PROCEEDINGS

OF THE

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Natural History and Philosophical Society,

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With Catalogue of Skulls collected by the late John Grattan, Esq., and now the property of the Belfast Museum.

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PRESIDENTIAL ADDRESS

ON THE

PRESENT STATE OF THE DARWINIAN CONTROVERSY,

DELIVERED BY

JOSEPH JOHN MURPHY, Esq.,

On November 1, 1873.

It is now seven years since the first time that you did me the honour of electing me as your president. My opening address on that occasion was chiefly on the subject of the origin of species and Darwin's theory; and to the same subjects I now design to return. I then, while avowing my agreement with Darwin to a considerable extent, stated where I thought his theory insufficient and unsatisfactory. During the seven years that have since elapsed, I have been conversing, reading, thinking, and writing on this subject, with the result of being now further than ever from agreement with Darwin. At that time, and when I wrote my book on "Habit and Intelligence," two years later, I went about three-quarters of the way with him. I cannot now go more than half. I cannot now agree with the distinctive parts of Darwin's theory at all. I agree with him only so far as he agrees with the great body of scientific men. The great body of scientific men are now believers in evolution. The doctrine of evolution, as applied to the science of life, means that all the species of living beings, both animal and vegetable, have not been originally created as we see them, but are derived from ancestors of lower and simpler organisation than themselves, by a process of descent with gradual modification:—that all species, however different they may now be, are descended from the same or perfectly similar ancestors, which, like the simplest living beings now known to exist, were minute gelatinous masses without organisation or structure. I cannot admit that there is any presumption against this theory. It is, no doubt, unlike anything in our experience, but the same is true of any possible theory of the origin of species: and of all possible theories of the origin of species, the theory of evolution is the least out of harmony with the ordinary facts of experience. The origin of species is a matter of inference, but the origin of individual organisms is a matter of observation. Every living organism has been evolved out of a perfectly simple germ, in which the microscope shows no vestige of structure; and it is surely more consistent with this fact to believe that species also have been developed, by descent with modification, from perfectly simple ancestral forms, than to believe that they have been created all at once just as we see them. The collateral reasons in favour of this theory constitute what is in my opinion a mass of argument of perfectly overwhelming force. The limited time at my disposal, however, makes it impossible for me to do any sort of justice to this argument, and consequently I shall not attempt to give it in even the barest outline.

The objection to the theory of evolution, which still lingers in many minds, appears to proceed from a notion that it somehow tends to get rid of the necessity for an intelligent Creator; but I shall give reasons for thinking that this is not really nor even apparently the case.

The doctrine of evolution is older than Darwin. Taking the origin of species by evolution as proved, and taking the known laws of life as his data, Darwin's theory is an attempt to explain the process of evolution by purely physical causation. The theory, in its extremest outline, is simply this: —All organisms are more or less variable: no two leaves in a forest are exactly alike, and the differences are often great enough to be quite conspicuous, as in the familiar case of human faces. At the same time, these variations tend to become hereditary. Now, if any variation is such as to give its owner any advantage over other individuals of the same species, the owner of such a "favourable variation" will be more likely than less favoured individuals to win a place in the struggle of life, to survive, and to leave offspring. These offspring will tend to inherit the "favourable variation" that caused their parent to survive, and the same competition will go on among them. Those which possess the "favourable variation" in the highest degree will again survive, and the improvement will go on progressing and accumulating through generations. This preservation of favourable variations is what Darwin calls natural selection. In answer to a possible objection it must be remarked that at Nature's feast there is not room for all; so many are born that only a fraction of the entire number can survive and leave offspring. There is, therefore, a "struggle for existence," and the race is on the whole to the swift, and the battle to the strong. This theory accounts not only for improvement, but also for divergence. Various kinds of "favourable variations" are possible, and it is improbable that they should be found together; thus, different variations will give rise to races having different characteristics. Either keen sight or keen scent, for instance, will be beneficial to beast of prey, and because the law of probabilities makes it unlikely that variation should occur in the direction of both at once, the race which is modified in the direction of improved sight, and that which is modified in the direction of improved scent, will be different and divergent races. Thus, no doubt, have arisen the varieties of dogs that hunt in different ways; only—let this difference be remarked—the formation of distinct races by means of the selection and preservation of those dogs which are endowed with the highest share of some useful character, has not been effected by means of natural selection, but mainly by the action of man. Darwin everywhere takes it as proved that natural selection acts with a degree of efficiency quite equal to the selection of domestic animals through human agency, but I shall further on have to offer reasons for believing that this is very far from the truth.

The whole of Darwin's theory, or rather the facts that constitute its basis, may be stated in the four following brief propositions:— 1. All species are constantly though slightly variable, and some of these variations, by the law of probabilities, must be advantageous to their owners. 2. Advantageous variations will give their owners the best chance of success in the struggle for existence, and will thus be preserved by natural selection. 3. Any improvement, once begun, will be perpetuated by inheritance and accumulated through successive generations. 4. In general, many variations are possible, each of which is separately an improvement, and as it is very unlikely that two such variations shall occur together, improvement will go on in different and divergent lines.

All these propositions are incontestable, and yet they appear to be a very insufficient basis for a theory which professes to account for the descent of the most highly organised animal and vegetable forms from those minute gelatinous masses without structure, which I have already mentioned as the simplest forms of life. It is not enough that a theory be founded on facts : the foundation of fact must be broad enough to bear the superstructure of theory. But further, the theory is utterly paradoxical. It is an attempt to account for the facts of vital organisation without the agency of an organising Intelligence ; and no paradox can be greater than this. No greater paradox can be imagined than to maintain that all the wonderful adaptations of the animal frame—of the wing for flight, of the ear for hearing, and of the eye for seeing—are in no way due to intelligence, but only to the action of blind unintelligent forces. Yet Darwin's theory implies this. Paradoxes, however, have sometimes proved to be true. It is not so very long since the earth's motion was a startling paradox, and at an earlier period the spherical form of the earth was a paradox also ; and when any theory, however paradoxical, comes to us with such authorities in its favour as Darwin, Wallace, and Huxley, it deserves at least a respectful consideration, with which no prejudices, religious or any other, ought to be permitted to interfere. I never can read Darwin's great work on the "Origin of Species" without a strong and admiring sense of the force of his facts and the ingenuity of his arguments. Nevertheless, I regard his theory as insufficient and unsatisfactory in every point. I believe, in the first place, that in the evolution of species, variations must have occurred which no theory of spontaneous and unguided variation is sufficient to account for ; in the second place, that natural selection among small spontaneous variations is incapable of acting to the extent required ; and, in the third place, that even if these causes were adequate, there are still large classes of facts which contradict the theory.

It must have been felt by every one who has bestowed even a little thought on the subject, that one of the greatest difficulties, and certainly by far the most obvious difficulty, of Darwin's theory, is that of accounting for the origin of a co-ordinated structure. I mean of a structure in which a number of parts are adapted to each other. The most remarkable of all instances of co-ordination of parts, or, in other words, of complex adaptation, are the organs of the higher senses, the eye and the ear; and it appears incredible these should be due to such a process as natural selection among spontaneous variations. Darwin shows that he has felt this difficulty, though he believes that it is capable of a satisfactory answer. I admit that I may have overstated this argument when I said, in my opening address seven years ago, that in order to improve such an organ as the eye at all, it must probably be improved in at least ten different ways at once. Of course, ten variations, all occurring together and co-operating with each other, would, on Darwin's principles, be improbable to a degree that could not be distinguished from impossibility. But it is at least conceivable, as Darwin has pointed out in reply to me,* that the various improvements needed in order to bring the eye to perfection, improvements in the lenses, the iris, the eyelids, the retina, the muscles that move the eyeball, &c., may be effected, not all at the same time, but one at a time; for a slight improvement in one of these may be useful when occurring alone, though a great improvement would be useless without other improvements co-operating with it; and thus such an organ as the eye, according to Darwin, may have been brought to perfection by innumerable slight improvements in each part separately. I do not deny that there is great force in this argument, but I think we can point to, at least, one case where improvements cannot possibly help each other unless they are absolutely simultaneous; I mean the two nervous connections of the iris of the eye. One of its nerves has its root in the brain, and contracts the pupil under the stimulus of light; the other has its root in the sympathetic ganglia, and opens the pupil again when the intensity of the light is diminished. It is obviously impossible that the efficiency of either of these two nerves could be increased

* See Darwin's Work "On the Variation of Animals and Plants under Domestication." Vol. II., p. 222.

separately; they will not be improved at all unless they are improved together; and this, on Darwin's principles, can only be done by means of accidental favourable variations occurring in both at once. But such coincidences are so improbable that they may be left out of account, as if they were impossible. I should think there must be many such instances in the anatomy of all the higher animals, though I cannot mention any other which is equally conclusive.

There is moreover this further flaw in Darwin's reasoning on the subject. It appears to take for granted that one variation, or the variation of one part of a structure, is as likely to occur as another; and that therefore the exact variation which is needed is certain to occur, if only time enough is allowed for the process of the evolution. It is obvious that this is all-important, for such an organ as the eye would be useless if it were left imperfect in a single important part; if, for instance, one of the lenses were considerably out of focus. Now, the assumption which Darwin thus tacitly makes appears inconsistent with fact. We do not find that one variation is as likely as an another; on the contrary, we find that different species are variable in different degrees; that one part of an organism is more variable than another, and that among variable parts there is a tendency to variations of a particular kind, and an equally remarkable steadfastness of character in other respects. I will mention one striking fact as to the constancy of a character which cannot be of first-rate importance to its possessors. Those lowly organised fishes, such as the lamprey, which have no jaws nor fins, have also only one nostril, but in all other vertebrates there are two nostrils. It is impossible to give any reason for the absence of variation in this comparatively unimportant character; but it is important as showing that indefinite and equal variability in all directions alike is not a law of nature.

In a remarkable passage of one of Darwin's works, he compares the action of natural selection in forming a co-ordinated structure to that of a builder who constructs a regular and harmonious work of architecture out of irregular masses of stone which have assumed their shape accidentally, by falling from a precipice. In such a case the form of no one stone has been purposely designed for its place, or designed at all, yet wedge-shape stones may be found for the arches, long flat stones for the lintels, and so on, which will serve the builder's purpose as if they were hewn to order. This comparison is ingenious, and illustrates Darwin's meaning well; but t may, I think, be shown that the facts of the organic world do not correspond with it. Suppose we were to examine such a building as Darwin has imagined, with the view of discovering whether the forms of the stones were such as to make possible for us to believe the assertion that they owed nothing whatever to the stone-cutter; and we were to find in one single instance a shape which could not possibly be due to any agency except human art, this would be enough to disprove the assertion that the builder had no stone-cutters in his employment. Now, I maintain that there are many instances in the organic world comparable to this:—instances of peculiarities in living beings which could not have originated in those slight random spontaneous varations which alone Darwin's theory admits. I will mention what occurs to me as one of the most conclusive instances of this kind. Some animals, of which the chameleon is the best known instance, have the power of changing colour. This power is of great value to its possessors, because they usually assume a colour resembling that of the surrounding objects, and thus at a little distance become comparatively invisible to the enemies that prey on them. This power must be invaluable to such an animal as the chameleon, which has neither strength nor swiftness nor any other ordinary means of attaining safety; and once a race of animals was formed with this power, there is not the least doubt that it would be preserved and perpetuated by natural selection. But how is it first to be formed? how many generations of animals without this power would have to live and die, before a single individual was born with the slightest tendency to change its colour in correspondence with the colour of surrounding objects? Another instance of the same kind is presented by those animals which change their colour with the seasons, turning white in winter, and putting on a dark colour in the summer. The ermine is perhaps the best known instance of this. The animals which put on a coat of white for the winter are benefitted by the comparative facility with which a white animal may elude its enemies among the snow; while their summer coat of brown or gray is safer during the seasons when the ground is not covered with snow, because a white animal would be dangerously conspicuous on grass or rocks. This power of changing colour with the seasons, when it is once acquired, is thus certain to be preserved by natural selection. But how is it to be first acquired? how is the first beginning to be made? Colour is no doubt a very variable character, but it seems impossible that the peculiarity of the ermine, which changes colour periodically with the season of the year, could ever originate in mere random unguided variations.

I go on to mention other instances of structures which appear impossible for mere unguided variation to originate. If they are less conclusive than those instances which I have just taken from the facts of colour, this is because the circumstances are more complex and less within the grasp of our knowledge; but they open far wider questions. If Darwin is right, and if there is no other agency at work in organic formation than that of natural selection among spontaneous, or, as I prefer to say, unguided variations, it necessarily follows that no variation can be preserved unless it is useful to its possessor. Darwin regards this as one of the fundamental data of his theory. But it will be seen that it raises a multitude of difficulties: for there are many organs whereof the usefulness is evident in their mature state, while it is difficult to see of what use their first germs could have been to their possessors. The usefulness of a bird's wing is obvious in the mature state, but ungrown wings are almost proverbially useless; and I am not aware that Darwinians have made any attempt to show what may have been the first incipient state of the bird's wing. Granting the theory of evolution, birds must be descended from reptiles, and their wings must be modified fore-legs. But, on Darwin's theory, how are we to account for the transformation of a leg into a wing? How was the period of transition got over, during which the limb was ceasing to be either a foot or a hand without having yet become an organ of flight? Natural selection would have been more likely to destroy than to preserve a race of animals in such a state. A similar difficulty occurs respecting the fins of the fish. On any theory of evolution, fishes that have fins are descended from finless fishes like the lamprey. [Here Mr. Murphy exhibited the skeleton of a lamprey.] But how could the first fins be acquired at all, if it was necessary that they should from the very beginning be of such service as to give their owners a perceptible advantage over fishes without fins? A fin in its first incipient state would be as useless as an ungrown wing. But these are cases where we do not know what the incipient state was, and the argument consequently can scarcely be thought conclusive. I go on to mention a remarkable case in which recent researches have brought to light what appears to be a structure in that incipient state wherein it is of no use to its possessor, and has been formed with the purpose of being useful, not at first, but after it has been perfected through countless generations. The great vertebrate class of animals—that is to say, the class of animals which have a back-bone to support the body and protect the chief nervous cord—has until very lately appeared to be quite isolated from all other classes. The affinities of the members of that class had been traced from warm-blooded vertebrates down to cold-blooded ones; from cold-blooded air-breathers like the frog down to fishes; from the higher fishes down to such fishes as the lamprey, which has neither jaws nor fins; and from this down to the amphioxus, a little creature which has no brain, no distinct heart, and no red blood, yet shows itself to be truly a vertebrate, though the lowest of vertebrates, by the possession of a true vertebral column; though this is only a membranous tube situated along the back and containing nervous matter. [Here Mr. Murphy exhibited an amphioxus preserved in a phial.] But here until lately the chain of affinities appeared to break off: nothing was known which appeared to connect the vertebrates with any invertebrate class. All vertebrates present fundamentally the same mode of development. If the developing embryo of a fish or a frog, for instance, is watched under the microscope, a deep groove is seen to form itself on that side of the original structureless germ which ultimately becomes the animal's back, and at the bottom of this groove a band of cartilaginous substance is laid down, which is afterwards developed into the vertebral column. This mode of development is common to all vertebrate animals from the amphioxus upwards, and is altogether unlike that of nearly all invertebrates. But a discovery has been made within the last few years which appears to supply the missing link between vertebrates and invertebrates, and to show from what lower forms vertebrate animals are most probably descended. The ascidians are molluscous animals of low organisation ; but it has been shown that some ascidians, when first developing, present an almost perfect likeness to the first state of a vertebrate embryo, having the essential features of the dorsal groove and the band which is formed below it. In the case of the vertebrates, the embryo undergoes a forward development, attaining to a higher organization ; in the case of the ascidians, the embryo undergoes a retrograde development, ending in a lower organisation than that with which it commenced. But, if the theory of evolution be true, we may infer that an animal having the characters common to the vertebrate and the ascidian embryos was the common parent of both vertebrates and ascidians ; and here we have the first beginning of vertebrate organisation. But how will Darwinism account for this? As we have seen, Darwinism requires that every variation shall be from the first generation advantageous to its possessor, because otherwise natural selection would not preserve it. Now, of what use can the dorsal groove and the incipient cartilaginous band below it be to these ascidian larvæ? or of what use can they have been to the common ancestor of ascidians and vertebrates? The muscular system of an almost microscopic animal cannot need the support of a vertebral column, and the band which appears to foreshadow a vertebral column cannot be serviceable for the protection of the nervous centres, because it is situated below the rudiment of a nervous system, and does not attain, as it does in the developed vertebrate, to the form of a tube surrounding it. It seems to me that in these very curious facts we see two most important characters—the dorsal groove and the cartilaginous band below it—which no possible benefit to the animal itself will account for, and which were at first introduced by the guiding Intelligence that directs the work of evolution, not with a view to the benefit of the animals in which they first appeared, but with a view to the ultimate evolution of the vertebrate class of animals from this lowly beginning. Here, to quote the words of Schiller, we "find in our search the Creator at work in creating."*

I have now mentioned some instances of peculiarities of structure and function, for the origin of which mere spontaneous variation

* Beschleicht forschend den Schaffenden Geist."—*Der Spaziergang.*

appears unable to account. I now go on to show the difficulty of believing that even when favourable variations occur, they will be preserved by natural selection to the extent required by the theory. Darwin, in the earlier editions of his "Origin of Species," constantly took it for granted that the action of natural selection was altogether unerring—that it was absolutely certain to preserve those individuals which present favourable variations. There is here an important flaw in the argument, which so far as I am aware, was first pointed out by Professor Tait,* formerly of the Belfast Queen's College, but now of the University of Edinburgh; and this, I may remark, is a good instance of the service that an able man may do to a science which is not his own, and of which he does not know the details. Professor Tait has pointed out that no favourable variation can give to any single individual possessing it the certainty of surviving and leaving offspring; all it can give is an extra chance, and in many, perhaps in most cases, a very small extra chance. Among all organisms the chances are against any one individual that is born growing up to maturity: among many, and those not the lowest tribes, the chances are hundreds to one; and if, as Darwin maintains, all variations are singly but small, what will be the value of the extra chance which some favourable variation will give its possessor in the struggle for existence? If the chances are a hundred to one against any single individual of the unimproved species surviving, and the chance in favour of survival is doubled by some favourable variation, the effect will amount only to this, that the chances are not a hundred to one but only fifty to one against the favoured individual. This argument appears to be conclusive against the opinion that species have arisen in individual random variations. The case will be quite different if a considerable number of individuals present the same variation at once; for the law of probabilities, which shows that the chance of the preservation of one favoured individual among a thousand ordinary ones is almost imperceptibly small, shows also that if a thousand possess the same favourable variation among a million of ordinary ones, a considerable number of the favoured ones will survive and give origin to an improved race. Darwin, in the latest edition of his "Origin of Species," admits the force of this argument, and says it

* See the *North British Review*, June, 1867.

shows that, in order to give origin to a new species, a favourable variation must occur in many individuals at once. But if variations take place at random and unguided, as Darwin maintains that they do, how is the same favourable variation to occur in a number of individuals at once? It seems to me that if Darwin only saw it, this admission amounts to giving up the entire case. I do not dispute that natural selection may give origin to races which possess in a higher degree some power or peculiarity of the unimproved stock; for where species are at all variable there will be many individuals that excel the rest in strength or swiftness or some other such favourable point, and these, especially if circumstances or their own instincts keep them apart, will give origin to a new race. But this process will account for only comparatively slight changes. It will not account for the origin of anything approaching to a new structure, for it appears impossible that this could originate in any other way than with single individual variations.

