of horse-power which are available in Niagara Falls, and have been partly utilized, give your country a decided superiority over all others.

But in spite of these natural advantages Germany has remained the ruling power in chemical industries, and I may venture to say that, in my opinion, we shall retain this commanding position in the immediate future. If I am asked to give my reasons for this opinion, I must say that the answer is neither simple nor easy, but I hope to be in the right if I remark as follows:

In view of the wealth of this country in products of all kinds, but in view of the want of labor, it has been and is still the chief task of the industry and of the engineer to devise means to render these products available in the simplest and cheapest manner. This is the field of the mechanical engineer, and American engineers, indeed, have accomplished the most magnificent results in handling and transporting vast masses and in the substitution of machinery for manual labor. This, indeed, is the essence and strength of the American industry and was the cause for the development of the mechanical industry, and in this respect America is the ruling nation and has set an example to the whole world.

But the conditions are quite different in the purely chemical branch of the industry, the object of which is to convert crude materials by means of numerous chemical processes and chemical forces into more precious ones; where a new process devised by a chemist revolutionizes the industries and makes the old processes unprofitable, even if they are performed by the most ingenious appliances constructed by the most talented engineer; where not only the art of construction, but the genius of the naturalist in recognizing the forces of nature and their products is necessary to accomplish the object in view; where never or only rarely the production of large masses comes into consideration, but where an endless chain of products of the greatest variety must be prepared in small quantities.

If I have sung the praises of the American engineer and of the American mechanical industry in the preceding portion of this lecture, I must now express my satisfaction with the German chemist and the German chemical industry. In this field lies the strength of Germany—a consequence perhaps of the peculiarity of the German character. Forced by the want of natural resources and unprovided with American abundance, the German in scientific exploration must proceed in a cautious and economical manner, always bent on patient and minute research. He is forced to live a simpler life and to be modest in his demands, which is contrary to the American temperament.

It is true you have already a very important industry in the inorganic field of our science and produce large quantities of acids and alkalies and, above all, of metals. In consequence of the immense and cheap water power at your disposal, a very remarkable electrochemical industry has been developed. But these works manufacture at present only inorganic products, and so far as I can see it is impossible up to date to manufacture organic products as economically by electro-chemistry as it is possible with the older chemical methods. You have also begun to isolate the products of tar distillation which are formed during the coking of coal, and it is intended to convert the hydrocarbons thus obtained into more intricate organic products. You have also the beginning of a coal-tar color industry, due to the protective duty of thirty per cent. ad valorem. I have also noted that in metallurgical and textile works, but above all in factories of heavy chemicals and pharmaceutical specialties, chemists exercise analytical control of the raw materials which enter into the process. At some places we found wonderful laboratories in which many chemists were employed. We saw above all how your universities and technical schools are endeavoring to promote our science. Excellent representatives of scientific chemistry are employed as teachers. Scientific research is carried on more and more. But, notwithstanding all that, I think that we Germans need not be alarmed in the near future. The time for the development of the *organic* chemical industries on a large scale has not yet arrived. As I have shown before, the Germans are masters in manufacture where numberless products are employed in a series of reactions which finally lead to the finished product, and require manual labor, which can not possibly be replaced by machinery, while Americans may claim to be masters where manufactures on a large scale are concerned, which can be done by machinery. Yet we must not leave out of consideration the very important facts that in America wages are extraordinarily high, that the conditions of life are here much more elaborate, and last, but not least, that the employees, and more particularly the workmen, manifest a spirit of independence, which has become especially noticeable during the last few years. By their labor unions the workmen attempt not only to raise wages to a height which will make manufacturing difficult and less profitable, but they are also endeavoring to take the control of the works out of the hands of the educated managers and put it into the hands of irresponsible labor leaders. This movement, as I have above shown, is especially fatal for the chemical industry in which our glorious science should be supreme. But nobody can deny that times will change in all these respects. Then you will be obliged to husband more economically your natural treasures, and you will experience changes which with us, in the course of historical development, are already things of the past. But this accomplished, the *organic* chemical industry of this country will commence to flourish. It will be found that the only way that leads to success in chemical manufactures is a combination of science and technics, the two branches of which eminent representatives are to-day assembled here, men who in their spheres have done so much already for the advancement of industries. It will be found that technical progress in this industry can only be secured on the basis of purely scientific research, and to the man who first recognized this fact and taught it to the world, to our great fellow countryman, Justus von Liebig, not only the German, but also the great American, nation, nay the whole world, owes eternal gratitude.

THE CONSERVATION OF ENERGY IN THOSE OF ADVANCING YEARS. III.

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How to Postpone the Degenerative Effects of Old Age.

A REVIEW of the foregoing phenomena of advancing years points clearly to the line upon which these may be in part controlled or delayed. It is not to be expected that we can secure the cooperation of most, or indeed many, people in pursuing preventive measures. If that were possible, and when it is possible, great things could be accomplished. However, certain principles obtain here which should be outlined so that whosoever may see fit to do so can follow these suggestions to their advantage. It will be found that the evidence of those who have studied this subject most carefully shows that normal bodily exercises are not to be forbidden, but rather encouraged. *Per contra,* if bodily activities are not pursued there must inevitably follow much more rapid retrograde changes in all the tissues. In respect to the diet it is universally admitted that after middle life the amount of food taken should be less than before that time and the changes in diet should be rather to use less of the structure-forming materials, though not always to exclude them. Again there should be used relatively little, indeed as little as possible, of stimulating articles of food, which make more for acceptability than necessity. In short, the simple rule should be observed of eating no more than a perfectly normal appetite craves, and as little as possible of those things taken because they are agreeable. As the period of old age is reached, by which is meant about seventy years, the regimen should be markedly simplified and always taken with the greatest deliberation. A general rule is recognized to obtain in most cases, that the more nearly the diet is reduced to bread and milk and fruits the longer will the person live and enjoy good health. It must be borne in mind, however, that exceptions will occur, and where the strength is being rapidly lost from any cause it is wise to increase the variety and encourage food taking until the strength is restored to the normal for the age reached. The digestive processes, as well as all the processes, are slower in advancing years.

Some persons can get along best with long intervals between feeding; others, the majority, do better by taking small amounts of food at short intervals. The evacuations appear lacking in activity and must be encouraged by rational measures, but not forced by purgative or strongly diuretic drugs. This is best met by suitable articles of diet, bulky and yet not calculated to produce fermentative changes. Such qualities are found in fruits, nuts, cereal compounds and salads. Probably the best drink is buttermilk, which seems to have a salutary effect on the action of both the bowels and the kidneys. Next comes koumyss or zoolak, upon which some elderly folk have been known to subsist almost entirely for years. It is easily made at home and can be thus supplied fresh and sound and is within the reach of all, poor as well as rich. Of the cereals, Indian meal is in some respects the best, in the form of either bread or porridge. Overmuch yeast bread is objectionable, disturbing digestion and encouraging rigidities. The question of the red meats must be studied with regard to the peculiarities of the individual, but is needed very little, usually not at all. Of fluids, these are best taken in abundance, but where the heart is weak it is not wise to take them freely before exercise, as at this time they throw a perilous strain on the cardiac structures. Medicated waters are oftentimes useful, but the less inorganic drugs enter the system the better. The habit of constantly using lithia salts, exerting as they do a certain form of irritation, is to be condemned. If arteriosclerosis is present the vaso-dilator drugs are useful, especially in the forms of natural mineral waters; aconite suits many better than nitrites.

The care of the skin is of paramount importance, and the first desideratum is to employ systematic and thorough rubbing and brushing of the surface from head to heel. The flesh brush or mitten made of coarse toweling, used by the patient for half an hour at a time night and morning, serves many admirable ends and is better than too much bathing. A good plan is for the patient before rising to employ this skin stimulus and mild exercise thoroughly while in the recumbent position; if preferred and he is strong enough it is better done while sitting. The skin of old age tends to become harsh, rigid and dry, and after this effleurage it is well to rub into the body a certain amount of some oil, and it will be found that the skin will take up thus sometimes an enormous quantity. Olive oil or cocoa butter is perhaps best, but preparations containing lanolin are excellent, especially if it is desired to increase the weight and aid accumulations of fat. Sometimes crude petroleum is found useful where stimulation of the surface is required. If the skin be hypersensitive, thought must be given and changes advised in these procedures until the skin becomes inured to a suitable amount of mechanical stimulus. Old people are sensitive to cold because their surface resistance is lowered and their heat-producing powers are waning. The tendency shown by many to stay indoors and keep themselves overprotected and over-clothed is a grave error. This habit should be overcome gradually but firmly, and the patient should be in the open air as much as possible, the clothing used being sufficient, but never too much.

This is particularly true of underwear, which should be light and porous, preferably linen next to the skin, which can be supplemented by extra woolen underwear placed over this to vary with the conditions of the temperature. Outings are essential to encourage free oxygenation through the lungs and the skin. Chill of surface is much more likely to follow exertion where too much or too heavy underwear is used, and the results are far more serious than if there is too little. If the skin be leaky, becoming readily moist on exertion, excessive precaution must be used lest secondary chill follow. If the underwear is made damp by exercise, it is important to change this as soon as possible and whenever it is produced. Above all the foot gear should be frequently changed to secure airing of these over-clothed members.