Let me illustrate by an instance the impossibility of a new structure arising out of small spontaneous unguided variations. The instance I shall take is in some respects favourable to the Darwinian theory, because it is a case of very simple adaptation. I mean the wing of the bat. This is very different from the wing of the bird. The bird's wing is nothing but an organ of flight; the bat's wing on the contrary has at least one of the functions of a hand, for it bears a claw by means of which the animal clings, and consequently the difficulty about the intermediate period of transformation of the leg or arm into a wing is much less in the case of the bat than in that of the bird. Moreover, it appears probable that birds flapped their wings from the first, but that the bat was originally a gliding animal like the so-called flying squirrel. In my work on "Habit and Intelligence," I agreed with Darwin, that natural selection among spontaneous variations was sufficient to account for the formation of the membrane which extends along the sides of the flying squirrel, and acts as a parachute, enabling it to take enormous gliding leaps; and that the same agency was further sufficient to develop a membrane like this into the wing of the bat. But further, thought, conversation, and reading on the subject have convinced me that it is not so, and that the advantage to the first squirrel or other animal which possessed the beginning of such a membrane was far too slight for it to be preserved by natural selection. The difficulty is twofold. In the first place, the earliest beginning of almost any structure will be of scarcely sensible magnitude; and, in the second place, even though it were sensible, yet when an improvement begins with some single individual, the chances, as we have seen, will still be greatly against its leading to the survival of its possessor. Moreover, even when an individual possessing some favourable variation does survive, it will be prevented from becoming the ancestor of a new species or race by this fact, for which, obvious as it is, Darwin appears to have made no allowance, that among the higher animals, every one which is born has two parents, while, by the hypothesis, the favourable variation is found in only one; and as the offspring are, on the average, of intermediate character between the two parents, the favourable variation will be transmitted to the offspring in only half its original force; and to their offspring again, with only one-half of this, or one-fourth of its original force—and so on, constantly weakening. It is true that this action will be counteracted by the effect of fresh variations and fresh natural selection; but it can be only under very favourable circumstances, if ever, that the effect of natural selection, accumulating through successive generations, can overcome the weakening of the original tendency through the crossing of the breed.

I have now endeavoured to show that spontaneous random variation does not occur to the extent, or in the manner, demanded by the theory; and that if it did, natural selection would be insufficient to fix and perpetuate these accidental varieties into permanent species. I have next to show how, in my opinion, even if the slight random variations of which alone Darwin admits the existence were sufficient to originate species, and if natural selection were sufficient to perpetuate them, there are still many of the most remarkable facts of the organic world which are demonstrably opposed to the Darwinian theory. One of the most conspicuous of all the facts of the organic world is the remarkable variety of characters as between different species and different groups, contrasted with their equally remarkable fixity within species and groups. It is on this fact that all classification depends, and it is the prominence of this fact which has until lately caused the belief to be almost universal that species are not only comparatively permanent but absolutely unchangeable. I have shown that I do not agree with this opinion. But I think that if natural selection among small spontaneous variations were the only cause of change, the facts of classification would be very different from what they are, and much simpler. There are many characters whereby one class or order is distinguished from another, which natural selection appears not to have the slightest tendency to produce. Take, for instance, the scales of fishes. If it is difficult, as it certainly is, to see how natural selection could have transformed a naked fish into a scaly one, the difficulty is not merely doubled or multiplied four-fold, but almost indefinitely increased, by the fact that there are among fishes, besides those which have the skin naked, four distinct types of scales, each of which is characteristic of entire groups of fishes. It appears impossible that such a character as a minute comb-like fringe at the edges of the scales, which is characteristic of one of these types, should be formed by natural selection; or, if it were, that so unimportant a character should be continued unchanged throughout entire groups. If Darwin's theory were true, the form and structure of the scales should either be a comparatively unvarying character, and the covering of all fishes should be nearly alike, as is the case among flying birds; or it should be a variable character, and then there would not be the great similiarity which is found through entire groups of genera. The same difficulty occurs, and is perhaps even more conspicuous, among plants. There is great diversity in the form of leaves; and yet how can one form be more favourable than another to the life of the plant? A Darwinian may argue that the prickles which arm the leaves of the holly have been produced by natural selection, because they no doubt are, or may be, useful to the tree by preserving its leaves from being eaten by cattle. If Darwin's theory is true, there are few simpler or better instances of it than this. But no such theory as this will account for the various characteristic forms of the leaves of the lime-tree, the oak, the ash, and the sycamore. The same remarks apply to the forms of flowers. Darwin has, no doubt, shown that many apparently anomalous structures among the flowers of orchids have really a very important function in insuring the fertilisation of the seed by the pollen brought by insects from other flowers; for the pollen of another flower of the same species is better for this purpose than that of the same flower. But these cases appear to be exceptional; the orchids are a very abnormal group, and no such explanation is possible of the characteristic differences that distinguish the orders and genera of normally formed flowers; such differences, I mean, as those between flowers with the seed-vessel below the calyx or above it; separate petals as in the rose, or petals united together as in the harebell; and stamens inserted below the seed-vessel, or in the calyx, or in the petals, or in the style. It is impossible to see how natural selection can have perpetuated such variations as these, because it appears impossible that any one of them can have given its possessor any extra chance of success in that unconscious struggle for existence which plants, as well as animals, are always waging. I believe that the only account we shall ever be able to give of the cause and significance of these endlessly beautiful varieties is, that variety is part of the Creator's purpose.

I go on to describe a still more remarkable instance than any yet mentioned of a structure which natural selection appears unable to account for. It has been mentioned in Mivart's able reply to Darwin, entitled "The Genesis of Species." It is admitted by all that the fins of fishes correspond to the legs of quadrupeds; and in some fishes the correspondence is nearly perfect in respect of position. If we accept the doctrine of evolution, we cannot doubt that the first fins which were developed on fishes were in positions nearly corresponding to the legs of quadrupeds, and that from such fishes all quadrupeds are descended, as well as all existing fishes with fins. But there are entire tribes of fishes which deviate very strangely from this arrangement, having the fins that correspond with the hinder legs of a quadruped as it were moved forward, and with them that part of the skeleton known as the pelvis, with which they are in immediate connexion; so that the skeleton presents the strange spectacle of both pairs of limbs, with their supporting bones, being situated almost close behind the head. Fancy how marvellous this would be thought if it were seen for the first time in a newly discovered fossil! [Here Mr. Murphy exhibited the skeletons of a garfish or sea pike, which has a pair of hinder fins in a position corresponding to that of the hinder legs of a quadruped; and of a sea bream, in which the second pair of fins, as well as the first, are near the head.] Now, how can Darwinism explain such a change as this? Darwin denies the occurrence of changes which are at once great and sudden among organisms in the wild state. But is it conceivable that such a change should take place gradually? Did the pelvis with the hinder fins creep forward gradually through ten thousand generations? I do not ask the question in order to put the idea in a ridiculous light: I should not deserve to occupy this chair if I were capable of doing so; but I mean how could this possibly benefit the race, so that the individual fishes which presented this character in the highest degree should be preserved by natural selection? The difficulty of accounting for the endless variety in organic forms has, I think, scarcely been seen by Darwinians; at least, I have met with no argument of theirs which appears distinctly to recognise it with the view of meeting it.

If Darwinism fails to account for organic variety, I am of opinion that it fails quite as conspicuously to account for organic progress. I know that Darwinians think this not a difficulty of their system, but one of its strong points. Their view is no doubt plausible at first sight; but it will cease to appear so when the bearings of the question are more clearly perceived. It appears certain that there has been a tendency to progress in the organic world. If the theory of evolution is true, there has been vast, though perhaps not constant, progress in living beings from those minute gelatinous masses, without structure or organisation, which were first endowed with the powers of life, up to the most highly organised animals. And, moreover, there appears to be geological evidence that when a more highly and a less highly organised class of animals come into competition with each other, the higher class tends to supersede the lower. Thus, the lamellibranchiates and the brachiopods are both of them bivalve mollusca, and adapted to the same kind of life; and the more highly organised lamellibranchiates appear to be at present superseding the more lowly organised brachiopods. In the same way pterodactyles, which were flying reptiles, have been superseded by birds; ichthyosauri, which were swimming reptiles, have been superseded by whales; and dinosaurians, which were grazing and browzing reptiles, have been superseded by the order of animals to which our cattle belong. Now, even if natural selection among random spontaneous variations were an agency that could account for the production of a highly organised being at all, we have still to account for what appears to be a general law, that the more highly organised classes, when produced, tend to supersede the less highly organised ones. It will be perceived that the questions are distinct. To Darwinians the answer to this latter question seems perfectly easy: they will say that the more highly organised any being is, the better it will in most cases be able to contend in the struggle for existence: it will have stronger muscles, acuter senses, and subtler instincts, and all or any of these will tend to give it an advantage, and so to increase the chance of transmitting its improved organisation to its offspring. This answer at first sight appears satisfactory, and it satisfied me for a long time. But it leaves two important factors out of consideration. In the first place, though it is quite true that the higher organisms have the advantage over the lower ones in respect of active power, it is equally true that the lower organisms have the advantage in respect of endurance. For instance, though a warm-blooded quadruped is a higher being than a crocodile or a lizard, and is, in general, though perhaps not in every case, superior in muscular, nervous, and mental power, and will so far have the advantage in the struggle for food; yet these advantages will be balanced by the greater power of the crocodile or the lizard to endure the want of food. It appears probable that these two advantages on the two opposite sides may be set off the one against the other, so that there will be no decided advantage in the contest on the part of either the higher or the lower organism. In the second place, the lowest organisms are well known to be the most prolific, and it is obvious that this must tend to multiply the chances in favour of a race surviving and spreading. I do not attach any great importance to this latter argument, because Darwin thinks, and on such a question I admit there is no higher authority, that the greater or less degree of prolificness is one of the least important of all factors in estimating the chances in favour of the survival or extinction of a race. Nevertheless, it must be a factor of sensible magnitude; and these two facts, that the lowest races are the most enduring and the most prolific, appear to be a perfect reply to the Darwinian argument, that the higher races are able to defeat and supersede the lower ones in the struggle for existence, by virtue of the greater efficiency of a high organisation. I conclude, then, that no such agency as natural selection among spontaneous variations is capable of accounting for the tendency to organic progess; and that it must be ascribed to an innate tendency imparted to living beings at the beginning by the Creator.

I now go on to mention an argument against Darwinism, which was first stated, so far as I am aware, by Mr. Mivart, in his admirable reply to Darwin, to which I have already referred. It is derived from the facts of what Mr. Mivart calls "independent similarities of structure." The meaning of this expression must be explained. In many cases there are organs belonging to different animals which are adapted to the same function, but are in all other respects totally unlike. Such is the case with the wing of the bird and the wing of the insect. Both of these are organs of flight, but they differ in everything else: in form and structure, in position, and in mode of development. The same is to be said of the eyes of insects and those of vertebrate animals, which are as unlike in structure as it is possible for two highly elaborate organs of sight to be. All this is quite consistent with Darwin's theory, and seems to be required by it: for if all organic change and progress begins in spontaneous unguided variations, the law of probabilities appears to require that if two organs are separately produced for the same function, they shall be produced in distinct ways, as the bird's wing and the insect's wing have been. Any close resemblance between two independently produced structures should, on Darwin's principles, be so improbable as to be practically impossible. Yet we do find such "independent similarities" in sufficient numbers to be a most serious difficulty, not to say an absolute refutation, of Darwin's theory, regarded as a complete theory of the origin of species. Were I to say all that I might say on this subject, I should have to reproduce Mr. Mivart's chapter which treats of it. I will only briefly enumerate the most remarkable of the instances which he mentions. 1. The marsupial mammals, such as the kangaroo and the opossum, which possess a pouch in which the young are kept, are quite distinct from the ordinary or placental mammals, and it appears impossible that either can be derived from the other. Yet each of these two great orders contains genera which bear the most striking resemblance to genera in the other. A species of mouse, which is placental, is figured beside a marsupial named antechinus, and the two can scarcely be distinguished at a little distance. In other cases the teeth are remarkably alike. 2. There are remarkable resemblances between the skeletons, and also the brains, of birds and pterodactyles ; and yet it appears certain that these resemblances are not due to a common descent. 3. The organs of sight and hearing in the cuttle-fish have a great general similarity to those of vertebrate animals ; and this cannot be due to community of descent : for, if these two classes had a common ancestor at all, it must have probably resembled the ascidian larvæ which I have already mentioned, and was certainly far too lowly organised to have any special organs of sense. 4. There are resemblances between the skull-bones of the ichthyosaurus and the whale, which cannot be due to community of descent, and apparently not even to the similarity of the conditions of their life. 5. There are some of the crustacea, that is to say animals of the same class with crabs and shrimps, which are protected by a bivalve shell like that of the true molluscan bivalves, and have a muscle for closing it like theirs, and yet there is no more true affinity between these two structures than there is between the shells of the crab and the tortoise. 6. The "bird's-head processes" of the polyzoa and the "pedicellariæ" of the echinus or sea-urchin are very similar, and yet cannot be inherited from a common ancestor.

The same argument against Darwinism, from the fact of independent yet parallel modifications, has been advanced in a much more elaborate form by Professor Cope of America, in a pamphlet entitled "The origin of Genera," which is in my opinion the most important contribution to the subject that any one has made since the first publication of Darwin's "Origin of Species," though it appears to be little known, and Mr. Mivart has made no reference to it. I will state his argument in my own words. Darwin's theory, that all variations are fortuitous and unguided, accounts perfectly for the divergence of one species, or genus, or order, or class from another. According to him, species, by their variations, have branched out into genera, genera into orders, and orders into classes ; so that the form of all true classification is that of a tree, with branches which diverge and rediverge in all directions without ever re-uniting. This view of classification is, no doubt, mainly true; but, as Mr. Mivart has shown, there are cases of independent similarities for which Darwinism will not account; and Professor Cope has shown further that these are not only found here and there throughout the organic world, but exist systematically; so that in many parts of the system the true form of the classification is not that of divergent groups, but of parallel series, as in the classifications of chemistry. Thus there are what Professor Cope calls transverse affinities; one set of affinities being between different members of the same series, and another set, transverse to these, between the corresponding members of different but parallel series.

The following, for instance, is a possible case:—Let us call three genera A, B, and C, and their species 1, 2, 3, and 4. The affinities of the species will then be thus represented:—

$$A^1,\ A^2,\ A^3,\ A^4.$$
$$B^1,\ B^2,\ B^3,\ B^4.$$
$$C^1,\ C^2,\ C^3,\ C^4.$$

The species of the same genus, as A^1, A^2, &c., have thus one set of affinities with each other, while the corresponding species of the different genera, as A^1, B^1, and C^1, have another set of affinities, transverse to these. This class of facts appears fatal to Darwinism, which, being based on the hypothesis of random unguided variations, is inconsistent with any systematic parallelism in classification. I do not say that instances so complete as that which I have expressed in symbols often occur, but there are a great number of cases where two species of different genera almost exactly resemble each other in everything except the generic peculiarity. I will mention two very singular instances of these transverse affinities. The first is that of two species of silurid fishes which resemble each other very closely in everything but a single character of generic importance; but in this they differ:—one of them belongs to a genus which has the distinguishing character of being without eyes. The other instance is that of two species of the order to which the frog belongs, agreeing in the extraordinary habit of carrying about their eggs, until they are hatched, on the back, which forms depressions in the skin to receive them; and yet these species belong to different genera. In such a case, shall we conclude that these two species have assumed this peculiarity separately?

This appears improbable in the case of so strange a habit as that of carrying the eggs on the back. Or shall we conclude that a species in one genus may be descended from a species in another genus, and that all the species of a genus have not necessarily the same origin? Professor Cope adopts the latter conclusion. He maintains that in a great number of instances the same species belongs or has belonged to different genera—that is to say, that the same specific form may put on the characters of various genera without ceasing to be the same species and to wear the same specific characters. This conclusion is supported by a statement made on the high authority of Agassiz, that in many cases the characters of the species appear earlier in the course of development than the characters of the genus. From these facts, for such they appear to be, of species retaining their characters as such, while, at the same time, they put on the characters of various genera. Professor Cope infers that organic evolution is guided by no such agency as natural selection among spontaneous variations, but by an innate and inscrutable law of development, impressed on living beings at the beginning by the Creator.