The most important specific recommendations I wish to offer for the postponement of the degenerative effects of age and for the recovery of so much of the normal vigor as is possible in each have to do with the forms and qualities of the exercises. As has been shown, the tendency of the tissues in advancing age is toward a steady and irretrievable hardening or stiffening or loss of elasticity, due to normal or abnormal increase in the connective tissue. The results of these changes are seen not only in the rigidity of the spinal column and ligaments, the skin, the muscle sheaths, the structures of the blood vessels, the connective tissue framework of the great organs, etc., which are obvious enough, but the really disastrous effects are those brought about by this xerosis upon the organs concerned in the processes of nutrition and of the special senses. This point I do not see brought out in any literature which has met my eye. Let me illustrate this. We have, as age creeps on, a loss in cellular activity in the functions of the special senses, well shown for example in dimness of vision, loss of hearing and slowness of cerebration. Much of this is inevitable and must continue. Some of this, however, can be delayed almost indefinitely. It will be observed that the tissues about the neck of an old person exhibit conspicuous loss of elasticity, so much that oftentimes dense rigidities are present, especially marked in the nuchal region.

I have been surprised and gratified to find that regulated movements of the neck and upper truncal muscles, employed for the purpose of accomplishing something else, resulted in a conspicuous improvement in hearing, in vision, in cerebration and, as a consequence of a betterment in cerebral circulation, also in sleep. Following this thought I have repeatedly been able to promise, and fulfil the promise, that an individual who had suffered impairment in these particulars should enjoy distinct improvement in the function of sense organs by employing regulated movements.

What is true of these structures is equally true of the abdominal viscera. A large proportion of the digestive disturbances, even of those in earlier middle life, are due to a relaxation in the supporting tissues of the great organs in the abdomen. It is estimated that dilatation, and letting down of the stomach, will be found in sixty per cent. of all adult persons. Oftentimes there are no symptoms indicating this, but when present they point toward a series of disturbances resulting from loss of muscular quality in the stomach itself. In those whose abdominal walls are feeble the organs have a tendency to sag and droop. This produces a series of alterations in the relationships of the organs and particularly of the blood vessels and structures concerned in their function. In the case of the kidneys, whose support is largely through the vessels which enter and leave them, and whose shape is so nearly spherical that they move readily, the suspensory tissues are not seldom twisted, thus shutting off the passage of waste material and interfering with the action of the nerves to the extent sometimes of causing pain and suppression of the function. In females this tendency to ptosis falls seriously upon the genito-urinary cycle, hence the uterus and ovaries are thrown out of their normal adjustments. In women who have borne children the abdominal parietes have all suffered more or less overstretching, and the slackening of these supporting tissues works mischief and discomfort. In some men, too, this is experienced. It becomes especially conspicuous where faulty attitudes are added to the structural defect. I have elsewhere expressed my opinions more fully on this and offered suggestions for relief (*Phila. Medical Journal,* January 10, 1903). These visceral ptoses are recognized as of large significance and their remedy is a matter of increasing importance. It can be seen at a glance that misadjustments of the abdominal organs require attention, sometimes to a very pronounced degree. The first means of relief sought by women is by the use of various forms of the corset. This garment is so universally used that we are compelled to accept it as a necessity, although I am of the opinion that we could get along very well without it if it were possible to bring women to believe so. However, the main thing is to induce women to use those corsets which will do the least harm. A certain amount of harm inevitably must follow the use of a needless artificial support. The walls of the abdomen should be competent to support the contained viscera. Where these walls are notably defective they should be supported artificially only until they can be trained to do the work adequately for which they were constructed. It is an axiom that all artificial support is merely for the purpose of conserving function until the tissues can be brought back to the normal. The first thing to be acquired in getting rid of these defects is to teach the person to stand correctly and continue to maintain proper attitudes under all circumstances. Wherever there is a stooping position maintained without effort at holding the abdominal organs in place voluntarily, there is a tendency for the abdominal viscera to pour out over the brim of the pelvis, which is thus necessarily in a slanting position.

If the neck-bones are held vertically, the ribs well lifted, and a moderate degree of tension exerted upon the abdominal walls, the viscera will rest upon, and within, the confines of the pelvis, and this position should be learned and practised; nor is it at all difficult if the attention is directed that way and some little familiarity acquired in maintaining the correct position. The body can not be held in normal attitudes unless the skeletal muscles are in fairly good tone. Most of these effects can be secured by a skillful use of breathing exercises.

It will be obvious to any one that those persons who habitually maintain an erect position in standing or sitting are stronger than those who stoop or slouch. It may be said that many of the last are perfectly well and strong, and it must be replied that they are not as well as and as strong as they should be, and further that their abdominal tissues are in perpetual danger, because an organ, or part of the body, which stands outside of its normal lines of adjustment comes closely to being in the position of a foreign body, and can not be so well protected by the central nervous control mechanism. Again, the position of the organs in the thorax are in less danger than those of the abdomen, because they have a well-constructed box to dwell in, but nevertheless they too are subjected to a good many perils if out of alignment. A person who stoops and allows the shoulders to sag down and forward and the ribs to fall back toward the spine, shortens the anteroposterior diameter of the thorax anywhere from two to five inches. It needs little demonstration to show that the lungs, heart, great vessels and other important structures in the thorax can not live, and move and have their proper being under such circumstances. Not only so, but prompt and adequate attention to these conditions results in not only improving the general health, but goes far toward maintaining symmetric functional action and the postponement of senile changes in the connective tissue.

In short, all these facts are rehearsed to give prominence to the conclusion, which seems to me inevitable, and abundantly demonstrated by data in my experience, that attention to proper attitudes, involving economies in interorganic relationships, is the one fundamental factor in postponing senile changes. The physiologic reason for urging care and persistence in retaining elasticity of tissues is to be found in the fact that sclerotic changes and faulty attitudes combine to interfere with peripheral vascular competence as well as peripheral innervation. To recur for a moment to the illustration used above, of the marked improvements following increased flexibility in the tissues of the upper thorax and neck, it is my opinion that this is to be brought about by thus promoting and encouraging fuller circulatory interchanges, especially of the lymphatic channels.

I am also of the opinion that arteriosclerosis is thus postponed, and sometimes prevented, hence the same principles hold good throughout the entire economy. It may not be necessary to develop this thought further, but to assume the truth of what I regard as an original observation, that systematized effort at elasticizing of the tissues is the basis upon which sclerotic changes generally can be delayed and made less. The means by which this result is to be attained consist chiefly in employing movements taught by a skillful person, and this should be the physician himself, assisted, it may be, by an expert trained by him to pursue the work in detail. Free exercises in the open air, proportional to the capacities of the individual, are of the greatest importance and should be regulated with the same care and supervised with the same conscientiousness as any other medical measures. Among those of the utmost importance are prescribed movements which differ in degree at least from the ordinarily employed remedial movements whose main object is to improve muscular tone, and which are largely flexor for the arms, with only a moderate degree of extensor activities. For older people there should be a steadily increasing attention to the extensors and less action demanded of the flexors. First these should be passive in the form of stretchings, rotations and torsions carefully and deliberately applied to the limbs and trunk and the neck. These should be moderately supplemented at first by voluntary movements in the same direction. Later, as vigor improves, and the heart action is strengthened, and the blood vessels recognized to be better able to stand the increased vascular tension induced by exercise,* these may be employed more forcefully until, by and by, the patient, even when well advanced in years, can endure a degree of muscular work which is surprising. Not only so, but this results in a feeling of well-marked enjoyment, not only of the restoration of sensations due to the improved circulation and in increased resistance to temperature changes, but in the procedures themselves which come to be distinctly relished.

In this connection let me say a word about the senile heart. It is generally accepted in a fatalistic sort of way that old people are unfit for activities, that they must do as they are inclined to do, little or nothing but exist, like vegetables. My own experiences and convictions in this particular seem fortified by the best authorities consulted. In my opinion the disinclination to movement and effort is rather the result of under-oxygenation, a habit, or other conditions which make for what one may almost call senile laziness, than an instinctive economic impulse. It is obvious that the healthier and happier old people are those who are reasonably active. My experience justifies the conviction that where activities have been encouraged, always with full

* This increased vascular tension as Oliver and others have shown, is quickly followed by a fall. Hence the most salutary means of lowering tension is by exercise to the point of skin relaxation—sweating.

estimation of the limiting conditions present, improvement results. This is true, and demonstrated to be so, under circumstances which would be considered prohibitive; for instance, where there have been observed those phenomena supposed to indicate threatened apoplexy, however that term be interpreted. I have had a number of cases under observation for many years where I was originally consulted for a train of symptoms which pointed toward cerebral changes such as vertigo, lapse of memory, sensory disturbances in hearing and in sight, formications, paresthesias, periods of brief unconsciousness, etc., in people of seventy years or more. Ordinarily the treatment advised for such conditions would be to reduce the individual to live the life of a hothouse plant. I have found in this contingency great practical advantage in attending to the cutaneous elimination, especially by frictions, oilings, massage, passive movements carried on to full stretchings as described above, and gradual increments of stretching exercises, forceful extensions and finally free movements and open-air life. Some of the individuals are now past eighty, strong and well. Even where there are found to be alterations in the kidneys, sometimes albumen, casts and sugar, the encouragement of the peripheral vascular stimulus was followed by the happiest results. Above all, in the cardiac arhythmias attention to the skin and regulated movements reduce these and sometimes cause them to disappear.