The theory that the variations in which new species arise are not fortuitous but take place according to predetermined laws, is strongly supported by a fact which Darwin, with his accustomed candour, calls a very important one, though he must be aware that it tells against his theory. The black-shouldered peacock, a variety which has all the appearance of a distinct species, has been hatched, not once only, but on five distinct occasions, from the eggs of the common peacock. This shows that the same variation may occur several times, though Darwin's theory would lead us to believe that this is impossible.

Finally, if all other objections to Darwin's theory were satisfactorily answered, this one remains, that geological time is not long enough for the production of the highest forms out of the lowest by the gradual accumulation of slight variations. It may be a little startling to many to hear it said that geological time is not practically infinite. But the most elementary principles of physical science show that the world must have had a beginning at a time which was not infinitely remote; and Sir William Thomson, than whom there is no higher authority, has calculated, from the mathematical laws of the cooling of heated masses, that the time which has elapsed since the earth was sufficiently cooled to be the abode of living beings, is certainly not more than five hundred millions of years, and probably not more than one hundred millions of years. Either of these periods so transcends the powers of the imagination that it may at first seem ample for any process whatever. But let us compare it with the periods demanded by Darwin's theory. Mr. Mivart says, and Darwin probably would not dispute this, that we cannot believe a distinct species to have been formed and established as such by any process of natural selection in less time than a thousand years. If, then, it takes this period to form a species, it ought to take something like ten-times as long to form a genus, a hundred times as long to form a tribe, and so on, the periods increasing in geometrical ratio as we go on to wider and wider groups, separated by greater and greater differences. Suppose, for instance, that it took a thousand years to develop the lion out of the original stock of the cat genus, it should then take ten thousand years to develop the cats out of the original stock of the tribe to which cats and dogs alike belong, and one hundred thousand years to devolop this out of the original stock of the carnivorous order, which was, I should think, more like a badger than either a cat or a dog. To develop this out of the original stock of the placental mammals would take a million of years, and ten millions to develop this out of the original stock of all the mammalia, which was probably more like the ornithorhyncus than any other known animal. To develop the first mammal out of a newt must have required probably a hundred times this, or a thousand million years; and to develop the first newt out of a fish a thousand millions more; and it must have taken at least as long a period for a fish with fins and jaws to be developed out of a fish like the lamprey, which has neither. It is, perhaps, not too much to guess ten thousand million years as the time needed to develop a fish like the lamprey out of such a fish as the amphioxus, which has white blood and no distinct heart; a hundred thousand million years to develop this out of an animal resembling the ascidian larvæ already mentioned, and at least as much more to develop this from one of those minute gelatinous masses without structure, which are the simplest of all living beings. We thus conclude that the time needed for the evolution of the highest forms of life out of the lowest would probably require, on the Darwinian theory, more than two hundred thousand million years, while the utmost possible duration of geological time, according to Sir William Thomson, is not more than one four-hundredth of this. Of course I do not offer this estimate as making the slightest approach to accuracy. It is only a rough attempt to show how the order of the magnitude may possibly be estimated, and the ever multiplying length of the periods of time needed for greater and greater evolutionary changes. But if it is wrong, it errs on the side of not making the periods too long but too short, and this for two reasons. In the first place, I have greatly understated the number of gradations in the classification of groups subordinate to groups; and in the second place, I made no allowance for what we have good reason to believe to be the fact, that variation of sufficient magnitude to give origin to new species is not going on always, but takes place only at intervals.

The limit which is necessarily placed to the length of such an address as this compels me to omit three of the most interesting of the special subjects opened up by Darwin's theory—I mean mimicry, sexual selection, and the origin of man. But with these exceptions—important exceptions no doubt—I hope that I have given a clear outline of the present state of this most interesting controversy. If I am told I have dwelt almost exclusively on the arguments against Darwinism, I reply that I trust this is not in consequence of any unfair controversial bias, but because all the arguments on Darwin's side are to be found in his work on "The Origin of Species," while many of the opposing ones are new, or, at least, little known. It may perhaps have excited some surprise that I have not referred to the writings of Herbert Spencer; but, though he is by far the ablest exponent of the general theory of evolution, he has added little to the specially Darwinian form of the theory. I began by stating myself to be a believer in evolution, but I have given arguments which to me appear conclusive against that special form of the theory of evolution which we call the Darwinian theory. I may now be asked whether I have any better theory to offer instead. It is not necessary to give any reply to such a question as this. We are not fit to engage in the search after truth unless we can endure to rest in negative conclusions, and remain without any theory at all ;—in other words, unless we are able to renounce what proves untrue, while admitting that we have no true theory to substitute. The positive conclusions which I think we may accept are somewhat indefinite, but nevertheless they are valuable if true. They are the following:—1. The rapidity of the process by which new species and new classes are formed has been much greater than Darwin allows ; and great changes have sometimes occurred quite suddenly. The most conclusive instance with which I am acquainted of a change which must have taken place suddenly is perhaps that of those fishes which have the pelvic bones and what corresponds with the hinder fins of other fishes as it were moved forward and situated close behind the head. 2. The variations by which new species and new classes are formed, are not fortuitous or at random, but take place according to a predetermined plan ; and the evolution of living beings is guided by Intelligence.

This latter conclusion is not advanced as a discovery; on the contrary, it is the general belief of thoughtful men, and probably has been so from a period long before the dawn of conscious philosophy and science ; but I believe the truest science confirms it, and that its denial by the Darwinian school will prove to be but a temporary aberration from those principles of common sense which cannot be safely disregarded in science any more than in the affairs of life. And if the existence of a guiding Intelligence, which cannot be resolved into any law of physical causation, is established as a scientific truth, we have a basis whereon to establish a science of natural theology. There are fashions in intellect as well as in everything else, and it is the fashion of the present day to decry natural theology as an impossible science; but I am convinced that this is only a passing phase of thought, and that philosophers, as well as men who make no pretensions to that name, will yet acknowledge God as manifested in His works.

Mr. Murphy in conclusion expressed his thanks to Professor Cunningham for lending him out of the Museum of the Belfast Queen's College the specimens exhibited during the address.

26th November, 1873.

JOSEPH JOHN MURPHY, Esq., F.G.S., the President of the Society, in the Chair.

A Paper was read by DR. HENRY BURDEN,

ON THE IMPERFECTIONS OF THE NORMAL HUMAN EYE.

AFTER some preliminary observations the author proceeded as follows:—In my opinion it is an error to attribute perfection to the material and imperfection to the immaterial part of our nature. I believe that they are both susceptible of improvement, and that they are in a great measure mutually dependent upon one another for the successful attainment of that end.

Deprived of the stimulus supplied to it by the material organs of sense the mind would be a "tabula rasa." Without the intelligent co-operation of the mind external impressions transmitted by the organs of sense would simply furnish the exciting cause of reflex acts. Our senses would continually play us false were it not for the wholesome discipline to which we subject their indications by the judgment and reason. Of all our senses that of vision is the one which most frequently leads us astray. The fault, however, is in most cases to be attributed rather to the erroneous conclusions we draw from unusual combinations of phenomena than to defects in the organ of vision itself. On the other hand the eye is not a perfect instrument, and yet we can with safety trust ourselves to its guidance. It is to the imperfections of the eye as an optical instrument that I wish to direct your attention this evening. Many of them have only recently been discovered. At one time, and that not long since, the eye was commonly believed to furnish not alone the best but the only true model for imitation in the construction of telescopes, microscopes,

&c. It turns out now that were any optician to supply an instrument with as many defects as are demonstrable in our eyes no competent judge would accept it as even a fair average specimen of skilful workmanship. Yet in spite of this we succeed by due care and attention in obtaining true images of the outer world, and then we must not forget that the human eye possesses many advantages which are deficient in all other optical instruments.

I must take it for granted that my present audience have a general knowledge of the structure and functions of the eye, for within the brief limits of a single lecture it would not be possible to survey with advantage so wide a field of study. Let us examine by what means a clear and well defined picture of objects, of the natural colours and proportions, is obtained upon the ground glass screen at the back of a photographer's camera.

In the first place, the instrument is provided with a combination of lenses, the optical axis of which is directed towards the object to be depicted, and which brings the rays of light emanating from the latter to a focus upon the screen. Next, the inner surfaces of the camera are blackened to prevent the reflection of light from them upon the screen, for this would detract from the distinctness of the picture.

Then means are supplied for the adjustment of the focus to the varying distances of objects. These usually consist in the attachment of the screen to an inner box sliding in an outer one, for the coarse adjustment, and of a rack and pinion connected with the tube containing the lenses, for the fine adjustment.

Further; lenses of clear, colourless glass, free from air bubbles, or opacities of any kind, in other words as homogeneous as possible, are selected.

Lastly, two defects of badly constructed instruments, namely spherical aberration, and chromatic dispersion, are more or less completely obviated by appropriate contrivances.

Spherical aberration is a consequence of the form of lenses as usually constructed, their surfaces being segments of spheres. It can easily be demonstrated that the rays of light which pass through such lenses are not all equally refracted, the amount of deviation from the primary course increasing in direct proportion to their distance from the optical axis. It follows that the focal distance of the rays varies inversely as their distance from the axis. And thus, when the screen is at the proper focal distance for rays which have passed through the central portion of the lens, though a tolerably well defined picture may be obtained in the vicinity of the optical axis of the instrument, its borders will appear as an indistinct halo, produced by rays which have passed through the circumferential parts of the lens, and, having already attained their focus, are diverging from one another.

This defect is partially remedied by the use of a diaphragm perforated by a circular aperture of smaller diameter than that of the lenses. The circumferential rays are thus arrested, while the passage of the central ones is unimpeded.

A more éfficient remedy, however, consists in the combination of converging with diverging lenses of different degrees of curvature and refractive power.

A similar device, as I shall explain presently, is adopted for the correction of chromatic dispersion, and so, by a fortunate coincidence, it is possible with the same combination of lenses to correct both errors simultaneously.

Chromatic dispersion is due to the circumstance that the several colours which are combined in white light are unequally refracted, red light being least and violet most refrangible. A lens, therefore, not only decomposes white light into its constituent colours, but also brings each of the latter to a different focus. Hence at a certain distance from the lens the violet rays are in focus, further from it the indigo ones, then in succession the blue, the green, the yellow, and the orange rays; and lastly, at the maximum distance, the red ones.

Nevertheless images of unmixed colour cannot be obtained in this way. Suppose, for instance, that our source of light be the sun's disk, and that the screen is in focus for violet light. A violet disk is without doubt present upon the screen, but coincident with it there is a series of disks consisting of the remaining colours of the spectrum. Rays of all the colours of the spectrum are consequently mingled in the central part of the image, and the combination appears achromatic, though in point of fact the colours of the blue end of the spectrum predominate, owing to their concentration being greater than that of the others. But this is the case only at the central portion of the image; for, on account of the convergence of the rays decreasing as we pass from violet to red, the indigo disk is larger than the violet one, the blue than the indigo, and so on until we arrive at the red one, which is the largest of all. Consequently each disk in the above order overlaps the preceding one, and its margin is combined with all the colours less refrangible than itself, but is free from mixture with the more refrangible ones. The margin of the red disk, therefore, extends beyond those of all the others, and is unmixed with any other colour.

The result is an apparently achromatic image, surrounded by a series of variously coloured rings of which the outermost is a pure red. [Experiment.]

A similar explanation can be given of the fact that when the screen is in focus for red light an apparently achromatic disk is surrounded by a coloured fringe, the outermost ring of which is pure violet. [Experiment.]

When the screen is in positions intermediate between the focus for red and that for violet rays, the relative degrees of intensity and modes of combination of the colours, though different in each position, are in no case such as exists in white light.

For the sake of simplicity I have taken the case of a disk, but the effects and their explanation are similar, whatever figure the object may possess.

One of the most interesting and instructive chapters in the history of optics is that one which relates to the discovery of the means whereby chromatic dispersion may be corrected.

Throughout a long series of years both men of science and practical opticians exerted their most strenuous efforts in the search after a mode of construction which would ensure achromatism in optical apparatus, but in vain, for the problem remained unsolved up to the time of Newton.

That illustrious philosopher took the matter in hand, and after diligent observation and research arrived at the conclusion that the evil was irremediable.

He founded his belief on the unwarranted induction, from a few unfortunately selected instances, that in all transparent media refraction and dispersion bear a constant ratio to each other. In spite, however, of the retarding influence of his high authority, attempts were still persevered in to attain the desired object. Euler, sharing the common belief of his contemporaries, that the human eye is achromatic, examined its structure in order to discover how this reputed property might be conferred upon it. From data thus obtained he framed mathematical formulæ to be applied in the construction of glasses. Practical opticians were, however, still unable, even with the aid of his formulæ, to manufacture instruments in which the proposed end was accomplished.

At last Dollond found out that by combining a convex lens of crown with a concave lens of flint glass an image of an object might be obtained nearly free from coloured fringes. Since then, the general applicability of the principle by which Dollond was guided having been recognised, various combinations have been tried until opticians may now be said to have almost reached perfection in this branch of their art.

Dollond and his successors availed themselves of the now well ascertained fact that the ratio of dispersion to refraction varies with the nature of the medium.

Thus the index of refraction for crown glass is from 1.531 to 1.563, and for flint glass from 1.576 to 1.642. The difference in refractive power is here comparatively small in amount. The difference between the dispersive powers of these varieties of glass is on the other hand very considerable, the ratio of dispersion in crown being to that in flint glass as 0.033 to 0.052.

By combining, therefore, a diverging lens of flint glass with a more powerfully converging lens of crown glass, the dispersive effects of the latter may be neutralized by those of the former, while the convergence of the transmitted rays will only suffer a certain degree of diminution, a sufficient amount being retained to bring the rays to a focus.

We will now turn to the structure of the eye, and see in how far it fulfils the conditions necessary for the production of a true picture of external objects. On comparing the eye with a photographer's camera, it will be apparent that the cornea and the lens of the former may be regarded as equivalent to the lens of the latter; that the iris and pupil, though subserving other important ends, represent the perforated diaphragm of the camera; and that the three coats of the eye—viz.: the sclerotic, the choroid, and the retina, correspond respectively, in a general sense, to the wooden walls, the black internal coating, and the ground glass screen of the photographer's apparatus. Further, there is an arrangement in the eye which acts, though in a very different manner, the part of the rack and pinion of the latter in adjusting the focus to the varying distances of objects. I refer to the ciliary muscle. The cavity of the eyeball differs from that of the camera, in being filled with a combination of fluid and semi-fluid matter, while the cavity of the latter contains nothing but air. We will first examine the refracting media of the eye. Of these there are four, viz.—the cornea, the aqueous humour, the lens, and the vitreous humour. Now, in a good optical instrument the lenses should, as I have already said, be perfectly transparent and homogeneous. Of the four refracting media of the eye the only one which can be said to possess these properties is the aqueous humour, a fact which can be made apparent in the cornea and lens by throwing a strong beam of light through them, when they will exhibit a peculiar cloudy opalescent appearance, accompanied in the case of blue light by fluorescence. The source of this imperfection will be found in the structure of the cornea and lens, which is far from uniform. They both contain numerous fibres and opaque spots. The indistinctness of dark objects in the neighbourhood of brightly illuminated ones arises from this cause. The vitreous humour also includes, even in healthy eyes, many fibres and corpuscles floating more or less freely in it. These are for the most part buoyed up to its upper part. The movements of the eyeball, however, cause them sometimes to pass across the axis of vision, and when this takes place, especially when they come near the yellow spot, they may occasion the appearance called muscæ volitantes. The lens, besides being imperfectly transparent, refracts light unequally in different parts. One consequence of this is that when distant brilliant sources of light, such as a star, a street lamp, the sun, or the electric light, are looked at, they present a radiated form. The structure of the lens fully explains the phenomenon. I shall, therefore, briefly direct your attention to some of the anatomical details of that body.

The human lens is bi-convex in form, the posterior being greater than the anterior curvature. It is about one-third of an inch in diameter, and one-fifth of an inch in thickness.

Its density increases from the surface to the centre. The substance of the lens is made up principally of fibres. But for my present purpose the most important structural arrangement is the following :—

If the surfaces of the lens, at an early stage of development, be carefully examined, there will be observed on each surface three faint striæ, which radiate at equal inclinations to one another from the centre towards the circumference. The striæ on one surface are situated opposite to the middle of the intervals between those on the other surface. These striæ indicate the position of lamellæ, which extend to the centre of the lens. In the lamellæ, which are themselves devoid of fibrous structure, the extremities of the fibres terminate. The fibres are arranged, with reference to the lamellæ, in such a manner that each of them terminates by one extremity in a lamella on one side of the lens, and forming an acute angle with it passes obliquely over, to end by its other extremity in the opposed surface of the nearest lamella on the other side ; and that a fibre which ends by one extremity near the axis of the lens ends by the other in the distal edge of a lamella, and *vice versa*, the extremities of the remaining fibres having corresponding intermediate positions in the two lamellæ with which they are connected. The extremities of the fibres become indistinct, and gradually merge into the substance of the lamellæ. The latter, though exhibiting a faintly granular appearance, are almost homogenous. The diversity of structure in the fibrous part of the lens and in its radiating lamellæ is accompanied by a difference in their refractive power. It will be obvious that this must have the effect of producing a radiated form in the image, corresponding to the arrangement of the lamellæ.

I have repeatedly noted with care the shape of the star as it appears to my own eye, and have invariably found it to answer to the following description :—It exhibits six radii, which make equal angles with one another, and divide dichotomously into branches at their distal extremities. The figure is not perfectly regular, for two of the radii diverge from one extremity of a short vertical line, at the other end of which two more are situated, while the two remaining ones extend horizontally in opposite directions from the middle of the vertical line.