The pulse in old people, as has been said, is quicker than in middle life. The average of those cases reported by Humphrey, all of them over eighty years of age, were for men seventy-three per minute, and women seventy-eight, and the average respiration was seventeen. The proportion of regular to irregular pulse was four to one. I find irregularity in the pulse more common, indeed, it is generally present more or less even in the healthiest. Humphrey also found in the majority of old persons examined, little or no change in the arterial system. Clifford Allbut makes the assertion that in many cases of extreme age no evidence of arteriosclerosis is to be found. One of the oft-recurring phenomena of old age is edema due to the loss of vascular tone and defective lymph circulation. This condition would be much less frequent if the tissues, especially the larger muscles, were kept in a condition of elasticity, thus relieving direct pressure and occlusion of the contained avenues of circulation.

The exhaustion after fatigue is not well recovered from in the aged, and hence it is not permissible to maintain protracted activities; these should be supplemented by definite periods of rest, and if the heart be not strong this should be taken lying down, but this is no reason to encourage complete inaction. Again, the change characteristic of the bones of the aged, their loss of weight due to diminution in size, the walls of the shaft becoming thinned throughout from within, especially towards the ends of the bones, as at the head of the femur, forbids strong muscular exertion such as lifting. Nor should activities be sudden and severe, otherwise the danger of a false step and a fall may result in a shock or fracture or both. Nor is it important nor desirable that the muscles should be kept at their full strength, even if it were possible. The quality of musculature is mainly desirable for the purpose of oxygenation and to maintain full skin activity, freedom from stiffness and the consequent compression upon the blood vessels and nerves. In short, the component parts of the machine in healthy old age are slowly and equally weakened. They fail to respond to calls, the centers giving out less early than the outer parts, but these same centers should be maintained at their best for so long as it is possible. Finally the wheels of the machine stop. This slow decline is really a beautiful spectacle and requires the sheltering influences of civilization and sympathetic care. In the state of primitive society man died even as the animals and birds die, the one by the hand of the stronger. When assailed by sickness or age, death came swiftly from one or another agency of nature, either from animal or man. In civilization much vigor can be conserved indefinitely, or at least to well toward the century mark, provided the aged persons exercise judgment in the manner of life lived; and if cut off before a reasonable time the fault lies within themselves or their circumstances. In this slower decline it is more possible for disease and decay to become manifest, but even here prevention is a large possibility. If the heart, or the digestive organs, shall be kept disproportionately vigorous they will overload and press the other organs, and one of these, the weaker one, gives way.

The use of inorganic drugs has little place in relieving the grave disorders of the old. When these are found in the form of the natural mineral waters they have, since time immemorial, been held in high esteem for definite and indisputable good effects, the nature of which has never been satisfactorily explained. Modern studies on the physiology of the blood, especially of the serum, helps to account for this. Recently Trunecek, of Prague, has announced a method of treating the phenomena of arteriosclerosis which has been not only most successful, but suggestive, and seems to me to throw light on the value of mineral waters which will prove a rich field for research. His thesis is that certain salts can be introduced into the blood current which shall aid in dissolving the calcium phosphate found in the structure of the sclerosed vessels. Hence he adopted the plan of throwing into the circulation direct, by hypodermoclysis or intravenously, a strong solution of sodium phosphate and magnesium phosphate which are found normally in blood serum but only in minute quantities. His followers have obtained gratifying results, and many modifications are made of his original solution. Leopold Levi used this by the bowel and the mouth and it was found that the latter gave just as good effects.

Under this treatment the usual discomforts and evidences of disturbed circulation, such as dyspnea, asthma, vertigo, angina pectoris and prostration, rapidly lessened or disappeared far better than by the use of aconite, iodides and nitrites, although it occasionally transpired that when these last were also used the progress was more satisfactory.

It occurred to me to review the analysis of the various mineral waters, and I was surprised to find how many of them exhibited likewise many of these ingredients, in varying proportions, along with one or other factor to which the virtue of the water was chiefly attributed. Hitherto these factitious items have been regarded as indifferent or to them have been attributed various hypothetic or conjectural virtues. We have been long recognizing that the use of certain of the alkaline waters lessened the acidity of the urine and presumably of the blood, and the laity have been taught, partly by the profession but chiefly by the manufacturing chemists and the public press, that if ever the demon of uric acid can be laid, by the ingestion of enough of lithia salts or of some of the new and wonderful substances the special product of the great laboratories, their imperiled lives can be saved and most ills removed. The reaction against this notion has set in, but the fad remains, and will prevail long among the people, and the non-reading of the profession, that alkalies are helpful in a vast variety of vague states accompanied by the output of the uric acid in the urine common to about one fifth of the community. The real point of effort should be the restoration of the functional activity of the liver, which has to do with the conversion of ammonium cyanate, uric acid and other end products into urea. This is to be accomplished in a number of ways, the basis of which is to bring about bettered circulation in the liver and more complete functional power. For this, as well as to accomplish many other functional betterments, no single measure is comparable to regulated, deep breathing exercises. Complete expulsion is even more necessary than full inspiration. The abdominal muscles can thus be made to press upon the viscera, especially the liver and great organs, aiding largely in vascular interchanges hence secretion and excretion. By this means chiefly, if not alone, bowel action is sometimes regulated, and kidney competence enhanced.

There may be, and it seems that there is, considerable efficacy in the use of natural mineral waters, which exhibit a reasonable proportion of those salts that exert a solvent action on lime salts or other adventitious substances. Drugs, however, serve a temporary purpose and, in such conditions as the discomforts arising in beginning degenerative processes of age, would seem to need an indefinite continuance. The real curative remedy and defensive measure is in aiding oxidation of the tissues by all rational means, special movements and stimulation of the vasomotor mechanism of the great eliminating organs.

THE CAUCASIAN IN BRAZIL.

BY THOMAS C. DAWSON,

SECRETARY OF THE U. S. LEGATION, BRAZIL.

CONTROL of trade routes and mineral supplies have been the two chief factors in determining the industrial and political supremacy of races and nations. It is evident that a third—the control of the food supplies from the tropics—will soon be equally vital to civilized man. The tropical zone is a great laboratory where nature's forces are manufacturing food on a tremendous scale. There the sun's vivifying rays fall in the greatest abundance, building up with a rapidity impossible in the temperate parts of the globe the elements of the air, water and soil in those complex compounds which are the essential basis of life. Leaving out of consideration the dream that inventive genius may some day devise artificial methods of employing the sun's chemical forces in directly producing food, it is certain that if he continues to multiply in his present geometrical ratio, the European must utilize the tropics.

India and the east already contain a dense population; but the negroes who inhabit tropical Africa do not begin to exhaust its potential resources, and South America, the queen of the continents from an economic standpoint, is virtually untouched. How and by whom shall these regions be occupied and developed? Three solutions are possible:

1. Races predominantly black or yellow, who shall have developed among themselves or acquired from the whites economic and political efficiency, may be the future masters of the now unoccupied parts of the tropical zone. Southern China is a proof that such an outcome is possible.

2. Colored people under the direction and government of northern nations may cultivate the soil and export the surplus. This would be something parallel to the present condition of India.

3. The whites of European descent may themselves emigrate to the tropics, crowd out or absorb the colored races, and either pure, or predominating in the resulting mixture, constitute the bulk of the population.

The last alternative is rarely taken into consideration, because it is an accepted commonplace of popular belief and scientific discussion that the white man is not fitted to the tropics—that the European races can not live and multiply in the fertile regions near the equator. It is assumed as a self-evident truism that the blacks or colored races can better resist the climatic conditions. The statescraft of to-day, acting upon this assumption, is bending its energies to laying the foundations of an external dominion over the hot regions of the earth. Spheres of influence, not fields for emigration, are the subjects of the preoccupation of European cabinets; trade and political control are more sought than opportunities for colonization.

The popular impression as to the suitability of the tropics for white settlement rests upon two commonly observed phenomena: The places most visited by travelers, and therefore best known, are inhabited principally by colored races; the white man loses vigor when suddenly transported into winterless regions from the more vigorous climates where his ancestors have been living for unnumbered generations. Besides, the white emigrant usually dislikes the social, industrial and political surroundings, becomes discouraged, and in most cases returns strongly prepossessed against the tropics.

As to permanent powers of reproduction and survival, the existing predominance of colored races and the ill health and dissatisfaction of newly arrived whites only create a presumption—they do not conclusively prove anything. The negroes may predominate in Jamaica, because black immigration to that island was vastly more numerous than white, and not because the whites that did go there died out. The Caucasian newly arrived in Rio de Janeiro is susceptible to yellow fever, but his children born in Brazil may not be less immune than the offspring of black slaves.

Many things I have seen during a long residence in tropical Brazil and in journeys through the states of that republic and of neighboring countries have led me to doubt the correctness of the general impression. Personal observations unaided by adequate statistics are notoriously untrustworthy, and one should be slow in drawing conclusions from them. However, no one can long travel and reside in Brazil without noticing that white families are large and their children healthy. A large proportion can trace their descent to colonial times. Whites are preferred to negroes, mulattoes or Indians as laborers on the railroads and coffee plantations, not only because they are more intelligent, but because they are stronger, healthier and more energetic. The white may be more susceptible to certain climatic diseases, but the negro is less able to resist others, and is decimated by such communicable maladies as smallpox and consumption. The white eats more and better food, lives more hygienically and protects himself more effectually against the weather.

A study of the population statistics of Brazil leads to some surprising conclusions. The returns of marriages and births show that the whites are more fecund, and the successive censuses appear to prove that during the three and a half centuries which have elapsed since the settlement of the country, the comparatively few white immigrants have multiplied at a far more rapid ratio than the multitudes of negroes brought over from Africa, or the Indian aborigines.