The elongation of the figure in the vertical direction I ascribe to a certain amount of astigmatism in my eye. I should feel much indebted to any one who would, after careful and repeated observation, furnish me with a diagram showing the precise form of the star as seen by his own eye. Of the six radii three are probably due to the non-fibrous lamellæ of one side of the lens, and three to those of the opposite side.

It may be thought by some that the appearance in question is due to something special in the source of light, or to an atmospheric cause; but that such is not really the case, anyone may easily satisfy himself by observing that the figure is exactly repeated in every instance, no matter what the nature of the luminous body may be, and that, on inclining the head to either side, it revolves through an arc corresponding to the movement of the latter.

The eye is not free from spherical aberration. This may be mathematically demonstrated from the data furnished by the curvatures and indices of refraction of its transparent media, which have been determined with great precision by Helmholtz. The spherical aberration of the eye causes the image of an object to be surrounded by an halo. If the object be not brightly illuminated, the halo is so slightly marked that it is not noticed, but in the case of intensely luminous objects, such as the electric light, the sun, and platinum wire raised to incandescence by the voltaic current, it has the effect of greatly enlarging the image. The curvature of the cornea is not symmetrical with reference to the axis of vision, being usually greater in the vertical than in the horizontal meridian, as has been shown by the observations of several oculists, with the aid of Helmholtz's opthalmometer. Helmholtz has also proved that the centering of the refracting media of the eye is not accurate, in other words, that their optical centres do not lie in the same straight line. Both of these circumstances concur to produce the defect called astigmatism, which in most persons renders the distance of distinct vision greater for horizontal than for vertical lines. The fact can be demonstrated by drawing two ink lines at right angles to one another upon a piece of white paper. It will then be seen that when the eye is adjusted for distinct vision of one line held horizontally, the vertical line is indistinct, and *vice versa*. This is apparently a normal condition of the eye, though we do not commonly suffer any inconvenience from it. In cases where the disproportion becomes excessive it may be remedied by the use of cylindrical glasses. That the eye is not achromatic, Dollond discovered more than a century ago, when he examined its structure, in order to ascertain, if possible, the best means for correcting errors in the lenses of telescopes. The amount of chromatic dispersion has been measured. It is such that when the eye is adjusted for red rays coming from an infinite distance it is in focus for violet rays at the distance of two feet. The dispersion is not observed under ordinary circumstances, owing to the intensity of the colours at the extremities of the spectrum, viz., red and blue, being so much inferior to that of those in the middle—namely, yellow and green. By looking, however, at a bright and distant light through a transparent medium, which will stop the yellow and green rays while it transmits the blue and red, the dispersion may be made very evident. Glass coloured by cobalt oxide is such a medium, and accordingly on looking through a piece of it, at the flame of a distant street lamp, the latter will appear red in the centre, but will be surrounded by a bluish violet halo. [Experiment.]

Let me next point out to you some of the defects of the screen which receives the image—namely, the retina. In order that what I am about to say may be intelligible to those who are not acquainted with the structure of this part of the eye, I shall describe its anatomy in as few words as possible.

The retina is the innermost, that is to say, is the nearest to the centre, of the three coats of the eye-ball. It is continuous with the optic nerve, of which it is commonly described as being an expansion. It is in contact by its concave surface with a delicate membrane (the hyaloid), which encloses the vitreous humour, and it rests by its convex surface upon the pigmentary layer of the choroid coat. It extends nearly as far forwards as the outer edge of the iris. During life it has a pinkish tint, and is almost perfectly transparent; but very soon after death, especially when brought in contact with water and other fluids, it becomes white and opaque.

The inner surface of the retina does not present a uniform aspect throughout its whole extent. On that part which lies in the axis of vision there occurs a yellow spot (macula lutea), of elliptical outline, and about the $\frac{1}{20}$th of an inch in diameter. At the centre of the yellow spot is a depression, called the fovea centralis, and here the retina is very thin. Again, about the $\frac{1}{10}$th of an inch to the inner side of the macula lutea is a circular slightly elevated white mark, which indicates the place of entrance of the optic nerve. This is called the porus opticus. The retina becomes gradually thinner towards its anterior border. The microscopic structure of the membrane is somewhat complicated. Several strata of diverse elementary composition may be distinguished in it. These are, enumerating them in their order from the convex to the concave side, as follow :—

1. The columnar layer.
2. The external nuclear layer.
3. The internuclear layer.
4. The internal nuclear layer.
5. The molecular layer.
6. The layer of nerve corpuscles.
7. The layer of nerve fibres.
8. The membrana limitans.

Traversing these layers at right angles are several sets of fibres which connect in a more or less distinct manner their structural elements, and binding together and supporting the several constituents of the retina is a network of connective tissue. A special artery, the arteria centralis retinæ, supplies the membrane with blood. It will be unnecessary, even did time permit, for me to describe all of these structures. The columnar layer, the nerve corpuscles and fibres, and the blood-vessels will, however, be alluded to in what follows, and for that reason I shall say a few words with regard to them.

The columnar layer comprises two different kinds of tissue, viz., rods and flask-shaped bodies called cones. The former are narrow, and of uniform diameter. They are of soft consistence, have a glistening aspect, and disintegrate quickly after death. They are closely packed together, with their long axes lying at right angles to the surface of the retina. The cones, which are much less numerous than the rods, are distributed among them over the greater part of the retina. They swell out into fusiform dilatations at their inner ends. The inner ends of both rods and cones differ in physical properties from their outer ends. These bodies are not mingled in the same relative proportion over all parts of the retina; for, while the rods greatly predominate near its free margin, the numerical disproportion becomes gradually less marked towards the posterior part of the membrane until the yellow spot is reached, which the cones occupy to the entire exclusion of the rods.

On the other hand, in the white spot, where the optic nerve enters the eye-ball, there are neither rods nor cones.

The inner ends of the cones and, by some authorities, of the rods also, are believed to be connected, through the fibres and nuclear bodies which intervene, with the nerve corpuscles, although the precise manner in which the connection is effected has not yet been satisfactorily demonstrated.

Experiment and observation alike concur in pointing to the rods and cones, especially the latter, as constituting the essential and distinctive elements of the organ of vision. In other words, it is probably through their mediation only that the vibrations of the luminiferous ether can, either directly or by initiating the liberation of some other form of energy, excite that mode of motion in the molecules of the optic nerve, which, on being transferred to the sensorium, appears to our consciousness in the form of light.

The nerve corpuscles are transparent, round or pear-shaped nucleated bodies, provided with from two to six branching processes. Some of these offsets pass outwards, and are believed to be the channels through which, though indirectly, the elements of the columnar layer are connected with the corpuscles; some anastomose with similar processes of adjoining corpuscles; and lastly, others become continuous with the fibres of the optic nerve. The nerve corpuscles are especially abundant in the yellow spot. The nerve fibres are prolongations of those in the optic nerve. Radiating from the porus opticus, they are collected into laterally compressed bundles, which unite to form a net work, covering the whole retina, with the exception of the central part of the macula lutea, where they are entirely absent. According to Bowman, these fibres differ from ordinary nerve fibres, in being without a medullary sheath. They have been traced into continuity with the branched processes of the nerve corpuscles.

The arteria centralis retinæ enters the eye-ball with the optic nerve, and the corresponding vein leaves it by the same route.

The artery divides into four or five primary branches, which sub-divide into numerous twigs. Its larger branches, and those of the vein as well, ramify principally upon the inner side of the nerve fibres; but the smaller ones pass between the bundles of the latter, and end in a capillary net-work, which lies in the layer of nerve corpuscles.

It will be evident from what I have said, that not only in appearance, but also in intimate structure, those parts of the retina called macula lutea and porus opticus, differ essentially from the remainder of the membrane. Thus, selecting the more important peculiarities, in the macula lutea cones are more abundant than elsewhere, and nerve fibres are, the circumference excepted, absent; while in the porus opticus, cones are not to be found, and nerve fibres are almost exclusively present.

This diversity of structure is accompanied by an equally striking dissimilarity in the physiological properties of different parts of the retina. For, while the porus opticus is dead to all impressions of light, the macula lutea, and especially its fovea centralis, is the most sensitive portion of the membrane. Hence only that part of the retinal picture which falls upon the macula lutea yields us a perfectly distinct sensorial image, the section which is in relation with the porus opticus is left out altogether, and those portions which lie upon the remainder of the membrane are hazy and ill-defined.

Consequently, though our range of vision is sufficiently extensive, yet we perceive accurately only that fragment of the landscape which casts its image upon the macula lutea. It is for this reason, that when we search for any small or distant object, we often fail to see it, though its image may all the while lie upon the retina, until it is brought to focus over the spot in question. For instance, when the mariner surveys the distant horizon, in order to discover the approach of vessels, even if one be present in the field of vision, he does not perceive it, unless the axis of his eye be made to coincide with its line of direction.

With regard to the porus opticus, which is called the blind spot by physiologists, it is a strange fact that no one ever finds out for himself its functional inactivity, and yet when his attention is specially directed to its deficiency in this respect, he readily recognizes it. The existence of the blind spot may be made very evident, by the following experiment :—

Take a sheet of paper and make upon it two ink marks, separated from each other by an interval of about three inches. For the sake of distinction let one mark be a cross, and the other a circular dot. Now hold the paper at the distance of about ten inches from the face, close one eye and fix the other upon the cross, keeping the dot on the same horizontal line with the latter, and to its outer side, with reference to the median plane of the body. Throughout the experiment direct the eye steadily towards the cross, but endeavour at the same time to keep the dot in view. Then on slowly moving the paper nearer to, or further from the eye, a position will be arrived at where the dot can no longer be seen, while beyond or within this position it becomes visible.

Under the conditions described, the image of the cross remains fixed upon the macula lutea, while the image of the dot moves nearer to, or further from, the inner side of that spot, as the paper is carried further from, or nearer to, the eye.

I have already stated that the porus opticus is about $\frac{1}{10}$th of an inch distant from the macula lutea, consequently when the image of the dot is at that distance from the latter, it falls upon the former. It can be proved that the dot disappears when this position of its image is attained, and that, therefore, the blind spot, and the porus opticus, must be identical.

The sensitiveness of the retina is diminished in a marked degree, by being exposed for some time to the influence of a strong light. We are all familiar with the fact, that in passing from the glare of broad daylight into a darkened chamber, we are unable to distin guish objects there clearly until the eye has recovered from the paralyzing effects of the previous stimulation. A limited portion of the retina may be affected in this way, as for example, when we look intently at a white figure of any shape, upon a black back-ground. For on directing the eyes immediately afterwards towards a white surface we shall see a similar dark figure, upon a light back ground, and numerous instances, of a like nature, will on consideration, suggest themselves, or may be found out by experiment.

If, after the retina has been exposed for some time to the influence of a monochromatic object, the eye be closed or turned away from it, an after image, or spectrum, of the complementary colour becomes apparent. Thus, if we look fixedly for a few minutes at a red wafer, and then direct the eye towards a sheet of white paper, we see a green disk. [Experiment.] This result is usually explained by saying that the retina, becoming, by exhaustion, more or less completely deprived of its sensitiveness for red light, is acted upon principally by that tint which remains on subtracting red from the white light reflected from the paper. Professor Cleland has, however, directed attention to the fact, that such an explanation is inadmissible, when the phenomenon occurs on shutting the eyes, or looking at darkness.

In sketching the structure of the retina, I pointed out that the bloodvessels are situated in its inner layers. They are, therefore, interposed between the source of light and the columnar layer; and being, especially the veins, more or less opaque, they must throw shadows upon the rods and cones.

If these latter, as we have good reason for believing, really constitute the sole medium through which light can affect the consciousness, then, unless specially provided against, the shadows should appear in the field of view. This would evidently constitute a serious defect. It is, however, practically obviated by the following circumstances:—

In the first place, in the immediate neighbourhood of the macula lutea, those parts of the retina on which the bloodvessels cast their shadows are probably more sensitive than the intervening portions; and, in the second place, the macula lutea itself, the seat of accurate vision, is free from any but capillary vessels.

Nevertheless, under special conditions, the shadows can be made manifest. On looking at the sky, for instance, through a small pinhole in a card, the latter being at the same time moved slightly from side to side, dark bands arising from this cause may be observed to extend across the field of view. The following experiment shows still more strikingly the phenomenon I am speaking of. Close one eye, and look towards the nose with the other. Then concentrate the light of a lamp or candle by means of an ordinary pocket lens upon the latter. The light should be situated on the same side of the body as that of the observed eye, and should be thrown upon the sclerotic as near as possible to the outer angle of junction of the eye-lids. A vivid picture of the retinal vessels may thus be obtained. They usually appear black upon a faintly illuminated grey back-ground, and resemble a branching leafless tree.

In this experiment the light penetrates all the coats of the eye, and, crossing its cavity, shines upon that part of the retina which lies further from the place where it passes in. A precisely similar appearance can be called forth by the following simple expedient :— In any place, otherwise unilluminated, having closed one eye, look straight before you into the darkness, and cause, by the movements of the hand carrying it, a small candle to revolve slowly round the axis of vision in a vertical plane not far from the body, so that its light may pass obliquely into the eye.

The shadows of the bloodvessels as thus seen are known by the name of Purkinje's figures. They are most clearly defined while the candle is passing below and to the outer side of the eye. In all these cases the rays of light are caused by artificial arrangements to enter the eye obliquely with reference to its axis, and they consequently strike upon parts of the retina which, being situated at a distance from the macula lutea, are not within the retinal boundary of distinct vision.

The foregoing are some of the more important and easily determined imperfections of the eye.

It will have been observed that most of them are only rendered evident by unusual circumstances, that experience has taught us to allow for those which are strikingly displayed, that few of them affect the seat of accurate vision, and that one or two are so trifling in amount that they may be disregarded. There are several other defects, such as long and short sight, deficiency in the power of accommodation, colour-blindness, &c., which, though unfortunately common enough, do not fairly come under the head of imperfections of the normal eye. In conclusion, I have taken up this subject in no captious or irreverent spirit; on the contrary, the more closely I consider the wonderful adaptations of the eye to the varied purposes it is destined to fulfil, the more I am filled with admiration at their all-sufficiency. For, notwithstanding the imperfect transparency and inaccurate centering of its refractive media, the want of uniformity in the structure of its lens, the non-symmetrical curvature of its cornea, its uncorrected spherical aberration and chromatic dispersion, its blind spot, the shadows thrown by its blood-vessels, and the variability of its sensitiveness, all of which must be admitted to be defects when we regard it simply as an optical instrument—notwithstanding all these, I have no fault to find with it as a faithful interpreter between myself and nature, when rightly guided by my understanding.

The lecture was illustrated by microscopical preparations, by experiments, and by diagrams.

17th December, 1873.

JOSEPH JOHN MURPHY, Esq., the President of the Society, in the Chair.

A Paper was read by Professor J. D. EVERETT, M.A., D.C.L.,

ON UNDERGROUND TEMPERATURE.

THE phenomena of underground temperature may conveniently be classed under two heads, according as attention is directed to the first forty or fifty feet, or to such depths as are attained in mines and artesian wells.

The annual wave of temperature is propagated downwards from the surface, at a rate which depends on the nature of the soil, and is on the average rather greater than a foot per week; while at the same time the amplitude (or magnitude) of the wave diminishes in a ratio also dependent on the soil, and amounting on the average to a halving of the amplitude for every five or six feet of descent.

Supposing the soil to be uniform, the surface to be plane, and the propagation of heat to be effected solely by conduction, a simple harmonic variation of temperature at the surface (which we may call in popular language a simple wave of temperature) will be propagated downwards with a uniform velocity, and with amplitude diminishing in geometrical progression. There will, moreover, be a definite relation between the ratio of this progression and the velocity of propagation, so that if the one is given the other can be computed. In fact, we shall have

$$2\pi \times \frac{\text{Time of propagation from one depth to another}}{\text{Period of variation}}$$

$$= \text{Napierian logarithm of } \frac{\text{Amplitude at 1st depth.}}{\text{Amplitude at 2nd depth.}}$$

$$= \frac{\text{Difference of depths.}}{\sqrt{\text{Period of variation.}}} \sqrt{\frac{\pi c}{k}}$$

where π denotes 3·1416, c thermal capacity per unit volume, and k conductivity.

If the variation of temperature at the surface, instead of being simple harmonic, be any periodic variation whatever, it can be reduced by Fourier's method to the sum of a number of simple harmonic variations, and each of these variations will be propagated according to the above law, unaffected by the rest.

As the square root of the number of days in the year is almost exactly 19, the above formula shows that the annual wave is propagated 19 times as fast as the diurnal wave, and that the falling-off in amplitude is the same in one foot for the diurnal wave as in 19 feet for the annual wave.

Of the different simple harmonic components which make up the whole variation at the surface, those of longest period are propagated downwards most quickly, and die away most slowly. For this reason, as well as from its greater original magnitude, the annual simple harmonic wave becomes more and more predominant as we descend, and the curve of temperature for the year approaches more and more nearly to the form of a simple harmonic curve, or curve of sines.

Observations taken at three stations in or near Edinburgh, and at Greenwich Observatory, have been reduced in accordance with the above principles, the result being in every case to show a satisfactory agreement between theory and practice; and the values of the thermal co-efficient $\frac{c}{k}$ thus obtained for these four stations, have furnished the basis of the most reliable calculations yet made regarding the earth's age as a habitable globe. For the three Edinburgh stations the value of c (which is the product of specific heat by specific gravity) was also determined by laboratory experiments conducted by Regnault, and hence the conductivity k was found by computation.

The following is a sample of the temperatures observed at Greenwich at the depths of 1 inch, 12·8 feet, and 25·6 feet. The warmest and coldest calendar months had the following mean temperatures :—

	Warmest.	Mean Temp.	Coldest.	Mean Temp.
1 inch	July	65·9	January	40·5
3 feet	August	62·5	February	41·1
12·8 ,,	September	55·5	April	46·1
25·6 ,,	November	52·0	June	48·6

The mean temperature at a depth of 10, 20, or 30 feet does not differ much from the mean temperature at the surface. A slight increase is, however, usually observable even at these small depths; and, when we penetrate to the depth of several hundred feet, we find the temperature higher by several degrees than the mean temperature of the surface. In fact, the deeper we go the higher is the temperature which we find.

Attempts were formerly made to explain away this phenomenon, the high temperatures observed in deep mines being ascribed to the presence of the men working in them, assisted in some cases by the slow combustion of pyrites; but the fact of a steady increase downwards, at a rate which is not exactly uniform but varies from about 1° Fahr. in 100 feet to 1° Fahr. in 40 feet, has now been placed beyond all question.

The following are a few specimens of actual observations :—

1. In a well at Kentish Town, near London, Mr. G. J. Symons, a skilled observer, has taken repeated observations at every 50th foot of depth from 350 to 1,100 feet, the well being full of water to within 210 feet of the surface. The results of observations at different times were almost precisely the same, as were also the results obtained at the same time with thermometers of different constructions. The following are the results finally adopted :—

Depth in Feet.	Temp. Fahr.	Depth in Feet.	Temp. Fahr.
350	56·0°	750	63·4°
400	57·9	800	64·2
450	59·0	850	65·0
500	60·0	900	65·8
550	60·9	950	66·8
600	61·2	1,000	67·8
650	61·3	1,050	69·0
700	62·8	1,100	69·9

2. In Rose Bridge coal pit, near Wigan, the deepest excavation in Great Britain, observations were made during the sinking of the deepest shaft, by filling a hole with water to the depth of a yard, inserting a thermometer, plugging the hole with clay, and after half an hour observing the indication of the thermometer. The following are the results :—

Depth in feet.	Temp. Fahr.	Depth in feet.	Temp. Fahr.
1674	78°	2235	89°
1815	80	2283	90½
1890	83	2325	91½
1989	85	2349	92
2013	86	2400	93
2037	87	2418	93½
2202	88½	2445	94

3. In a bore hole 2½ inches in diameter, at the bottom of South Hetton Colliery, Durham, the following observations have been taken, the top of the bore being 1066 feet below the surface of the ground, and the depth of the bore itself being 670 feet.

Depth from surface of ground in feet.	Temperature, Fahr.
1166	66°
1266	68¾
1366	70
1466	72
1566	74½
1666	76⅛
1736	77⅛

For additional examples I must refer to the Reports of the Underground Temperature Committee, printed in the British Association Reports, from 1868 to the present time. Several of the best observations give a rate of about 1° Fahr. for 56 feet of descent; and this appears to be a fair average of the various rates which characterise different localities.

If the annual escape of heat were the same at all parts of the earth's surface, it would follow as a consequence that the number of feet per degree of increase, in any place where the isothermal surfaces are horizontal, would be a direct measure of the conductivity of the soil, provided that the word conductivity be used in a broad sense to include all the agencies by which heat is propagated (for example, the percolation of water). This follows at once from the definition of conductivity—that is, from the equation

$$\text{Rate of flow} = \frac{\text{Difference of temperature}}{\text{Distance.}} \times \text{conductivity.}$$

We have not at present sufficient data to enable us to pronounce to what extent the annual escape (or rate of flow per annum across unit area) may differ at different places. The difference is probably restricted within narrow limits; but in the present state of our knowledge, the proportionality of conductivity to the number of feet per degree can be positively asserted only when we are comparing different strata at the same place.

The rate of increase in descending (or the reciprocal of the number of feet per degree of increase) may conveniently be called the thermometric gradient. A rapid increase, or steep thermometric gradient, is (under the limitations just stated) an index of low conductivity; and the rate of flow through unit horizontal area is in every case equal to the product of gradient and conductivity. I will now proceed to show the bearing of the above facts of underground temperature upon the question of the earth's age.

From the conductivity of the superficial portion of the earth, in conjunction with the thermometric gradient, we can deduce the rate of flow; that is to say, the rate at which heat is escaping from the earth into external space. Sir W. Thomson has made the calculation; and has shown that if the mean conductivity, as deduced from the Edinburgh observations, be employed, in conjunction with a gradient of 1° F. in 50 feet, the present annual loss of heat from the earth would in twenty thousand million years suffice to cool the whole earth from a state of fusion to zero Fahrenheit, supposing the whole earth to be composed of rocks similar to what we find at the surface.

But, on any conceivable theory of the origin of the earth's heat, the rate of escape of heat in times past must have been much more rapid than at present, and the limit of age is thus brought much lower.

The most probable theory is that which ascribes the heat to collision and condensation, taking place in the early periods of the earth's history, before it was fitted for habitation; so that the history of the earth as a habitable globe is the history of a hot body cooling. Supposing the earth to have been in a state of fusion when the cooling began, it is probable that, as the outer portions cooled and solidified, they sank in the liquid beneath them; for the experiments of Bischof show that melted granite, slate, and trachyte all contract by something like 20 per cent. in solidifying. This process would go on until the sunk portions had built up a solid framework extending to the surface. "In the honeycombed solid and liquid mass thus formed there must be a continual tendency for the liquid, in consequence of its less specific gravity, to work its way up; whether by masses of solid falling from the roofs of vesicles or tunnels, and causing earthquake shocks, or by the roof breaking quite through, when very thin, so as to cause two such hollows to unite, or the liquid of any of them to flow out freely over the outer surface of the earth; or by gradual subsidence of the solid, owing to the thermodynamic melting,* which portions of it, under intense stress, must experience." "The results which must follow from this tendency seem sufficiently great and various to account for all that we see at present, and all that we learn from geological investigation, of earthquakes, of upheavals and subsidences of solid, and of eruptions of melted rock."

Looking, then, upon the earth as a solid body cooling, the following are some of the principles which must guide us in estimating the time which has elapsed since the surface was cool enough for life to exist upon it.

I. The surface temperature depends almost entirely upon external circumstances, and not to any sensible extent upon the internal heat of the earth. For the heat conducted up from below must be equal to the excess of the heat which the earth emits above that which it receives, since the surface remains from year to year at sensibly the same temperature. We know approximately, by means of the Edinburgh observations, the amount of heat conducted up, and we also know to a rough approximation how much the earth's radiation would be increased by an increase of one degree in the temperature

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* See my edition of Deschanel, § 237 A.

of its surface.* It is thus found by calculation that the surface of the earth is warmer by about $\frac{1}{100}$ of a degree than it would be if there were no heat conducted up from below. In order to raise the temperature of the surface one degree, the thermometric gradient would need to be something like a degree per foot.

II. A good approximation to the law of cooling of the superficial parts of the earth will therefore be obtained by supposing the whole earth originally raised to a uniform high temperature, then the surface brought instantaneously to another uniform temperature, and permanently maintained at this second temperature. It is also allowable to treat the earth as an infinite solid with a plane surface; for it can be shown that, even after the lapse of 1000 million years, the original temperature will exist almost unchanged at depths exceeding 500 or 600 miles.

Sir W. Thomson has worked out the problem on these suppositions, and finds that the thermometric gradient at depth x after the lapse of a time t from the cooling of the surface, is represented by the formula

$$\frac{V}{\sqrt{\pi \varkappa t}} e^{-\frac{x^2}{4 \varkappa t}} \qquad (1.)$$

where V denotes half the difference of the two initial temperatures, $\varkappa$ the conductivity divided by the thermal capacity of unit volume, and π the ratio of the circumference of a circle to the diameter.

Putting $x = o$ in the above formula, we find, for the thermometric gradient near the surface, the expression

$$\frac{V}{\sqrt{\pi \varkappa t}} \qquad (2.)$$

Giving $\varkappa$ the value deduced from the Edinburgh observations, and supposing the initial difference 2 V to be the difference between the melting point of rock and the present atmospheric temperature, Sir W. Thomson finds that when t is 100 million years, the value of the expression (2) is $\frac{1}{50}$ of a degree Fahr. per foot, which we know from observation to be approximately the present thermometric gradient.

* The calculation is easily made with the aid of the data published by Mr. M'Farlane [British Association Report, 1871. ii., p. 44] on the radiation of polished copper and of blackened copper.

A gradient of $\frac{1}{60}$ of a degree per foot will require the value of t to be 1.44 million years.

By assigning to x in formula (1) different values from 0 to 100 miles, Sir W. Thomson obtains the following results :—

"The rate of increase of temperature from the surface downwards would be sensibly $\frac{1}{51}$ of a degree per foot for the first 100,000 feet or so. Below that depth, the rate of increase per foot would begin to diminish sensibly. At 400,000 feet it would have diminished to about $\frac{1}{141}$ of a degree per foot. At 800,000 feet it would have diminished to less than $\frac{1}{50}$ of its initial value—that is to say, to less than $\frac{1}{2550}$ of a degree per foot, and so on, rapidly diminishing, as shown in the curve. Such is, on the whole, the most probable representation of the earth's present temperature, at depths of from 100 feet, where the annual variations cease to be sensible, to 100 miles, below which the whole mass, or all except a nucleus, cool from the beginning, is (whether liquid or solid), probably at, or very nearly at, the proper melting temperature for the pressure at each depth." *

The limit of 100 million or 150 million years, which the above calculations assign to the earth's age as a habitable globe, will be brought still closer, if we choose to reject the postulate that the earth was originally at the temperature of fusion. For instance, if we suppose the initial temperature to have been the arithmetical mean between the present surface temperature and the temperature of fusion, we thereby assign V, in formula (2), only half the value above estimated, and must, therefore, divide t by 4 in order to keep the value of the expression unaltered.

If we make the supposition that the present internal heat is due to the earth having passed through a region of space 50° Fahr. hotter than that which it now occupies ; or, more precisely, if we suppose the initial temperature to have been 50° Fahr. higher than the present surface temperature, formula (2) leads to the result that t is only 5,000 years—that is to say, the surface 5,000 years ago must have been 50° warmer than at present—a result which cannot be admitted. If the date of transition from the warmer to the colder region be assigned as 20,000 years ago, the temperature must have been 100° Fahr. higher than at present. In Sir W. Thomson's words, "the further back the time of the heating, the hotter it must have been.

* Thomson and Tait's Treatise on Natural Philosophy, p. 720.

The best for those who draw most largely on time is that which puts it farthest back, and that is the theory that the heating was enough to melt the whole."

These conclusions regarding the earth's age are borne out by another line of argument derived from astronomy. Astronomical records seem to indicate that the earth's velocity of rotation is diminishing, the most probable value of the retardation being such that if one clock were rated to keep time with the earth at any given epoch, and another clock were rated to keep time with the earth a century later, the second of these clocks would lose upon the first at the rate of 44 seconds per century.

Assuming that the retardation has been uniform, the earth's rotation 100 million years ago must have been 1½ per cent. greater and centrifugal force 3 per cent. greater than at present. A thousand million years ago, centrifugal force would have been greater than at present, in the ratio of 4 : 3 ; and if the earth had then solidified, we should have at the present time a great mountain surrounding the earth at the equator, separating the Northern from the Southern Oceans. A third line of argument, based on the possible age of the sun, leads to a similar result.

This paper makes no pretentions to originality. I have merely endeavoured to sketch a connected outline of the leading facts of underground temperature, and the leading steps of the deductions thence drawn regarding the earth's age. The following references will enable the reader to pursue the subject :—

J. D. Forbes.—*Experiments on the Temperature of the Earth.* Trans. R.S.E. 1846.

Sir W. Thomson.—*On the Reduction of Observations of Underground Temperature.* Trans. R.S.E. 1860.

——————*On the Age of the Sun's Heat.* *Macmillan's Magazine*, March, 1862.

——————*On the Secular Cooling of the Earth.* Trans. R.S.E. 1862. Reprinted at the end of Thomson and Tait's "Treatise on Natural Philosophy."

Sir W. Thomson—*The Doctrine of Uniformity in Geology Briefly Refuted.* Proc. R.S.E. December, 1865.

————*On Geological Time.* Trans. Geol. Soc., Glasgow. Vol. iii., part i.

————*Of Geological Dynamics.* Trans. Geol. Soc., Glasgow. Vol. iii., part ii.

J. D. Everett.—*On a Method of Reducing Observations of Underground Temperature.* Trans. R.S.E. 1860.

————*On the Mean Temperature of a Stratum of Soil.* Trans. R.S.E. 1862.

————*Reduction of the Observations of the Deep-sunk Thermometers.* Greenwich Observations, 1860.

————*Reports of Committee on Rate of Increase of Underground Temperature.* B.A. Reports, from 1868 onward.

14th January, 1874.

JOSEPH JOHN MURPHY, Esq., F.G.S., President of the Society, in the Chair.

A Paper was read by G. T. GLOVER, Esq., T.C.S.,

ON WATER FOR DRINKING PURPOSES.

FOR various reasons, which were stated, it is only recently that the frequency of the impureness of drinking water has been recognised, and the present great town development has further given it a consideration it might not otherwise have had. Though it is only one of the many sanitary evils afflicting the country, it is a most important one.

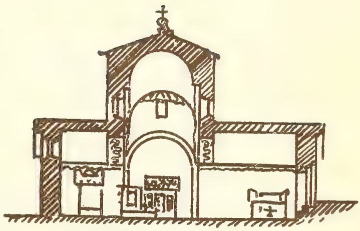
The fact of the effectiveness of water in assisting to spread disease is now established, and the reader did not consider it necessary to adduce any instances in support of it, but confined his remarks rather to the chemical history of impure water, the extent and limits of chemical knowledge respecting the impurities, and the possibilities of their removal from water once soiled by them. The conclusion on the last head was that artificial systems of filtration must be considered as only partially successful, and the object must be rather to prevent contamination than to try to purify already polluted water.

The normal constituents of good healthy drinking water were described, and, after referring to the occasional though very rare occurrence of natural metallic impurities in water, the reader called attention to the not uncommon presence in it of metals in dangerous amount, contracted from the vessel in which it is stored. Leaden holders of water are most objectionable, for though water dissolves only a minute quantity of the metal, yet because lead accumulates in the system, the small quantity taken habitually will finally produce the hurtful effect. Though some waters do not take up lead, as for instance the water supplied to Paris from the Seine, yet they are exceptional, and this metal should not be used in any case for conveying or storing drinking water. As lead pipes and cisterns have their conveniences in construction and use, some methods of protecting the metal from the action of water by coatings were considered : it is preferable, however, to employ coated iron pipes and cisterns of the same, or of stone.

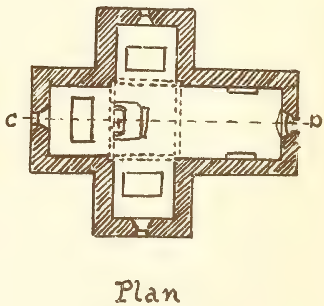
Amongst other impurities afterwards described, was the most filthy and very usual one of animal organic matter, derived from sewage, and the opinion expressed was that most wells in close human neighbourhood, whether in town or country, are tainted by it. The reader then explained how a water may often contain this pollution, and yet the presence of it not be evident to the unassisted senses. This is chiefly because this impurity generally drains through some thickness, more or less, of earth, before it reaches the well, and the reader entered particularly into the wonderful changes that are effected on it in this passage through the soil. The soil acts chiefly as a conveyer of the oxygen of the air in an active state to oxidise or burn the organic impurity. Though the purification effected is astonishingly great, and filtration through earth properly conducted will fit sewage for entrance into rivers according to the standard of purity recommended by the Royal Commissioners appointed to inquire into the pollution of rivers, yet it cannot be depended on to purify contaminated water and fit it for drinking use. It is true that people very often drink polluted water partially purified in this way, for a long time, without knowing any bad result, but when zymotic disease is in the vicinity, they are under imminent risk of receiving it through the tainted water.

The reader dwelt on the process of putrefaction of animal organic matter in reference to its presence in water, and the importance of the various conditions of combination of the nitrogen, after leaving the original molecule, as an indication of how far the process had gone ; the conditions of nitrogen as ammonia, nitrites, and nitrates.

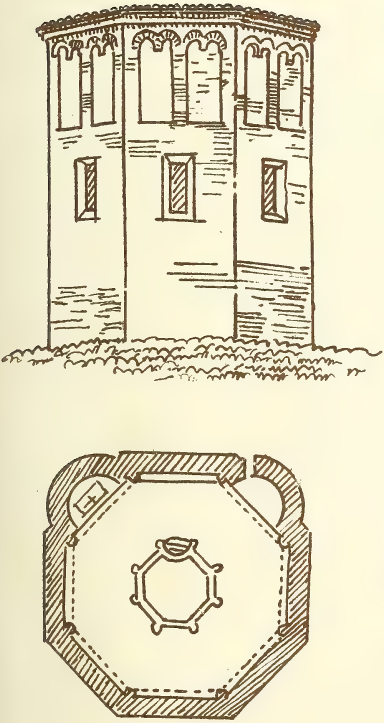
The presence of salts, which accompany the animal organic



Section on C.D
of Tomb Church of G. Placidia



Plan



S·Giovanni In Fonte.

matter, may be a most important indication respecting the original contamination, but these, as also the inorganic compounds of nitrogen, may be exceptionally derived from a natural source, which possible exceptions have always to be taken into account.

The permanganate of potash process, used by the analysts of the waters supplied to London to ascertain the amount of oxygen required by the easily oxidisable organic matter of a water, was shown, and the limits of its use and trustworthiness defined. The valuable process of Mr. Wanklyn was also noticed.