In 1890 an enumeration was made of the married couples in the city of Rio de Janeiro; the race and color of each partner was ascertained and reported, and also the number of children born of each marriage. The average number of children in families where both parents were white is given as 3.507, while the black families produced only 2.987, and the intermarriages of blacks and mulattoes, 2.908. Of all the children 75.2 per cent. were the offspring of parents who were both white, leaving 24.8 per cent. for children of mixed or colored blood. The total white population was returned as 62.7 per cent. and of the other races at 37.3. Taking the four races separately, the whites, numbering 62.7 per cent. of the total population, took part in only 6.9 per cent. of the marriages and only 6.1 per cent. of the children had one or both parents black. The Indians were 3.4 of the population and furnished 2.4 per cent. of the marriages and children. Those reported as mulattoes composed 21.6 per cent. of the population, but took part in only 13.9 per cent. of the marriages, which produced 13.2 per cent. of the children. Irregular unions producing children are reported as marriages, and therefore the differences indicated above can not be explained by assuming that negroes, mulattoes and Indians live in concubinage more than the whites. A considerable number of those reported as 'white' have a small amount of negro or Indian blood in their veins, but this fact does not affect the conclusion that fecundity increases with the predominance of white descent.

Leaving out the mixed marriages, the superior fecundity of the whites is still more apparent. Of the children of unions where both parties belonged to the same race, 81.6 were white; 11, mulatto; 5.3, negro, and 2.1, Indian, while the respective percentages of total population were: white, 62.7; mulatto, 21.6; negro, 12.3, and Indian, 3.4.

It is therefore clear that even in Rio, a seacoast city whose climate is reputed particularly fatal to Europeans, whites now show a greater propensity to marriage than the black or mixed races, and that their unions are more prolific. Comparative mortality statistics are not available, but it is probable that the acclimatized whites are longer lived than the other components of the population, and that this has cooperated with their superior fecundity in bringing about a more rapid increase as compared with other races. The various censuses of the city of Rio de Janeiro taken in the last hundred years show the result that was to be expected from the above figures. The percentage of whites increased from 45 per cent. in 1799 to 55 per cent. in 1872, and 62.7 in 1890. That of the negroes fell from 54 to 14.5 and then to 12.3 per cent. in spite of the excess of negro over white immigration, which continued until the suppression of the slave trade in 1854. Since that date European immigration has been great. However, the proportion of whites of foreign birth decreased from 34 per cent. in 1872 to 30 per cent. in 1890. Native whites numbered 34 per cent. in 1872 and 51.6 in 1890, while the blacks fell from 21.7 to 16.3.

The movement of population from Rio to and from the surrounding country undoubtedly affects the relative proportions of whites and blacks. This element of uncertainty does not exist when the population of the country as a whole is studied, and the successive general censuses of Brazil afford a better basis for calculation.

Brazil was settled in the middle of the sixteenth century by the Portuguese—a people formed of the mixture of many nations, all of them, however, of pure Caucasian descent and the vast majority belonging to the Mediterranean race. The country was found inhabited by red Indians, who closely resembled the North American aborigines, and who readily submitted to white domination. The reports of the Jesuit missionaries and parish returns show that the process of incorporating them with the religious, political and industrial framework of the colony was begun immediately and continued for nearly a century and a half. About five thousand Indians were so civilized and incorporated.

Almost simultaneously with the original white settlement the importation of negro slaves from the near-by African continent began, and it was continued on a large and increasing scale for three centuries. By the end of the eighteenth century the arrivals had reached twenty thousand yearly. It is estimated that about two millions of negroes were imported into Brazil during the colonial period.

White immigration was surprisingly small. Portuguese policy did not aim at erecting a new Portugal across the sea, but at making a profit out of the region by the labor of Indian and negro slaves. No foreign whites were allowed to enter Brazil, and it was difficult even for a Portuguese citizen to obtain the required passport. About twenty thousand emigrated to central Brazil with the early expeditions by the colonial proprietors and the government. In the beginning of the eighteenth century several thousand Azoreans went to northern Brazil. A century later the discovery of gold in Minas Geraes stimulated a rush estimated at twenty or thirty thousand. In the middle of the eighteenth century there was a considerable influx of Azoreans into extreme southern Brazil. With these exceptions whites came singly or in small bodies, being mostly officials, soldiers, proprietors coming to take possession of huge land-grants from the crown, merchants and a few convicts. The total white immigration for the whole colonial period was about two hundred thousand.

No census was taken in 1807, but partial enumerations made shortly before indicate that the population of Brazil was then composed approximately of 900,000 whites or very light mulattoes; 2,000,000 negroes; 400,000 mulattoes, and 260,000 civilized Indians. In 1808 the mother country was overrun by Napoleon's armies, and the Portuguese king fled for refuge to Brazil, accompanied by thousands of office-holders and soldiers and most of the court. Fifteen thousand persons crowded the ships which carried John VI. out of the Tagus. His first act on arriving in Brazil was to open its commerce to all the world, and thenceforward immigration was unrestricted. White arrivals from 1808 to 1817 were 40,000, and those of negroes, 200,000.

The census taken in the latter year gives the white population at 1,043,000; negroes, 2,350,000; mulattoes, 426,500, and Indians, 259,-500. The whites had constituted only 8 per cent. of the original components of the population, but now numbered 28 per cent., while the negroes had fallen from 74 to 62 per cent. and the Indians from 18 to 7.

In the fifty-five succeeding years until 1872, 813,000 blacks were imported and 432,000 white immigrants arrived from Europe. The census taken in the latter year gives the white population as 3,787,289, and that of negroes as 1,959,452. Therefore the 672,000 whites who had come to Brazil up to that date had increased 562 per cent., while the 3,013,000 negroes had decreased to 65 per cent. of their original numbers. The civilized Indians surviving were only half as numerous as their ancestors.

In making a calculation of the total proportions of the three races in the total population of the country there are two uncertain elements which must be taken into consideration. In the census of 1872, 3,750,000 persons were returned as mulattoes or 'caboclos' (white and Indian, or negro and Indian), and no data is given as to what proportion of the three bloods entered into the mixture. Some of those returned as 'whites' were in fact light mulattoes or 'caboclos.' The latter fact would certainly tend to increase the apparent ratio, and it is also probable that the proportion of white blood in those returned as mulattoes is smaller than the proportion of negro and Indian blood. Personal observations indicate that the non-Caucasian element in those returned as 'white' is less than one fourth, and that about two thirds of the ancestors of the mulattoes are negroes or Indian—principally the former. Assuming these ratios in default of statistics on the subject, the population of Brazil in 1872 was 42 per cent. white, 53 per cent. negro and 5 per cent. Indian, while the percentages in the original immigrants were, respectively, 16, 72 and 12.

European immigration from 1872 to 1889 inclusive amounted to

611,000, while the negro arrivals had ceased almost entirely with the abolition of the slave trade. The census of 1890 does not give race numbers as to many localities, but estimating these on the basis of the sections where the relative proportions were ascertained, the percentage of whites is 44; of negroes, 18; of mulattoes, 35, and of Indians, 3. Dividing the total population into its race elements according to the principle already used with the figures for 1872, after making an allowance for the lessening proportion of dark blood among the reported 'whites,' we find that in 1890 there was 49 per cent. of white blood, 47 black and 4 Indian.

The tendency of the pure negroes to decrease in numbers is conclusively shown by the accurate statistics of the slave population kept during the existence of that institution in Brazil. In 1818 the slaves numbered 2,350,000; in 1872, 1,510,806; in 1887, adding their children born free under the gradual emancipation law of 1873, 1,183,250.

The immense extent of Brazil, the wide variations in climate, soil and altitude, the predominance of sugar culture with the employment of great gangs of slaves on large plantations in some localities, and of the cattle industry which the whites are fond of in others, and the fact that sometimes the Indians were collected into villages of their own and sometimes were enslaved and almost exterminated, have caused great differences between the various states in the relative numbers of the three races. The limits of this article do not permit a discussion of each state separately, but it would confirm the conclusions already indicated.

Even in the parts of Brazil which are the most tropical and least attractive to Europeans, and where white immigration during the last century was inappreciable, such as the non-coffee and sugar states of the central and northern coast, and the wild and remote interior included in the states of Goyaz, Minas and Matto Grosso, the whites have increased more rapidly than pure negroes or Indians. The latter tend to disappear into the mass of mixed bloods who constitute the bulk of the population. A large proportion of the Caucasians have, however, maintained themselves in direct, prolific and unmixed lines for three hundred and seventy years, and their commercial and intellectual dominance has never been threatened.

In the favored regions of the south the preponderance of the whites is enormous and is rapidly increasing. On the coffee plantations of Sao Paulo, where the negro slave formerly did all the work, he has been completely displaced by the immigrant from Europe. The negroes and mulattoes have little chance of intermarrying with the whites; their unions among themselves produce a small number of children, and they show little providence in forming and taking care of families. They do not have, as do their contemporaries in the

United States, the stimulus of a comparatively rigorous climate, and the examples of white neighbors organized into a complex and highly competitive industrial civilization. The reserve of foresight, energy and ambition which the white Brazilian has inherited from his ancestors stands him in good stead in the easy and enervating surroundings, while the negro will only work when he is obliged to.

The race which will inherit the fertile and salubrious plains and plateaux stretching north from the Argentine border to the lowlands of the Amazon will probably be of Caucasian origin and descent, although its characteristics may have become much modified in fitting its new surroundings. The Azorean hoes his little patch of ground with the painstaking industry of the Norman peasant, but his gaucho descendant in Rio Grande neglects agriculture for riding after cattle. A capacity for indolence may perhaps be one of the conditions of survival in tropical climates, and the future master of these regions will possibly possess oriental characteristics, and may lose some qualities he inherits from his immediate ancestors, the restless Latins, Celts and Teutons of western Europe.