Because the pollution of water by decomposing animal organic matter is most frequent and most dangerous, it is to be very much regretted that the processes for ascertaining its presence are very complicated, and can only be employed by the chemist. A simple method, which anyone can use, is much to be wished for. The only approach to such a method is that of judging by the smell, which is certainly simple enough, and very valuable as far as it goes; but the positive results only can be trusted—the negative results must not be relied upon. If the water has a faint, sickly odour when fresh, or even after having been in a clean, corked bottle for a day or two in a warm room, it may be considered polluted; though if it yields no smell on this trial, it must not, therefore, be considered as free from contamination. Animal charcoal is the best material for a filter, and the *rationale* of its action on organic impurity was entered into; but its uses have a limit, and it cannot be trusted to perfectly purify water.

Right views on the subject of these impurities are very important: to know what has been ascertained to be true and what is doubtful. It is of additional importance, now that irrigation is the means most likely to be employed for purifying the drainage of towns.

4th February, 1874.

JOSEPH JOHN MURPHY, Esq., F.G.S., President of the Society, in the Chair.

A Paper was read by Mr. ROBERT YOUNG, Clarence Place, Belfast, entitled—

EARLY CHRISTIAN ART IN RAVENNA.

To an educated Englishman, the name of Ravenna brings up many interesting but for the most part melancholy associations. The last declining years of the old Roman Empire, and the Exarchate; Dante with his life-long sufferings, in mediæval times; and our own Byron, with his sins and sufferings, some forty years ago. Thoughts of these would probably blend together, in one confused image, when he thinks of Ravenna. Owing, however, partly to the way in which this city lies remote from any of the main routes by which the traveller is accustomed to approach Rome from the North of Italy, but perhaps in a large measure to the dread of the malaria that haunts its swampy neighbourhood, it is but rarely visited by tourists. And thus, in comparison with Florence, Milan, or Rome, it is not much exaggeration to say that its art monuments are unknown to our countrymen. Yet, in the history of Christian Art, Ravenna will always occupy one of the most important places, if not the foremost.

The observations now offered are the result of a visit to Ravenna last Autumn, and of the examination I then made of a number of its more important remains. As it was only possible in the limited time at my disposal to take hasty notes of salient features of the buildings, I have taken advantage of the work of F. von Quast to prepare the large drawings now on the walls from the small, but very accurate, engravings which he gives of a few of the oldest buildings.

Ravenna had been a place of considerable importance in the time of the Roman Republic, and Augustus increased this by founding its famous harbour, in which lay the Roman fleet, built from its adjoining pine forests, and giving its name, Classis, to its principal suburb.

Although it was one of the earliest seats of Christianity, through the zeal of Apollinaris, who is said to have been a disciple of the Apostle Peter, yet there is no tradition or remains of any ecclesiastical building before the year 400 A.D., when the Cathedral of S. Urso was founded, and became the fruitful mother of a wonderful succession of churches erected during the two following centuries.

Two great movements had taken place in the Roman world about this time, which serve to explain how the course of events ran so strangely in this direction. One was the complete and legal overthrow of paganism, leading to the diversion of the wealth and influence of the rulers to the objects they thought would advance the new faith ; and the other and more special one was the rapid decline, and shortly the abandonment, of Rome as the seat of power, and the choice of Ravenna as the residence of the Emperors and the capital of Italy.

(An outline was given of the history of the Western Empire, from the death of Theodosius, with whom universal authority over the Roman world ended, and when an Eastern and a Western Empire took its place, showing that there were three well-marked periods in the history of Ravenna, during the fifth and sixth centuries, with each of which a group of its buildings can be identified, partly by what still remains, and partly by the descriptions of Agnellus, who wrote in the ninth century.) The writer then continued as follows :—

I have compiled the following catalogue of these buildings from Quast's work, which will show the great number and importance of the public and chiefly ecclesiastical edifices erected in the course of 175 years in this remote part of Italy, and will serve as a brief historical notice of those which still exist in whole or in part, and which, where visited, I propose to describe, both in regard to their architectural features and internal decorations.

The first period of the history of art with which we have to do is from the introduction of Christianity to the destruction of the Roman Empire, A.D. 476.

Cathedral of S. Urso, founded by that Saint, who died about 412 A.D. The presbyter Agnellus, who lived in the middle of the ninth century, and wrote lives of the Ravenna Bishops, relates that Ursus built this church "that as a good shepherd he might collect into one sheepfold his herds scattered through different individual chapels." This shows that there were churches before this date; but no trace of them has been left, and no writer gives any account.

Church of S. Peter in the suburb of Classis, built by Bishop Peter, sen., about 415 A.D., destroyed about 750 A.D. by an earthquake.

Basilica of S. Lawrence in Cesaræa, built by the Chancellor Lauritius with the money of the Emperor Hono rius, who was enraged when he discovered what had been done. This must have been built about 400, A.D., as St. Augustine mentions it as being renowned in the year 412 A.D. It was completely removed in A.D. 1555, by Pope Pius IV., and its columns taken to Rome. The site is now marked by a white marble cross, placed on a fragment of an antique column, on the side of the road to Classis, about a half-mile from the city.

Baptistery of S. Urso, built by Bishop Neo, who succeeded Bishop Peter in 425 A.D.

Baptistery of S. Pietro in Classe, built immediately after this in rivalry of that at the cathedral erected by Petrus Chrysologus. This building was destroyed at same time as the church.

Basilica of S. Giovanni Evangelista, built by Galla Placidia in 425 A.D.

Basilica of Sta Croce, built by Galla Placidia, about A.D. 430, completely changed by rebuilding in modern times.

Ss. Nazario e Celso, or Mausoleum of Galla Placidia, founded by her about A.D. 440, where she was buried in 450 A.D.

S. Giovanni Batista, built in A.D. 438 by Galla Placidia for the body of her confessor, St. Barbatian. In 1683 A.D., it was almost completely remodelled; only some of the original columns remain.

Sta Agnese, built by Gemellus, sbudeacon, about 430 A.D.; the original form is quite lost by the subsequent alterations.

Sta Agatha, supposed to be built by the same Gemellus, now exists only in a very modified form on the old foundations.

Basilica of S. Pietro, but now called S. Francesco, built by Peter Chrysologus about 450 A.D.

Chapel in the Archbishop's Palace, close to the Cathedral of S. Urso, built by Peter Chrysologus about 450 A.D.

The Second period is from the destruction of the Roman Empire to Theodoric's death, 476 A.D. to 526 A.D.

Most of the ecclesiastical buildings of this time were outside of the city, and were built by the Arian Bishops.

Two in the North suburb, dedicated to S. Eusebius and S. George, were built by Bishop Unimund in 516 A.D., and were destroyed about 800 A.D.

In Classis the churches of S. Sergius and S. Zeno, built about the same time, have now entirely disappeared.

In the city the following were erected in this period :—The Bapistery attached to the Arian Cathedral of S. Theodoro, now called S. Spirito. The Baptistery itself is now called Sta Maria in Cosmedin.

Basilica of S. Martino in cœlo aureo, now S. Apollinare Nuovo, built by Theodoric about 500 A.D.

Palace of Theodoric, built about 495 A.D.

Tomb of Theodoric, built by Amalasuntha, his daughter, about 530 A.D., subsequently dedicated as a church, under the name of Sta Maria Rotonda.

The Basilica of Hercules was built about this time; but the site is very doubtful. Some large marble columns standing in the market place are thought to belong to it, as some bear the monogram of Theodoric on the capitals.

The third period is from the death of Theodoric to the death of Bishop Agnellus, 526 A.D. to 566 A.D.

Basilican Church of Sta Maria Maggiore, built by Ecclesius in 520 A.D. Completely altered in sixteenth century.

S. Michele in Affricisco, built by Julius Argentarius in 540 A.D. The apse alone remains; the nave is destroyed.

S. Vitale, commenced by Ecclesius on his return from Constantinople in the year 526 A.D., and completed in 547 A.D.

S. Apollinare in Classe. Bishop Ursicinus ordered it to be erected, and it was dedicated by Bishop Maximianus in 549 A.D.

S. Andrew and S. Stephen, built in 550 A.D. by Maximianus, in the town. Both have been completely destroyed.

S. Severus, built in 575 A.D., by Peter the IV. in Classis. The sole remains are some capitals of the columns preserved in S. Apollinaris in Classe.

Proceeding in chronological order, we begin with the original building of the Cathedral, founded by S. Urso in 412 A.D. Nothing is extant but some remains of the original paving. This consists of geometric patterns of green and purple porphyry and coloured marbles, of very pleasing design. There are, however, in the sanctuary some very early and interesting remains. One of these is the ivory chair of Bishop Maximianus, which is a most costly and elaborate work. The ancient marble sedilia has evidently been the type on which it was modelled. Many scenes from Bible history are represented in high relief; those illustrating the history of Joseph are still in good preservation; the feet are covered with admirably carved foliage and animals. It is a beautiful and unique example of late classic art. Unfortunately, about 30 years ago, it was much injured by a cleaning process to which it was ignorantly subjected.

There is also an Easter Calendar, from 532 A.D. to 626 A.D., cut in marble lines, of much historical but little artistic interest.

At the rere of the tribune are several white marble slabs, on which are carved in relief figures of fish, deer, peacocks, and doves, well recognised early Christian symbols. These are the remains of the original ambos, or pulpits. There is also a white marble sarcophagus of Bishop Barbatius, with some figures in relief in the classic style.

Unfortunately, the whole of the fabric of this church was so completely altered in the beginning of the last century that its value as an early monument has been well nigh lost.

The portions of the original Church of S. Urso that still remain are the campanile, or bell-tower, and a crypt only lately discovered under the choir. This crypt is semi-circular in plan, and has an aisle round it, separated by columns on each side. The capitals are partly Ionic and partly Corinthian, with very coarse leafage. The roofing is a curious mixture of cylindric and cross vaulting. Owing to the way this crypt is flooded, up to the capitals, it is impossible to examine it. The campanile, like all the other buildings, is constructed of rather coarse brickwork, very plainly finished, without string-courses or other external ornament. The upper stage, with three arched openings, and covered with a flat roof, is a later addition.

The Baptistery, which is now called the Church of S. Giovanni in Fonte, is situated close to the Cathedral, and is one of the most remarkable buildings not only in Ravenna, but in Europe.

It was necessary in those early times, when it was usual for a great number of adults to be baptized at the same time and in a public manner, to have this building so arranged so as to afford accommodation for as large a number of spectators as possible. The rotund, or octagonal, building, used by the Romans for their temples, supplied the type for the desired form. The ground plan of this example is an octagon. The exterior is very simple, of rather thick bricks, coarsely made, but laid with finer mortar-joints than Roman work. The only ornament is at the upper stage, where each of the eight sides has two slightly sunk panels, covered with a double arch. This is the first known example of this peculiar style of ornamentation, afterwards so frequent in Romanesque building; and it is very curious that the only other instance of it in Ravenna is at S. Vittore, built in 564. The cornice has also already a very Middle Age character. It is composed of bricks, placed diagonally, oversetting one another in courses, separated by horizontal tiles. Nearly all the Ravenna buildings have a similar finish at the eaves.

The great basin, or font, of white marble contains a pulpit for the officiating priest in one of its octagonal sides, and on its ledge stands a small porphyry basin, much like an ancient bath. It probably held the anointing oil; but it is doubtful if this is original, as it is said that the old pavement is about ten feet below the present surface. The appearance of the columns would agree with this, as they seem stunted and have no visible bases.

The interior is divided into two stories. The lower one has a wall-shaft in each of its eight angles, from which spring semi-circular arches. The wall surfaces between these are adorned with slabs of marble and porphyry, except two sides, where there are niches with altars. The spandrils over the arches have mosaics, with figures of yellowish green, on a black ground, enriched with a flowing ornament of acanthus leaves, heightened with gold. The capitals of the columns are Roman composite, with a peculiar double arrangement of volutes at one angle of each, which seems so unmeaning here that it suggests the idea that they were taken from some earlier building, in which they were placed in a way unknown to us, but no doubt consistent. The leafage under the bell, not less than that on the abacus, shows the strongest affinity to the work of best Greek period.

In the angles of the upper story are also wall-shafts. Between each two stand two other smaller shafts, which are joined by round arches, of which the central one is considerably elevated above the others. The columns are smaller than those of the lower story, and have roughly-formed Ionic capitals, all of the same design. Every three arches have over them a larger inclosing semi-circular arch, springing from consoles, which rest on the angular wall-shafts. This inclosure of groups of arches under a larger arch is about the earliest example of what was to become a noteworthy feature in mediæval architecture. The spandrils of these arches are covered with a beautiful interlaced decoration, among which deer are intertwined with foliage. This is a recognised old Christian symbol of the soul panting after God. The rest of the decoration is of the Rococo period, to which the windows also belong. Above these eight arches the hemispherical dome springs, the consoles serving for a termination to the pendentives, that is to say, the solid work filling up the angular spaces where the circle overhangs the octagon. This is thought to be the oldest building in which this method of forming a circular cupola from an octagonal ground plan is known.

The pendentives are adorned by rich foliage in mosaic, but the upper part of the dome, divided into three unequal zones, is still richer. The lower and narrowest zone contains in its eight divisions representations of thrones, sepulchres of saints, and altars with fantastic architecture, which is all designed in the antique style like Pompeian art of the best character. In the next zone are the twelve apostles, separated by golden acanthus plants. These figures, among which Peter and Bartholmew are prominent, are very admirable productions The names of all the apostles are written beside them, without which the characteristics would not be discerned. They bear no resemblance to the conventional types used by the mediæval artists. All wear a lofty tiara like the Phrygian cap, which gives a somewhat odd appearance to the otherwise stately figures. The centre is occupied by the Baptism of Christ. He stands in the midst of Jordan, whilst John pours water on his head from a cup. The Holy Ghost descends in the form of a dove. A high cross, set with precious stones, separates them. On the other side, the River-God rises from the water, and holds out a napkin to the Saviour. The wonderful state of preservation and brilliancy of these mosaics after well nigh 1500 years is truly astonishing.

Basilica of S. Giovanni Evangelista.

This church, which was founded by Placidia to commemorate her escape from a storm when on her passage, with her son Valentinian, from Constantinople, seems, from contemporaneous accounts, to have exceeded all other Ravenna churches in magnificence. Although the mosaics have been destroyed, yet the whole scheme of decoration was of such a complete and gorgeous a kind that it is worth while to give a short sketch of it from contemporary sources.

The triumphal arch of the tribune was supported by two immense columns covered with silver. In the centre of the tribune the majesty of the Lord was shown, between the seven golden candlesticks and other apostolical emblems, reaching a book to John and saying "Accipe librum et devora illum." At the feet of the apostle the words "Sanctus Joannes Evangelista." A sea of glass, bordered with palm trees, occupied both sides of the rest of the wall, on which were represented two ships tossed with the wind; the people in them were drawn after nature, and showed in their despairing faces the danger in which they were placed; St. John, who is here a second time represented, is guiding the helm. On the same wall, at right and left, were mosaic pictures of the Christian Imperial relatives, with their names, Constantinus, Theodosius, Arcadius, Honorius, Theodosius Nep, Valentinianus, Gratianus, Constantius, Joannes Nep. Probably these were half length figures as in the contemporary church of St. Sabina in Rome. In the apse was a sitting figure of Christ of gigantic size; twelve closed books were beside him, emblems of the apostles; below this was placed again the Redeemer with a book, on which were the words "Beati misericordes, quoniam ipsi misericordiam consequentur." At each side the evangelists were represented, but whether by the symbolical beasts or by a book is now doubtful. Below this there seems to have been a broader belt, in which windows alternated with portraits, as in S. Apollinare in Classe at the present time. The portrait of the bishop who dedicated the church was in the central space. He was represented as blessing the eucharist, an angel standing behind him. The rest of the space next the floor was covered with slabs of polished porphyry.

The outer parts of this church were in perfect keeping with this grandeur. The columns at the doors were also covered with silver. The pulpit and enclosure of choir were of the rarest marbles, as well as the four columns carrying the canopy over the altar, on which a cross was placed rising between lilies and apples, and under it hung many lamps of gold and silver, one of which was shaped like a flying dove.

We now come to the Mausoleum of Galla Placidia, which was one of that kind of early Christian buildings known as a tomb church. This church forms a portion of the Basilica of S. Croce, the second church built by Galla Placidia, but now much altered. It exists at present under the name of S. Nazario e Celso. There are no contemporary inscriptions, but there seems no doubt but that Galla Placidia was the actual builder.

The splendid richness of the interior is in strong contrast with the plain exterior. The antique forms throughout show it to be simply a mausoleum of a period anterior to any inroad having been made by Northern art.

The ground plan is most singular, being a Latin cross like that of the basilica adjoining. This form was already seen in the greater basilicas at Rome, but arose in what may be called an accidental manner, and was not fully developed, as the apsis takes the place of the head of the cross. The cruciform plan here is made more important by a dome, visible outside, covering the central place. Though by far the oldest example of an extant church, where this important architectural feature is applied in this manner, the dome rising from an octagonal plan was seen at the Baptistery of S. Urso; and it is likely that at an earlier period in the East, the native land of the dome, it may have been applied over a square space. And it is known that the Church of the Apostles at Constantinople, in its general plan was a Greek cross, with the dome at its centre; but it did not remain long enough to serve as a model for others. So this little church seems to be the oldest extant having a dome on the square space of a Latin cross.

The pendentives are still wanting, and there is no cornice or moulding dividing the vertical surfaces from the curved ones of the dome, as appears in Latin examples. The only moulding one remarks is a small impost where the tunnel vaulting rises from the walls of the arms of the cross.

On the exterior the dome is hid by the walls rising to the level of the antiquely formed eaves cornice, and is covered by a flat roof. All the work is built of large tiles. Simple round arched panels adorn each wall; three on the ends of the cross, and two on the side wall, all similar, only that the middle ones of the front side are a little larger. Regular flat pitched gables terminate the arms, in each of which is an opening. The cornice and covering of these pediments are formed partly of moulded tiles and partly of a blackish stone.