So far as it has gone, Brazil's experience tends to prove that the white man has the adaptability, vitality and fecundity to ensure his preponderance in the tropics as well as in the temperate zone, and that the other races will exist there upon his sufferance.

THE AIR OF THE LURAY CAVERNS.

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AT Luray, Page County, Virginia, is located a health resort which represents an idea unique in hospital or sanitarium construction. The dwellers in Limair may keep their doors and windows closed summer and winter, and still breathe air as pure as that of the mountain side.

My acquaintance with this institution began in the fall of 1901, when making a vacation drive through the Shenandoah country. After a ramble through the Luray Caverns, our party was shown through the sanitarium and treated to the novel experience of living in the caverns' air, while enjoying a full measure of light and sunshine.

Limair has an elevation of about one thousand feet above the sea level. It stands on a hill about two hundred feet above the neighboring water courses, and commands a magnificent view of the Page Valley with the enclosing mountain ranges—the Blue Ridge to the east and Massanutten range to the west. These mountains are from three thousand to four thousand feet high, and as seen from the elevation in the center of the valley they present a panorama of never-failing interest. The Page Valley is said to enjoy more sunshine than can be elsewhere found in the United States east of the Rocky Mountains. A pine forest of about one hundred and forty acres which covers the Luray Caverns hill affords beautiful walks and drives, and is not the least of the attractive features of the place, when considered as a health resort.

Mr. T. C. Northcott, builder and proprietor of Limair, is a heating and ventilating engineer of twenty years' experience, and he has devoted many years to the problem of establishing an institution that would combine the advantages of sunlight and beautiful surroundings with an air supply at once voluminous and pure. After investigating the caves of New York, Ohio and Virginia he secured building and park privileges over the Luray Caverns as a site comprising the greatest number of healthful and attractive features. A reference to the photographs (Figs. 2 and 3) will give an idea of how well the site has been chosen. The drawing (Fig. 1) explains the methods of air supply and ventilation, but only a visit to the institution will demonstrate how completely the theories of the engineer are being worked out in practical results.

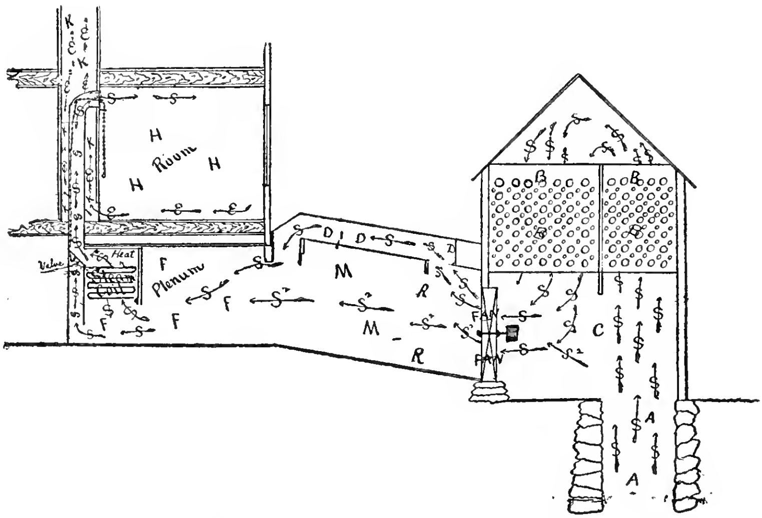


Fig. 1. Showing Methods of Air Supply and Ventilation.

The fan, shown in drawing, is run by steam-engine (not shown) and draws the air upward, from the great chambers of the caverns, through the shaft *A*. By opening door *C*, also door *R*, the air can be forced through corridor *M*, directly to plenum *F*, as indicated by arrows marked S^2, and distributed through the rooms without passing through condenser. With door *C* closed the whole volume of air is drawn through condenser *B* before coming to the fan. Passing through the fan (door in partition at *R* being closed), the air passes through an auxiliary condenser *D* to plenum *F*, whence it is forced by pressure of the fan into all rooms. The air from plenum is forced through a heat chamber, over steam coil, in cold weather, thence through opening into the air supply pipe *G* and discharged into room *H* through a register just below ceiling of room. If room becomes too warm, the volume of *warm* air flowing in pipe *G* may be reduced or entirely stopped, by pulling cord or chain suspended from the inflow register in room, thus moving valve in pipe *G*. The movement of this valve permits as much *cool* air to rise through a lower opening, as warm air is shut off by closing the opening from the coil, or heat chamber. Process last described may be traced by arrows marked *S*. The outflow of air from rooms may be traced by arrows marked *E*. Air is forced from room *H* into vertical duct *K*, which is continued to top of building permitting air to escape outdoors. *The air passes into, through and out of the rooms in volume equal to the filling of each room in the building every five minutes continuously.* In the summer there is, of course, no heat in the steam coils. The air drawn from the caverns being about 54 degrees, when forced into the building, cools the rooms to any degree comfort may demand, however intense the heat prevailing outside.

At my first visit, in the fall of 1901, I saw demonstrated the remarkable volume in which the air enters and leaves each room without creating appreciable draughts, and the fact that the air is practically free from atmospheric dust. Tyndall ('Lectures on Dust and Disease') has shown that if we darken the ordinary room and allow a streak of sunlight to enter, the condition of the atmosphere revealed is such that we can not without repugnance step into the illuminated area and breathe. Such an experiment in a room in Limair reveals scarcely a particle of dust floating in the air; *i. e.,* the air is optically pure. Noting this fact, I became interested in the bacteriologic condition, and determined to visit Luray again, supplied with culture media and sterile plates.

In December, 1902, fitted out with five dozen sterile plates and six dozen tubes of agar-agar, I spent four days at Luray studying the bacteriologic conditions in the caverns, sanitarium, out of doors, and in neighboring homes. My plates were prepared by being wrapped in separate paper covers, sterilized in dry heat and transferred to a box still wrapped in their paper covers. The agar-agar was in separate tubes stoppered as usual with cotton plugs. Each morning before starting in quest of bacteria the required number of fresh plates were prepared. That my technic was entirely satisfactory was demonstrated by setting a closed control plate at each place where other plates were exposed. The readings from the plates were made after incubation for twenty-four hours at 85 degrees F. On the first day the exposures and results were as follows:

1. In the caverns: Three plates in Vegetable Garden, 50 yards from entrance; plates exposed five minutes and one hour and the control plate were all negative.

Three plates at Crystal Spring, 100 yards from entrance; on plate exposed five minutes, two colonies; plate exposed 50 minutes, negative; the control plate, negative.

Three plates at Skeleton Gorge, 200 yards from entrance; 5 minutes, 35 minutes, and control, all negative.

Three plates at Cathedral Room, 300 yards from entrance; 5 minutes, 30 minutes, and control, all negative.

2. In the air passage between the cave and the house (see Fig. 1) four plates were exposed for one half hour as follows: Plate 1, at the mouth of the air shaft coming from the caverns, *A;* plate 2, in the beginning of the long auxiliary condenser, *D,* just beyond the fan; plate 3, at the other end of the auxiliary condenser; plate 4, on the floor of the plenum, where the air rushes down from the condenser. On none of these plates was there any growth.

3. In the sanitarium three plates were exposed for respectively 5, 20 and 60 minutes in each of three rooms, viz., the library on the first floor; a guest chamber on the second floor, not used for the previous week; and in a bedroom on the second floor, in constant use. The morning work had been done in this latter room one hour before my plates were placed on the bed. One colony on the five-minute plate, and three colonies on the 60-minute plate in this room, and two colonies on the hour plate in the library were the only results from these nine plates.

On the evening after my first day's work, the daughter of the household gave a party to about fifty young people of Luray, and on making my first examination of the plates, I was so astounded at the results that I immediately prepared more plates, thinking that enough dust and dirt would have been left in the house on the previous evening materially to alter results. I was even more surprised after exposure of plates for two hours in the library, reception hall and game room, to find the most contaminated plate to contain only nine colonies. This was the plate exposed on the mantle shelf immediately above a large open fireplace in the reception hall, between the hours of eleven and one o'clock noon, when the household of about six people was moving about as usual on a winter morning.

Plates were set for two hours in the caverns on the second day at the same places as on the first day. Again two colonies developed on the plate exposed near the Crystal Spring, while the other plates were negative.

For the sake of comparison, and to learn whether all houses in that vicinity contained unusually pure air, I exposed a plate in the house of a well-to-do farmer within a mile of Limair. The house was scrupulously neat and clean. The plate was exposed for one hour on a mantle-shelf back of a heating stove in the sitting room, where five or six people were passing in and out. In other words, the conditions were about the same as those under which nine colonies developed after a two-hour exposure at Limair. After 24 hours of incubation 143 colonies were visible on this one-hour plate.

In a physician's office at Luray 92 colonies were implanted in one hour. I expected to catch more bacteria in a physician's office than in a farm-house, and the difference may possibly be explained by the location of a large, open fireplace opposite the door entering from the street, thus affording a means of constant ventilation, with repeated additions of fresh air from the outside.