The exterior differs not only from the other ecclesiastical buildings here, but also from contemporaneous Roman basilicas, and adheres much more closely to the antique forms. The designer seems to have determined to lavish all the resources of his art on the decoration of the interior, and to have grudged any expense outside. The walls to the height of the vaulting are now quite stripped, so that we must remember that they were at one time covered with slabs of marble like those of S. Vitale. Only some small fragments here and there show what it once was. The magnificent mosaics, however, remain on the whole of the vaulting, and on the wall surfaces between.

The drawing of the figures may not be equal to that of some mosaics found at Rome and Pompeii, although there is not wanting a fine vigorous expression of form; but in completeness of design, allied throughout to an architectonic form, they are quite unrivalled in this style of art.

Five marble sarcophagi are placed in the interior of the church. The two smallest are built into the walls, near the door at the north. These have only a cross in relief, and are the tombs of the tutors of Honoria and Valentinius. The three larger ones occupy respectively the three upper arms of the cross. This arrangement is based on antique models. A beautiful tomb, precisely resembling this as regards arrangement, was discovered in A.D. 1839 in Rome, at the Porta Pia, near the Pretorian camp. In plan it was a square, eight feet on each side, and covered with quadripartite vaulting. Each side had a niche nearly four feet deep, covered with a cylindrical vault, the soffitte of which was inlaid with terra cotta tiles. In three of these were sarcophagi. Small window openings are over each of these, as at Ravenna. The door occupies the fourth side.

But to continue the description of the church.

The sarcophagus at the right hand is the most artistically treated. The lid is semicircular, covered with scales, and having pilasters at the angles. The sides contain amphoræ, with birds drinking, carved in relief. On the front are three little niches, separated by twisted columns. The centre has a small gable over it, and it contains, before a reared up cross, a favourite symbol of Christ—viz., a lamb looking backwards. The side niches also have a cross in each. This tomb is said to contain the remains of the Emperor Honorius, the brother of Galla Placidia. The one on the left hand has an angular roof, with classic acroteria at the corners, having the monogram of Christ on each. The front has the symbolic lamb looking back, around its head a glory, with monogram of Christ incised. At each side is another lamb, and behind each a palm tree. The remains of Constantius the Third, the second husband of Galla Placidia, are believed to be enshrined in this. These are the only tombs of the Emperors of ancient Rome that have remained in their original position since their erection.

The last sarcophagus is at the head of the cross, and, although in general form like the one described last, is perfectly plain, except that a tablet for an inscription occupies the centre. The sides are pierced with many holes, showing that it was once covered with costly metals. Within this Galla Placidia's body was placed, no doubt embalmed, seated on a throne of cedar wood, arrayed in the imperial robes and insignia, and in this condition, extraordinary as it may appear, she remained till 3rd May, 1577, when some boys, prying into the lower opening with a taper, put it too near the robes, which took fire, and all that was left of the Empress was a little heap of ashes.

Before this sarcophagus and under the dome an old and very remarkable altar is placed. It is raised some steps above the pavement. The marble shelf is supported at its sides by small shafts, and it is quite open behind. The front is formed by a slab of translucent oriental alabaster, which is adorned by a raised cross, with two lambs and two peacocks carved at either side.

We come now to the surface decorations in colour.

The general ground is a dark gloomy blue, which harmonises all the other colours, and throws out the figures in a most wonderful manner. The tesseræ are of a semi-transparent glass, and have resisted the action of the elements without change. They are of irregular shape, and are fixed in a coating of good lime mortar. The wall surfaces above the four arches carrying the dome have each figures of two saints standing on a green sward, clothed in simple white garments. The drawing of these shows the decline of art more than elsewhere, and it is somewhat stiff and angular. Between the saints, in the middle of the foreground, is a well of water, as a symbol of eternal life. On the margin are beautiful birds, resting and sipping the water. A large shell of grey mosaic, with golden lights, surmounts each of these pictures. The wall arches are treated in a very peculiar manner. Golden vine-leaves and grapes are laid on a dark blue ground, whilst the under sides are adorned with a waving ribband of varied colours, the lights being touched up with gold. The under side of the cross arches separating the dome from the four cylindrical vaults contrasts strongly with these. The two next short arms, or the transepts, have rectilinear ornaments—the one towards the entrance having also on a white ground a decoration of green leaves and golden fruit, whilst that next the sepulchre of Galla Placidia has a rich intertwining fret of contrasting tints, very beautiful both in harmony of colour and form. The cylindrical vaulting of the nave is covered with beautiful rosettes and stars, but that in the transepts is still more complete and striking.

Within the simple fret which surmounts the whole, a rich vine-leaf ornament rises to the top of the vault from each side, meeting in a circular panel containing the monogram of Christ. Everywhere gold is used on a dark blue ground, both for figures and for leaves, except where narrow red and white lines separate the fret from the other ornament; and the panel with monogram is alternately a brown red and a pale green. The semicircular wall surfaces at the end of the transepts are likewise ornamented. A similar fret surrounds the space on which, interlaced by highly conventionalised acanthus foliage, are represented harts hurrying to a fountain of water which issues from among reeds. The harts and the water are given in approximately natural colours: the first with golden lights and antlers, the plants with green and golden lights.

The corresponding surfaces at top and bottom of the cross are filled with large figure subjects.

Above the sarcophagus of Galla Placidia Christ is represented. He is engaged in burning upon a gridiron heretical books, whilst a reading desk beside him holds the orthodox books, amongst which appear the Evangelists.

Above the door opposite this is the finest picture of all. Christ, represented as the "Good Shepherd," is seated in a landscape, in the midst of his sheep. No work of early Christian art appraaches to this in its noble and antique conception. The broad and simple treatment of the subject remind one greatly of Giotto's frescos in the under-church at Assisi.

We come now to a building erected sixty years after the last-described—St. Apollinare Nuovo, or Basilica of St. Martini in Cœlo Aureo.

This is the finest of the existing Arian churches. It was founded by Theodoric about 500 A.D., close to his palace, and still preserves most of its original features. The exterior is of plain brickwork, similar to those described before. The interior has on each side twelve grey marble columns separating the nave from the aisles at either side. The capitals are Corinthian, having square imposts of quite Byzantine character, representative of the old architrave. Above the arches which spring from these are a range of medallions containing pictures in mosaic. Near the door there is a contemporary likeness of the Emperor Justinian, and opposite this one of Bishop Agnellus. From this point this mosaic frieze extends towards the apse; on the south side, or *pars virorum*, there are holy men and women: the former are martyrs and confessors of the Ravenna Cburch, with their names inscribed beside them; all are clad in white robes, and divided from

S. Apollinare · Nuovo
part of the Arcade and mosaic pictures over it.

one another by palm trees. They approach towards Christ, who, surrounded by four angels, is enthroned close to the tribunal, and reach out their crowns towards him. They come as if from Ravenna, which, in a panel next the door, is indicated by a view of the palace and other buildings. On the north side, or *pars mulierum*, the frieze shows the suburb Classis, a harbour surrounded by towers with some ships; and from this point a procession of holy women in shining garments, with crowns in their hands, proceed to join the train of the Three Kings, who are humbly approaching the infant Saviour, enthroned on the lap of his mother, and offer gifts at his feet. Four angels stand beside the throne, with sceptres in their hands. Above the frieze are lofty and wide windows, or arched recesses, one above each arch, mostly walled-up, so that only a small quantity of light comes into the church, and the figures are not seen to advantage. Mosaic pictures of saints, in niches, stand on the piers between the windows. The roof is of timber, flat, and pannelled, and bears traces of painted decoration. When the Saracens, about 850 A.D., ravaged the coasts of the Adriatic and plundered the church of St. Apollinare in Classe of its silver ciborium, Archbishop John escaped with the body of S. Apollinaris, and laid it in this church. At a later time, contentions began between this church and that of S. Apollinaris in Classe as to which had the true body of the Ravenna apostle. Pope Alexander III. at last decreed that the honour belonged to the church of Apollinaris in Classe; but the other still kept the name of the saint.

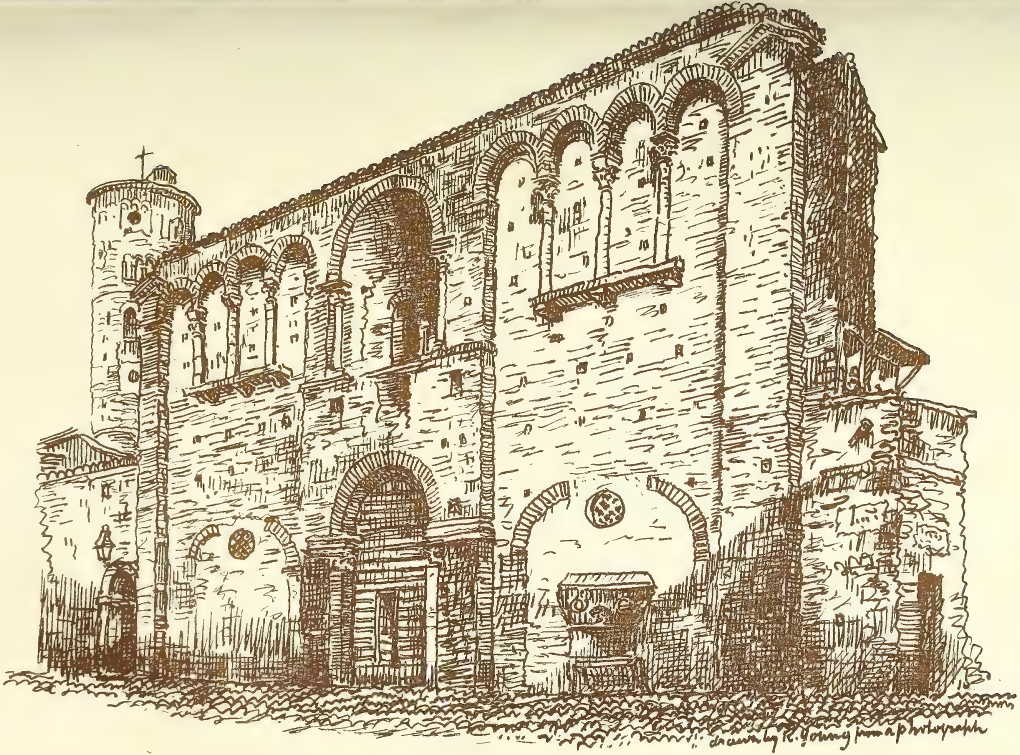
We now come to the Palace of Theodoric, where we see a fragment of the earliest of the secular buildings in the Romanesque style in Italy, and its interest consists greatly in its preserving amidst its generally classic features the details and mouldings of the newer style which was already in movement. This was, by the accounts of ancient writers, a very extensive and sumptuous building, occupying a large space, now covered by the garden of the Fransiscan Monastery. Of this palace only a small part at the angle of two streets still remains. Such was once its splendour that Charlemagne, when visiting Ravenna, asked and obtained permission of Pope Hadrian, and carried off nearly all the columns to adorn his new palace at Aachen, which was in progress.

There are two other sources, in addition to the remnant referred to, from which a notion can still be gained of what this building was like in its pristine state. One is the account given by Agnellus the historian; the other is its representation in mosaic in S. Apollinare Nuovo. In the latter it is shown with a portico of four Corinthian columns, connected by richly-moulded arches bearing a gable, under which "*palatium*" is inscribed on a horizontal cornice. Three other Corinthian columns with arches are on each side, but lower than the centre. Above is an arcade with windows. A roof, apparently of tiles, covers all.

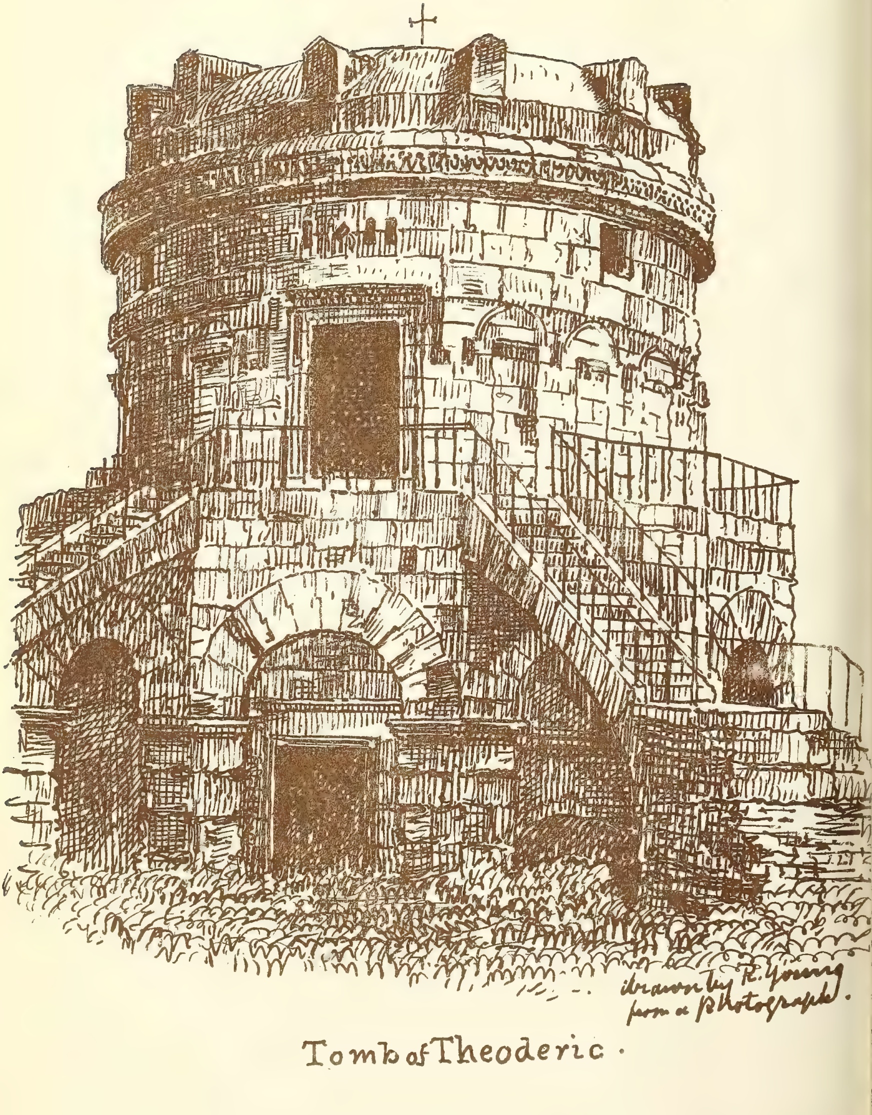
The present fragment is evidently not part of this facade, as the picture represents it as seen from the sea, the town of Ravenna, with its churches and fortified wall, appearing behind it. It is probably a portion of an inner court, as was usual in the arrangement of Roman palaces. It is of very thin brickwork, with stone for columns and carved portions. It has on the projecting centre a wide and lofty doorway with semicircular arch rising from pilasters, the capitals of which are decorated with a flat treatment of the acanthus, among the leaves of which is placed a cross. At a height of about fifteen feet above this door is a large semicircular niche, the arch of which springs from nook shafts, the capitals of which are treated with a very Gothic feeling. In the centre and at the bottom of this niche are two small openings through the wall, with arches resting on a bracket-formed abacus above a slender shaft. An arcade of four small arches decorates the upper part of the building on each side of the niche, the outermost arches springing from square piers, which form a solid finish to the facade on both sides. The three stone shafts which support the arcades are disengaged from the wall, and rest upon a shelf supported by stone corbels of a very interesting section, being quite of a Gothic character.

The eaves cornice and the small pediments covering the piers at the angles are formed of bricks and flat tiles laid in a simple fashion like that at the old Baptistery.

On the ground level there were two arched openings on each side of the entrance; these are now walled up, and certainly the most interesting relic extant in this quarter is here placed against the pier between two of these arches—this is the sarcophagus of Egyptian



Palace of Theoderic



Tomb of Theoderic.

porphyry, said by some to be that in which the body of Theodoric was entombed on the top of the mausoleum. It was only placed here in 1560 A.D.

The tomb of Theodoric next engages our attention. It is situated in a dreary, swampy spot, a little way from the Porta Serrata, and impresses one greatly by its aspect of massive strength and power of endurance.

It is a decagon in plan, and two stages in height; entirely constructed of finely-wrought Istrian limestone, in solid ashlar, and having the first floor resting on a vault, and the upper covering consisting of one solid stone, thirty-six feet in diameter, resembling a saucer inverted, and having large handle-shaped projections rising at intervals around its rim, no doubt used in the process of lifting to its seat this roof of some 400 tons weight.

There is a considerable amount of quiet ornamentation on the doors, and small openings for light in the upper story of this building. The architraves of the doors are classic in feeling, but the undercut mouldings of the roof are very Gothic in their character; and in the upper portion of a series of square panels, which form an ornamental feature just under the roof, a very singular and effective decoration is used, bearing a strong resemblance to a series of pairs of pincers. Whilst it is a form unknown in classic art, it is interesting to know that it was in use by the Gothic races, as it is found on a small scale on the armour of Odoacer, preserved in the local Museum.

This monument illustrates as forcibly as any we have yet seen the way the old classic types were being modified by the Northern race. Whilst the Mole of Hadrian at Rome gave the general idea, the Cyclopean roof and most of the details were imported or originated by the Gothic builders.

The only other relic of this period to which I can refer as having seen are two columns of the so-called Basilica of Hercules, which stands much hidden by debris in the Piazza Maggiore. The capitals are carved with foliage, resembling pieces of seaweed thrown against the bell, and exhibiting a strong Byzantine character without any trace of the classical remaining.