Outdoor exposures were made at Limair on a clear morning following a day of rain and freezing temperature. The temperature was 38 degrees and a mild wind was blowing. Four plates were exposed in the pine woods at some distance from the house, the exposures lasting from one to two hours. Three plates each showed two colonies, while the fourth had four colonies; of three unopened control plates one showed one colony. To compare the air in the city, I exposed a plate for one hour on the stone wall surrounding my back yard. The plate was exposed at 5 P.M. on a clear, bright day, the temperature being below freezing, and the wind blowing about twelve miles an hour. The previous two or three days had been clear and dry. After 36 hours' incubation at 85° F. 450 colonies had developed on the plate. A plate placed on the seat beside me in a Madison Avenue car, during

FIG. 2. LIMAIR SANITARIUM, LURAY, VIRGINIA. Notice the absence of roofed verandas. Large sun rooms occupy the south side of the sanitarium. Massanutten Mountains just visible in the distance.

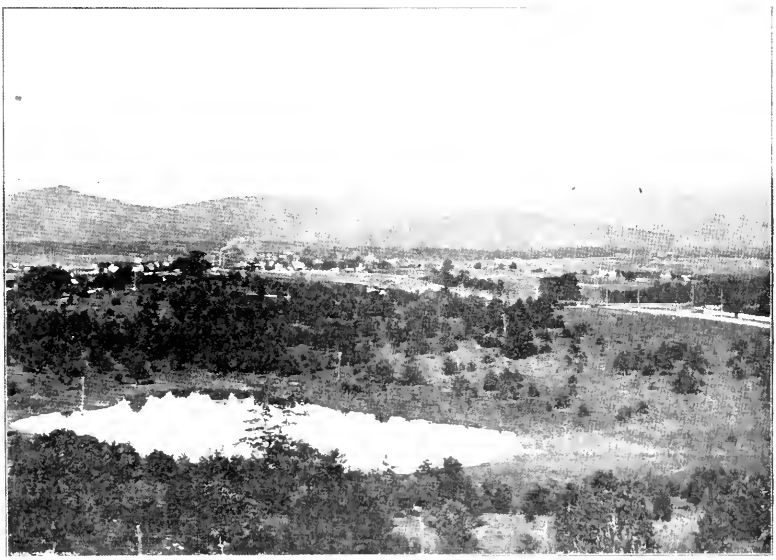


FIG. 3. VIEW FROM SUN PARLORS OF LIMAIR SANITARIUM, LURAY, VIRGINIA. Luray one mile distant. Blue Ridge Mountains beyond.

a twenty-five minute trip from Broadway to Lafayette Avenue, showed over 1,600 colonies after a thirty-six-hour incubation at 85° F. Plates exposed for one hour in the surgical and gynecologic operating rooms at the Johns Hopkins Hospital showed, respectively, 65 and 58 colonies after incubating 48 hours at 100 degrees. These comparative studies are suggestive, and the studies in the caverns and sanitarium demonstrate that with optical purity or freedom from atmospheric dust, we have air that is practically free from bacteria.

FIG. 4. SHOWING FLAG BENEATH THE CEILING CARRIED OUT HORIZONTALLY BY THE INFLOW OF CAVERN AIR. Also the flame of the candle deflected by the outflow of air from the bedroom.

But in spite of the bacteriologic purity of the air in Limair Sanitarium, I am sure many will protest against breathing the polluted, moldy emanations from a source never penetrated by the rays of the sun. I must confess this was my first impression, and the same prejudice has been expressed by many friends with whom I have conversed. But what are the facts, and what is the condition of the caverns' air? In the first place the air is not stagnant. In any part of the caverns the guide's candle, if placed on the floor or on the ledge of a wall, shows by the deflected flame a very decided current of air. Owing to the differences in temperature, there is a constant interchange of air between the caverns and the outside world. This circulation takes place through many natural filters distributed over the hillside in the form of crevices in the rock, which have become filled by porous soil. Both air and water are cleansed in passing through these earth filters. If there be any open fissures for the admission of unfiltered air, its organic particles would soon be deposited on the damp caverns' walls. The action of water passing over and causing the slow dissolution of such a vast surface of limestone can not but be beneficial to the caverns' air. It would be trite to dwell on the advantages of lime as a purifier and disinfectant.

Again, we find no organic matter in the caverns undergoing decomposition, and have on every hand the beautiful, clean, limestone walls and draperies being corroded and reformed by the constant action of myriads of water courses (see Fig. 5). Can we arrive at any other conclusion than that here we have the purest and cleanest atmosphere that can anywhere be found?

Mr. Northcott's control of the temperature and humidity conditions is a feature over which the thoughtful visitor must grow enthusiastic. The temperature of the caverns registers from 54° to 56° F. throughout the year, and the relative humidity varies but a fraction of a per cent. from 87. In the hottest summer weather the sanitarium temperature ranges from 70° to 74° F., and the relative humidity is reduced to 70 per cent. or less, merely by the expansion in volume incident to an increase in temperature from 56° to 70°. In the winter the air is easily raised in temperature from 54° to 70°, and the problem of humidity, while somewhat more complicated than in the summer, is perfectly controlled. As seen in Fig. 1, the air is sent through a boiler-like box of sheet iron (*B*) and comes in contact with a wide surface of iron tubing, the opposite surface of which is exposed to the cold air outside. This one box failing to reduce the humidity sufficiently, there was built a long sheet-iron passageway (*D*) over the summer air corridor, and by placing a closed door (*R*) the air is forced through this accessory condenser to be still further robbed of its moisture.

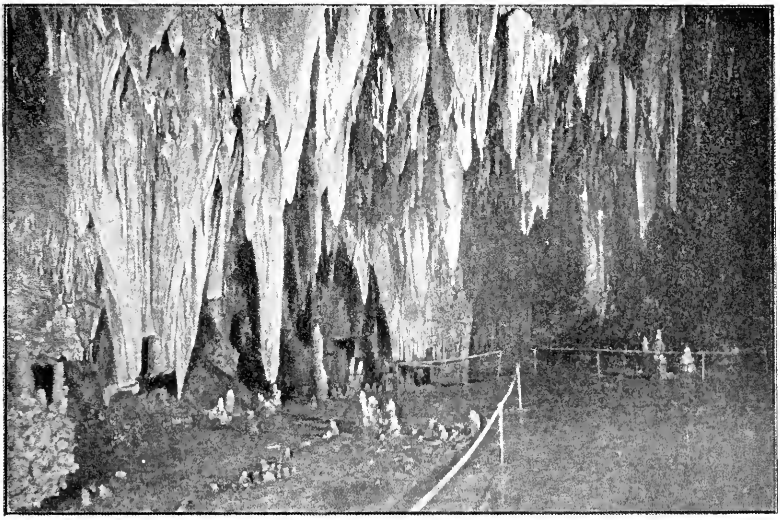


FIG. 5. SIDE VIEW OF BALL ROOM.

Dr. Wm. C. Bailey, who is doing such excellent work with consumptives at Las Vegas, N. M., informs me that the yearly average of humidity at his altitude is 40 per cent. The average at Denver is about 50 per cent. at 70 degrees temperature. When we consider the great and rapid changes of temperature at such favorable locations, and think of the wide range of relative humidity experienced even in the course of one day, we see at once that the engineer at Limair, starting with his great caverns of air of a uniform temperature, and uniform percentage of relative humidity, has a simple problem to solve in keeping the sanitarium at an equable temperature, and in what is considered the normal percentage of relative humidity. Attempts are now being made to furnish hospitals and large public buildings with these desirable conditions of a dustless, cool air, of uniform temperature and humidity; but while the problem is theoretically possible, the outside conditions are such as to make the undertaking one of such expense as to be impracticable.

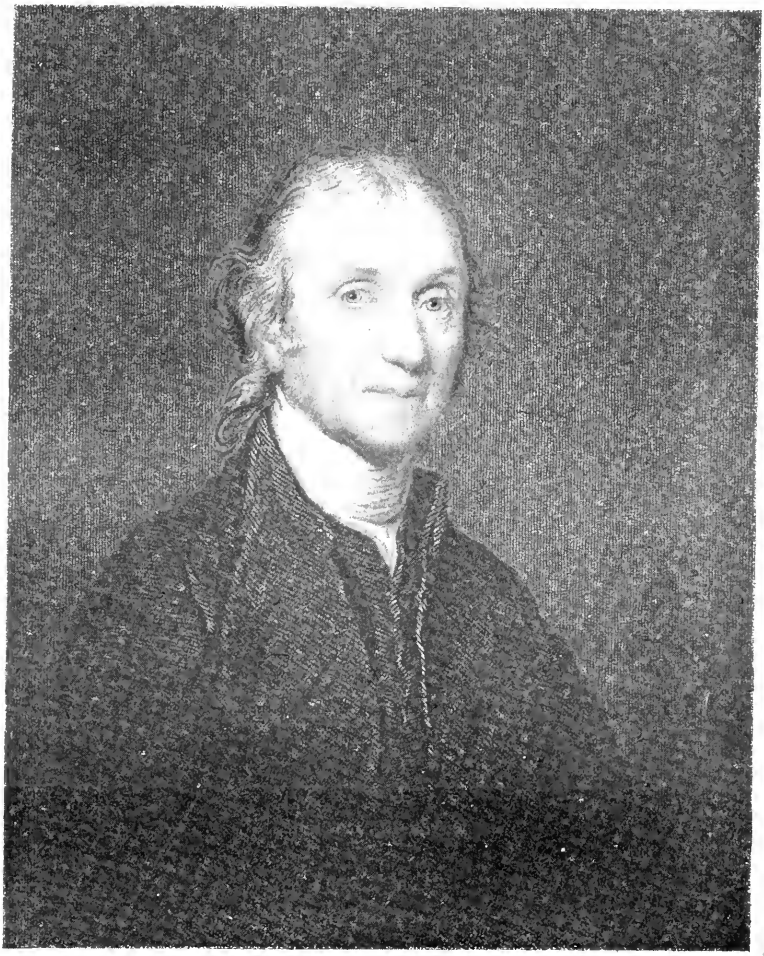
The practical side of this question from a therapeutic view-point appeals to those familiar with throat and lung diseases. For hay fever, asthma and all bronchial affections, not tuberculous, these conditions are ideal, and for patients of this class have already given excellent results. We can not imagine conditions better calculated for the preservation of infant health during the hot summer months, when the rapid atmospheric changes of our cities play such havoc with their powers of resistance to intestinal infections.

We now know the relatively minor rôle that the tubercle bacillus plays in the destruction of the consumptive patient, and the great advantage of placing the early tuberculous process in an air free from dust and the secondary bacterial invaders. We know how injurious to some patients are the climatic changes of a sea voyage, or of the seaside resort, and how badly others react to a change of altitude. Here we have an abundance of cool, pure air rapidly circulating in sunny rooms easily kept at constant conditions of temperature and humidity. Consumptives are not taken at this sanitarium, but I think it is only a question of time when those afflicted with tuberculosis of the air passages may enjoy the benefits to be derived at Luray and other caverns of the world by living in houses modeled after Limair.

THE PROGRESS OF SCIENCE.

THE CENTENARY OF THE DEATH OF PRIESTLEY.

PRIESTLEY died on February 6, 1804, and the centenary of his death has been commemorated in Great Britain and in the United States. Thirty years ago the centenary of the discovery of oxygen was celebrated, and at that time this magazine published several articles on the life and work of Priestley. In the issue for August, 1874, a biographical sketch and an appreciation by Dr. John W. Draper will be found. An address given by Huxley on the occasion



JOSEPH PRIESTLEY.

Professor Eduard Zeller.

of the presentation of a statue of Priestley to the town of Birmingham is printed in the issue for November, 1874. Priestley's own account of the discovery of oxygen was reprinted in the issue for December, 1900. To these articles those readers may be referred whose attention has been attracted to Priestley by the recent commemoration.

Priestley's discoveries were of epoch-making importance in the history of chemistry; his radical views in politics and theology anticipated in certain directions the course of subsequent thought, and his career is full of dramatic interest, especially to us in America, among whom he took refuge from persecutions at home. Yet it is not often that one of the twenty-five volumes containing Priestley's collected works is taken down from the shelves of the library. The vast range of his controversial writings belongs to the past, and his scientific work was in a sense an episode in his life and in the development of science. But the courage with which he defended what was then heterodoxy in religion and radicalism in political affairs deserves our admiration, and the discovery of oxygen will always remain a landmark in the progress of chemistry.

At the middle of the seventeenth century, chemistry had not yet found its Copernicus or Newton. From our point of view the confusion was extreme. Air, water and fire were regarded as elementary substances. It was supposed that when anything was burned or when an animal breathed, a substance called phlogiston passed into the air and vitiated it. So when Priestley discovered oxygen, he called it dephlogisticated air, it being, 'between five or six times as good as common air.' Priestley did other work of importance in connection with gases, but did not appreciate the real bearings of his own discoveries and can not be placed in the same rank with Cavendish and Laviosier. But he will always be remembered for one of the most important discoveries in the history of science.

PROFESSOR EDUARD ZELLER.

It appears that in Germany, as in England, the great men of the nineteenth century have scarcely bequeathed their genius to their successors. It is quite impossible for Berlin to fill the places vacant by the deaths of Helmholtz, Virchow and Mommsen. One man of that generation the university still has, and it does well to do him honor on his ninetieth birthday. Professor Zeller does not rank with the greatest of his contemporaries, but he represents the highest scholarship, the type which is in danger of submergence beneath the flood of executive work and business detail of modern life.

The work of Professor Zeller carries us a long way back. Starting from the then prevalent Hegelianism, he was one of the first to take a decided stand against the *à priori* construction of the world, and claim that we must go back to the epistemology of Kant and develop it in the light of modern science. But he is best known for his 'Philosophy of the Greeks,' the first volume of which was published sixty years ago. This work has continually been revised for subsequent editions; it was followed in 1872 by a history of German philosophy since Leibnitz and by numerous other publications, especially on the relation of philosophy to science and on the philosophy of religion.

CHARLES EMERSON BEECHER.

Yale University lost only five years ago its eminent paleontologist, Professor O. C. Marsh, and now we are compelled to record the untimely death of his successor, Professor C. E. Beecher, which occurred on February 14, at the age of forty-eight years. Beecher was graduated from the University of Michigan in 1878, and for ten years was assistant to Professor James Hall in the New York Geological Survey. In 1888 he was called to Yale University to take charge of the invertebrate fossils of the Peabody Museum, and received the degree of Doctor of Philosophy in 1889. In 1892 he was made assistant professor and in 1897 professor of historical geology, the title being changed to professor of paleontology in 1902. In 1899 he was elected a member of the National Academy of Sciences. In this year, when he succeeded Professor Marsh as curator of the geological collections, he presented to the museum his collection of fossils, which he had been gathering since he was twelve years old and which contained over 100,000 specimens.

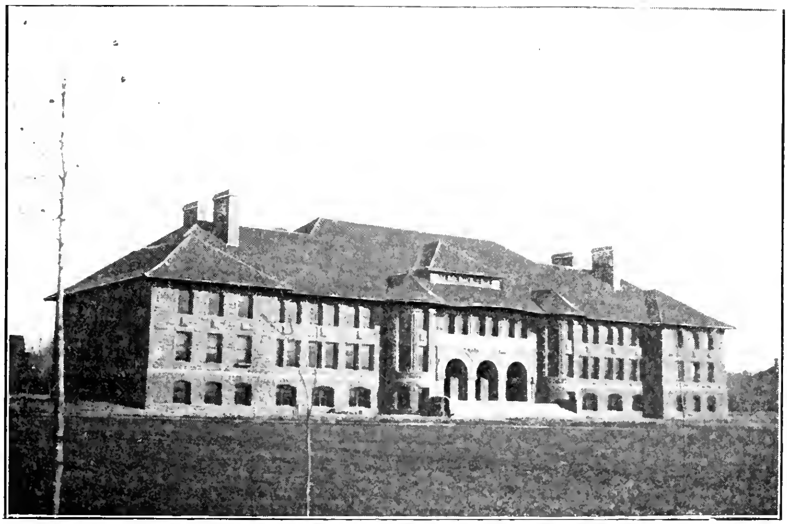
CHARLES EMERSON BEECHER.

Beecher published about sixty papers on invertebrate paleontology, concerned especially with brachiopods and trilobites. He obtained specimens of the latter in which the antennæ and legs were preserved, and made careful studies of the ventral anatomy. He also published a classification of the trilobites, and was at work on an extensive treatise on these primitive crustaceans at the time of his death. Beecher did much work in the field and was skilful in preparing specimens and as a draughtsman. He was also interested in the philosophical aspects of evolution, being counted among the American neo-Lamarckians. In an important paper he finds that species having spines fully developed leave no descendants.

SCIENCE AT COLORADO COLLEGE.

The state universities of the central and western states have developed with remarkable rapidity, and are now beginning to rival the older institutions of the Atlantic seaboard. It is sometimes said that public support of education interferes with private endowments. But Stanford University and the University of Chicago have been established side by side with the state institutions, and in each case both the state and the private institutions are found to help rather than to interfere with one another. In Colorado in the same way the state university has not in any way prevented the development of Colorado College, and there is every reason to suppose that these institutions will continue to work togther for the educational welfare of the state. In all western institutions, science occupies an important if not a predominant position, and of this the erection of Palmer Hall at Colorado College is significant.

This new building, which was dedicated on February 23, contains provision for the scientific departments and administrative offices of the college. It has received its name in honor of General William J. Palmer, one of the trustees of the institution. As shown in the illustration, the building has three stories; it is built of sandstone with modern fireproof construction. The basement contains laboratories for chemistry, physics and psychology, the first floor, the general offices and lecture rooms and other laboratories for chemistry and physics, and the second floor houses the departments of biology and geology, with the museum.



Palmer Hall, Colorado College.

Nearly ten years ago Dr. D. K. Pearson, to whom American colleges are so greatly indebted, offered to give $50,000 to Colorado College, on condition that a building costing $60,000 should be erected. This money was secured and the building planned, but subsequently larger plans were adopted, and the present building cost nearly $300,000; $30,000 have also been secured for equipment. The dedicatory exercises were carefully planned. President David Starr Jordan, of Stanford University, made the principal address, which we hope to have the privilege of publishing in this magazine. On the preceding day addresses were made by Dr. C. R. Van Hise, president of the University of Wisconsin, on 'Colorado as a field for scientific research'; by Dr. Samuel L. Bigelow, of the University of Michigan, on 'The growth and function of the modern laboratory'; by Dr. C. E. Bessey, of the University of Nebraska, on 'The possibilities of the botanical laboratory,' and by Dr. Henry Crew, of Northwestern University, on 'Recent advances in the teaching of physics.' The president of the college, Dr. William F. Slocum, said in his address: "We dedicate then to-day this building devoted to the high purposes which led to the founding of the college; to the cause of learning and scientific study, to the up-building of the educational movement throughout the state. It is an added contribution to what other similar institutions are accomplishing in Colorado and throughout our country. In all the years to come may it help to broaden and enlarge the scope of human knowledge and aid in bringing into this section of the United States such a love of the larger life of thought and accurate study, and that new meaning will come to many as they read over its entrance, 'Ye shall know the truth and the truth shall make you free.'"

THE SIZE OF FAMILIES OF COLLEGE GRADUATES.

The statistics on the size of families of college graduates published last year in this magazine by Professor Thorndike and by Dr. Engelmann have been considerably amplified by President Stanley Hall and Mr. Theodate L. Smith, and form the subject of an article in the last number of *The Pedagogical Seminary*. It is pointed out that the decrease in the number of children per wife is less than per man, owing to the fact that the graduates of the last century so frequently remarried. The conditions for the wives of clergymen in colonial times appear to have been unfortunate, about forty per cent. dying under the age of fifty. But the authors are scarcely justified in saying that 'on this biological blunder of estimating the increase of population per man instead of per woman and too narrow a study of statistics is based much of the alarmist outcry in regard to the future population of the United States.' As far as the increase of the population is concerned, it matters but little whether it is due to strict monogamy or to successive polygamy.

The figures given in the paper are substantially those with which we are familiar. The size of family of the married college graduate has decreased from about four in the first part of the last century to about two and a half in the second half, and at the same time the percentage of those unmarried has increased. Great care must, however, be taken in interpreting such statistics. For example, the members of the class of 1883 of Yale College are reported to have only five living children; but we find that the report relates to a period three years after graduation. Even when the period is as long as fifteen years the number of children will increase by about 50 per cent. The ominous fact stands, however, that college graduates do not now reproduce themselves. If the figures for Harvard College are correct, they are exterminated with startling rapidity, a hundred graduates produce only 68 boys in the next generation, and leave only 30 great-grandsons. It must, however, be remembered that the conditions in the race and class from which graduates come may be as bad. Thus the number of children living for every native Massachusetts woman, between the ages of forty and fifty, was, in 1885, only 1.80.

The statistics for the women graduates are of special interest, although they in most cases relate to such recent classes that they are difficult to interpret. They are also reported by diverse methods and are probably not very accurate. Thus when it is said that of 176 children only 11 have died, we infer that the deaths have not been reported rather than that the death rate is remarkably low. The only group fifty years of age consists of the first ten classes of Vassar College ending in 1876 with 323 graduates. Fifty-five per cent. had been married as compared with 80 per cent. in the native population, of whom about one third were barren, about twice as many as under normal conditions. The average fertility of those having children is three (including presumably those deceased), which is fully as large as that of the male graduates. The data from later classes are difficult to use. 42.7 per cent. of Smith College graduates prior to 1888 are married and 46.5 per cent. of the Wellesley College graduates. These women are of the average age of over forty years. If only one half of college alumnæ marry and one third of these are barren, while those who have children only reproduce themselves, the 'species' would be completely exterminated in five generations. If colleges for women must be regarded as modern nunneries, there is no special cause for gratification in the fact that in twelve years the number of women students has increased from about 10,000 to about 28,000.

THE STUDY OF THE SCIENCES AND OF LATIN IN THE SECONDARY SCHOOLS.

There is annually published in the report of the United States Commissioner of Education an interesting table showing among other things the percentages of students pursuing different studies. The table from the last volume referring to the year 1902 is here reproduced.

It will be noted that the percentage of students studying Latin is recorded as increasing from 38.80 in 1891–92 to 49.52 in 1901–2, whereas in physics there has been a decrease in the same period from 22.04 to 17.39 per cent., and in chemistry from 10.08 to 7.70 per cent. These figures have been widely quoted, and are certainly discouraging to those who are interested in scientific education. It must, however, be remembered that figures are illusive. It has been said that there are three kinds of lies—white lies, black lies and statistics. The figures given in the table are on their face difficult to un-

Students and Studies.	1891–92	1892–93	1893–94	1894–95	1895–96	1896–97	1897–98	1898–99	1899–00	1900–1	1901–2
Males	44.01	43.62	43.39	43.00	43.40	43.84	43.50	42.93	43.16	42.83	42.49
Females	55.99	56.38	56.61	57.00	56.60	56.16	56.50	57.07	56.84	57.17	57.51
Preparing for college, classical course	9.18	9.90	10.34	10.00	10.05	8.94	7.99	7.87	8.32	8.30	6.89
Preparing for college, scientific courses	7.59	8.22	7.33	7.11	7.16	6.57	6.03	6.18	6.21	6.54	5.97
Total preparing for college	16.77	18.12	17.67	17.11	17.21	15.51	14.02	14.05	14.53	14.84	12.86
Graduates	10.87	11.46	11.88	11.60	11.73	11.95	11.75	11.78	11.74	11.95	11.86
Per cent. of graduates prepared for college	39.15	36.62	30.92	32.44	32.69	32.60	30.60	31.61	32.95	33 48	33.67
Studying—											
Latin	38.80	41.94	43.59	43.76	46.22	48.01	49.44	50.29	49.97	49.93	49.52
Greek	4.68	4.92	4.99	4.73	4.58	4.60	4.50	4.27	3.95	3.58	3.36
French	8.59	9.94	10.31	9.77	10.13	9.98	10.48	10.68	10.43	10.75	11.13
German	11.61	13.00	12.78	12.58	13.20	13.76	14.24	14.91	15.06	16.09	16.94
Algebra	47.65	49.92	52.71	52.40	53.46	54.22	55.29	56.21	55.08	55.66	55.27
Geometry	22.52	24.36	25.25	24.51	25.71	26.24	26.59	27.36	26.75	27.26	27.56
Trigonometry	2.96	3.61	3.80	3.25	3.15	3.08	2.83	2.58	2.42	2.54	2.42
Astronomy	....	....	....	5.27	5.19	4.89	4.40	3.94	3.43	2.96	2.64
Physics	22.04	22.25	24.02	22.15	21.85	20.89	20.48	19.97	18.88	18.24	17.39
Chemistry	10.08	9.98	10.31	9.31	9.15	9.18	8.55	8.64	8.00	7.86	7.70
Physical geography	....	....	....	22.44	24.93	24.64	24.33	23.75	22.88	22.42	22.22
Geology	....	....	....	5.52	5.20	4.93	4.66	4.41	4.02	3.88	3.48
Physiology	....	....	....	28.03	31.08	29.98	29.38	28.62	26.96	26.27	24.83
Psychology	....	....	....	3.35	3.82	3.82	3.64	3.23	3.19	2.98	2.53
Rhetoric	....	....	....	31.31	32.27	33.78	35.30	36.70	37.70	39.69	41.90
English literature	....	....	....	....	....	....	38.90	40.60	41.19	43.90	45.60
History (other than United States)	31.35	33.46	35.78	34.65	35.73	36.08	37.68	38.32	37.80	38.41	38.90
Civics	....	....	....	....	....	....	21.41	20.89	21.09	20.60	19.87

derstand, as students are reported as studying on the average 1.8 studies in 1891 and 3.6 studies in 1901. In answer to a request for an explanation of these figures, the U. S. Commissioner of Education has kindly replied as follows:

I have your letter of recent date referring to the remarkable increase in the numbers of students in certain studies in the high schools since 1890. When this office began to classify the statistics of secondary schools more than fifteen years ago it was found that many schools had been reporting a large percentage of elementary pupils as in the high schools when in fact they pursued no secondary studies. It required several years to devise a form of inquiry which would enable this office to eliminate the elementary pupils.

It is probable that in 1890 a pupil was reported as a secondary student if he had *one* or more secondary studies. Now he must have at least *two* secondary studies to be so classed. (See marked form herewith.) Every year we are able to get a better classification and by insisting on answers to question 14 (the studies pursued) we are able to eliminate the elementary pupils. The classification was not so close in 1890.

We now state in our summaries *how many* schools reported students in certain studies (see page 1652, report for 1902 sent under another cover). This was not done in 1890.

The three and a half subjects studied (the average mentioned in your letter) is not excessive. In many schools the minimum required is four subjects each year.

If the fact that students were reported in 1891 as studying on the average less than two subjects was because certain elementary pupils taking only one study were included and if high school students on the average pursue four studies, it would follow that about 70 per cent. of all students reported in the high schools were elementary students. This was of course not the case, and with the data at hand we can only conclude that in 1891 the studies pursued by many students were not reported, and that we do not know what percentage of students studied Latin at that time. It may have been 60 per cent. The percentage of students studying Latin has probably decreased, because relatively more students are now prepared for the college scientific course than for the classical course, while at the same time the percentage of graduates entering college has decreased. The percentage reported as studying Latin has decreased since 1898 when the figures may be assumed to have become more accurate.

The decrease in the number of students studying physics and chemistry is not, however, so easily explained away. It may be that in 1891 elementary students taking physics or chemistry were reported, whereas but few elementary students would take Latin. The percentage of girls has increased, and this would favor literary as compared with scientific studies. The figures for zoology and botany are not given, and in the increase of the number of studies open to secondary students, there would naturally be a decrease in the number studying each subject. Still there is reason to believe that physics and chemistry as taught in the high school and college are not attractive to students. Indeed, we have grounds for fear that the high school course as a whole is not as useful as it should be, especially for boys. The figures given in the table show that 42.49 per cent. of secondary students are boys, whereas the boys graduating from the high school are only 34 per cent. of the total number. Only about 20 per cent. of students—boys and girls—entering the high school stay to graduate, and in Boston only 10 per cent. of the boys who enter the high school remain as long as the fourth year.

INDEX.

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CONTENTS

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