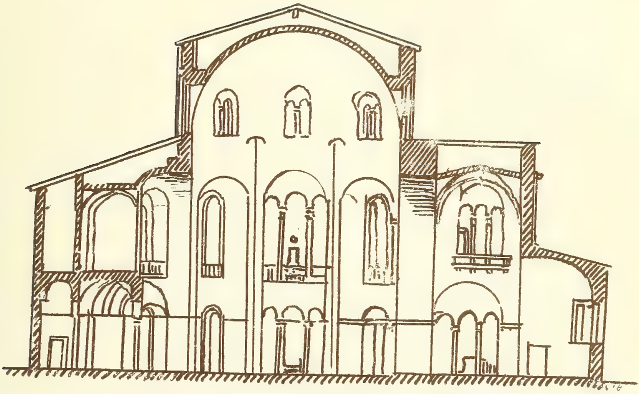
We now pass over some years, and come to the church of St. Vitale.

This building is unlike any other in Ravenna; indeed it is so remarkable that its place in the sequence of architectural development has been the cause of much contention. It is a compound of polygonal and curved forms, and in its ground plan is more complicated than any previous church of which an account has been preserved. In general design it may be said to be founded on that of the temple of Minerva Medica at Rome; but it is an octagon instead of a decagon like the latter, and there are several peculiarities connected with it which make it very probable that its plan was an Eastern one, as Eusebius describes a very similar church at Antioch in the third century, and we know that it was on his return from Constantinople, where he would probably hear of this, that Ecclesius began its erection in the year 526. Its plan may be described as being an interior octagon of fifty feet, surrounded by an exterior one of one hundred and ten feet diameter; the inner one covered by a dome, and the outer space by groining.

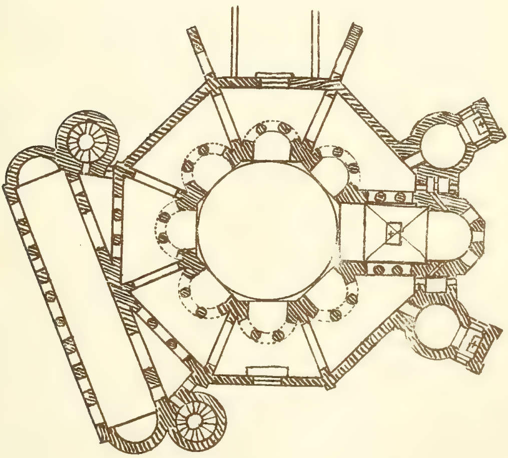
The inner octagon has on seven of its sides semicircular apses, formed by three open arches supported on marble columns with beautifully carved capitals. On the eighth side there is a choir. Above the range of arches on the ground floor there is a second tier corresponding in every way with the lower ones, except in being much loftier; and in front of the apses rise round arches between the piers, on which the octagon rises, and then is formed into a dome, having eight double lights in its base. A gallery is formed all round the central area, supported on groined arches at the level of the second tier of arcades. In front is placed a very spacious narthex, or porch, with round ends, at both of which circular stairs conduct to the galleries. This narthex and the triangular spaces connecting it with the church are also groined, and the whole of the surfaces of piers and arches and pavements are covered with costly variegated marbles.

The effect of the building inside is wonderfully fine. The complexity and mystery of its plan, the fine effect of light and shade on its numerous arches, groined roofs, and dome, and its beautiful and costly decorations, render it a perfectly unique structure, and one of the highest importance in the history of art.

The mosaics which cover the surface of the dome and the groining



Section of S. Vitale
scale 50 ft to 1 inch



Ground Plan

of the double tier of aisles are of admirable design and execution. The scheme of arrangement is as follows :—

Opposite the original entrance, now built up, is the choir, in the centre of which Christ is represented enthroned on the globe ; angels are on either hand ; beyond these Saints Vitale and Ecclesius, with a picture of the church ; below, on the left side, the Emperor Justinian and St. Maximian, both in rich robes, and surrounded by figures, all life size ; on the right the Empress Theodora, with the ladies of her court, shown in magnificent costumes. On the triumphal arch (corresponding with the chancel arch of Gothic churches) are represented Jerusalem and Bethlehem ; above this, at the sides, the four Evangelists, seated ; Isaiah and Jeremiah, standing; Moses loosing his sandals from his feet and receiving the Law. Above all these, Christ as the Good Shepherd. Farther to the right, an altar with bread and wine; at the sides the bloody sacrifice of Abel, and the bloodless offering of Melchisedec ; then on the left a table, at which the three angels are being entertained by Abraham, whilst Sarah is represented as standing in the door laughing ; in the archway are half-length figures of Christ, the twelve Apostles, and Ss. Gervasius and Protasius.

We now come to the Church of St. Apollinare in Classe.

This, perhaps, taking it all in all, is the most noteworthy edifice in Ravenna, if not in Italy, from its complete scheme of gorgeous decorations, and its present wonderful state of preservation. It is situated about three miles from the city, in the desolate marshy tract where once stood a flourishing city, with numerous public buildings, and adjoining which the Roman fleet rode at anchor.

The exterior of this building, although built of the common Roman brick, and with little or no attempt at decoration, is very striking and picturesque, from its general form and grand proportions. The internal plan of wide nave, with side aisles, is clearly expressed outside by the blank arcading both of the aisle walls and by those of the nave, which rise above their low-pitched tiled roofs.

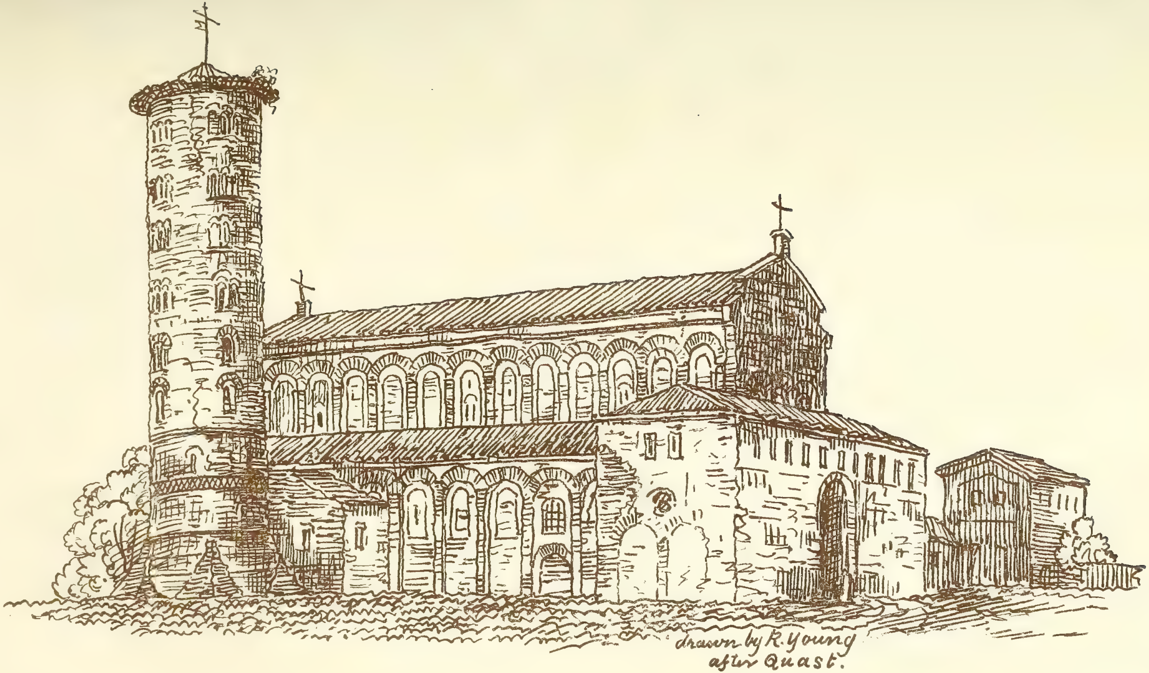
A great appearance of stability is given by the unusual depth of the arches, which are of flat tiles, the outer order springing from a simple brick impost ; the inner order being quite plain, and apparently never intended for window openings, but to contain fresco or mosaic pictures, as they have all been coated with plaster, on which, however, no trace of art is now visible.

In only three of the thirteen upper arched recesses at each side of the nave is any light admitted, and in each case it is by two very narrow lights, coupled under a subordinate enclosing arch, all of which seem coeval with the building. Some large windows, quite out of keeping with these, light the aisles ; but it is evident they are late insertions.

A large plain square building, with a lofty arched opening in the centre, subtends the west end of the church, and is, in fact, the representative of the antique atrium, or fore-court, of the Roman Basilica. At the north-east end, but not incorporated with the church, rises the lofty campanile, of circular form, with flat pitched tiled roof, and numerous round-headed openings, so often referred to by those who are in want of a prototype for our Irish round towers. A great batter is given to the first ten or twelve feet of the base, which is also strengthened by four spurs or broaches of brick-work, as if rising from the angles of a square base, as in a broached spire. About ten feet over this there is a very nice ornamental band of tiles, in two colours, placed in diamond patterns : but, with the exception of the arched heads of the numerous lights being formed also of tiles in two colours, there is nothing to adorn its perfectly bare surface ; and yet it leaves an impression of simple majesty and completeness which larger and more elaborately wrought towers often fail to give.

From the whole aspect of the exterior, one cannot fail to see that the builders were avoiding, as far as possible, the style in vogue for constructing heathen temples, where the greatest expense was gone to in adorning the exterior with marble and porphyry columns and sculpture, but here all is exactly reversed.

Entering the church, we find that the aisles are divided from the nave, which is of the unusual width of fifty feet, by twelve columns of variegated Greek marble on each side. The columns are singular, both in respect of their bases and their capitals. The former are flat, and raised on square plinths, decorated with an incised lozenge ornament. The capitals are of the same kind as those in the market square, supposed to belong to the Basilica of Hercules. This peculiar



S. Apollinare in Classe.

capital, which afterwards appears in the exterior of St. Mark's at Venice, differs from the usual arrangement which is best shown in the upper gallery of St. Vitale. The Ionic volutes are diagonal, but do not form a prominent feature, and only project slightly over the bell, and are joined by one egg and dart moulding. There are then placed separately two rows of leaves, with sharply cut outlines. These seem as if thrown against the bell without growing out of it as is usual. The capitals of the large piers or pilasters at the end of the arcades are of unusual height and form. They are formed by thickish leaves, placed flatly against the vertical plane of the cap in three tiers, of which the lower one is an expansion of the classic necking. The strong marking of the leaf veins, both in the column and pilaster capitals, is very remarkable. In the former they show as a projecting band adorned by round sinkings, whilst in the latter they appear, as they are so often seen in mediæval sculpture, wrought into square facets. No doubt this is the earliest example of this style of decoration.

The continuous frieze running above the arches at each side, and below the upper windows, contains a series of portraits of the Ravenna bishops from St. Apollinaris to the present time. These occupy the place of other mosaics and inlaid marbles which were taken away by Sigismund of Malatesta in 1450 A.D. to adorn a church in Rimini; however, those that remain in the other parts of the church are known to be not later than 670 A.D., or one hundred years after its dedication by Maximianus. Of these the finest mosaic is the representation of the confirmation of the privileges of the church, containing portraits of the Emperors Constantine, Heraclius and Tiberius.

A marble chair for the bishop is at the rere of the apse, on which is the inscription—"D. N. DAMIANUS ARCHIEP FECIT."—691 A.D.

A very remarkable ciborium of the year 800 A.D. stands in the north aisle against the east end. It is supported by four twisted columns of Greek marble, and the capitals, although adorned with crosses and foliage, have no longer the old Byzantine vigour, but show much poverty in their details. The circular arches have an enrichment of twisted bands like the later Byzantine and Romanesque. Its date being exactly known, this work fixes an important epoch in the decline of art.

Having now completed the notes of the buildings I was able to visit, I have to say in conclusion that much has still to be done to elucidate the art remains of Ravenna, as very little has been yet attempted in the way of accurate measured drawings to a proper scale.

28th February, 1874.

Joseph John Murphy, Esq., F.G.S., President of the Society, in the Chair.

A Paper was read by Professor G. J. L. HODGES, M.D., J.C.S.,

entitled—

Notes on Japan and Japanese Life.

25th March, 1874.

A Paper was read by JOSEPH JOHN MURPHY, F.G.S., President of the Society,

On the Origin and Metamorphoses of Insects.

The present paper is meant as little more than a review of Sir John Lubbock's work on the same subject. I agree with him in beginning by taking as proved the doctrine of evolution :—that is to say the doctrine of the derivation of every species by descent from some lower and simpler form ;—and I agree on the whole with his conclusions, though I think he is inclined to underrate the difficulties of the subject. I regard the metamorphoses of insects as one of the greatest difficulties of the evolution theory, though this is not true of all metamorphoses.

Metamorphosis is defined as development with change of plan. All winged insects acquire their wings by metamorphosis—no insect has wings when it leaves the egg. It ought however to be mentioned that the transformations of the Echinodermata (star-fish, sea-urchins, &c.) are phenomena of quite a different order from the metamorphoses of insects. In true metamorphoses, as those of insects and frogs, the parts of the mature form are developed out of the corresponding parts of the larva. In the transformations of the Echinodermata this is not the case; the earliest form, which Dr. Wyville Thomson calls the pseudembryo, but which I should prefer to call the pre-embryo, is not a larva, but is its function more analogous to a placenta. In the star-fish it is cast off like a placenta when the mature form has been produced; in the sea-urchin its substance is absorbed; but in no case are its parts transformed into the parts of the mature animal.*

* See Dr. Wyville Thomson on the Embryology of the Echinodermata, *Natural History Review*, July, 1863.

These transformations appear to me a great difficulty in the way of Darwin's theory, or any other modification of the theory of evolution. So far as I am aware, no suggestion has yet been made towards accounting for the origin of this extraordinary mode of development. The subject of true metamorphosis will on the contrary be found fertile in such suggestions.

Among true metamorphoses, none appear to throw so much light on the process whereby one class of organisms has been derived from another, as the transformations of the Batrachia (frogs, newts, &c.) from aquatic and water-breathing into terrestrial and air-breathing animals. Both the respiratory and the motor systems are altogether changed; the branchiæ, or gills, of the tadpole wither and disappear; lungs are developed; legs bud forth; and in the frog, though not in the newt, the tail is absorbed and disappears. Some light is thrown on these transformations by the facts that among the water-breathing classes of animals generally the respiratory organs are remarkably variable in form and position, and among Invertebrates they are so even as to their presence or absence—that in many cases they do not appear till a late stage of the animal's development*—and that in all the lowest organisms, and in many which are not among the lowest, there are no distinct respiratory organs, and the entire surface is a respiratory surface.

The Batrachian class also contains good instances of the loss of metamorphoses through suppression of stages of development. Thus the land newt, which lives in dry mountainous regions where there are no pools of fresh water, is an exception to the general law that Bartrachians leave the egg in a tadpole form. It passes through the tadpole state before leaving the egg. And it has been lately stated, apparently on good authority, that the same is true of a variety of the frog found in the volcanic island of Guadaloupe, where also there are no pools of fresh water.†

If the theory of evolution is true, the larval forms in such cases

* For this fact among the Crustacea, see Fritz Müller's "Facts for Darwin." Dr. Rolleston mentions (Forms of Animal Life, introduction, p. cxvi.) that the tracheæ or breathing-tubes of the insect *Chlœon dimidiatum* are absent in the early developmental stages.

† See *Nature*, 27th March, 1873.

as that of the Batrachians represent ancestral forms; frogs are descended from tadpoles or tadpole-like fishes. What makes such a change possible is, that variations sometimes occur at a not very early age;—in this case, at the age when the metamorphosis of the tadpole begins;—and when this occurs, the variations are, according to Darwin, generally inherited by the offspring at the same age. What makes possible the loss of metamorphoses, as in the case of the land newt and the Guadaloupe frog, is the fact that variations are sometimes inherited at an earlier age than that at which they occurred in the parent: thus, if, as every believer in evolution will admit, the species now mentioned are descended from species which went through the usual Batrachian metamorphoses, the metamorphoses have in these cases disappeared by occurring at an earlier period—namely, in embryonic life. The embryo of the land newt before it leaves the egg is a tadpole. But it is probable there are cases where all trace of the ancestral form is lost, even in the larva and the embryo; and if this has taken place throughout any entire class, its true ancestry and affinities will have thereby become almost, if not quite, impossible to discover. Had the entire Batrachian class lost all trace of the tadpole state, its close affinities with fishes would probably be scarcely suspected.

The metamorphoses of the Batrachia are adaptive metamorphoses: that is to say, their purpose is to adapt the animal to a new kind of life—to raise it from an aquatic to a terrestrial existence. It seems probable that the first impulse to the transformation of a tadpole-like fish into an air-breathing animal was given by the drying up of the pools of water in which it lived. This conjecture is supported by experiments on the axolotl, a member of this class, which does not always undergo metamorphosis, but frequently remains a permanent tadpole, and propagates in that state. As in all members of the class, its metamorphosis, when this occurs, partly consists in the withering of the branchiæ or gills; and it has been found that the change of the animal's colour, which normally accompanies the withering of the branchiæ, is promoted by their removal: an operation which does not appear to be injurious.

One of the most important discoveries in zoology since Cuvier's time is that of the development of the Cirrhipedes or Barnacles from

Crustacean larvæ. Cuvier, and Linnæus before him, knowing this remarkable class only in the mature state, regarded them as Mollusca; but no naturalist has hesitated to place them among or near the Crustacea, since it has become known that their larvæ are scarcely to be distinguished from other Crustacean larvæ. The same is true of the Lerneæ, which in the mature state are parasitic on fishes, and were formerly supposed to be worms. And the Linguatulina, which in their mature state are internal parasites of air-breathing animals, and resemble worms, are shown by their larval state to belong to the Arachnida, of which class the spider and scorpion are the highest types. All these three are adaptive metamorphoses, being accompanied by a total change in the mode of the animal's life: the larva is free, but the mature animal is absolutely or at least comparatively fixed. They are also retrograde metamorphoses, being changes from a higher to a lower existence. All retrograde metamorphoses are probably adaptive, but the converse is not true; the adaptive metamorphoses of the frog and other Batrachians are not retrograde but progressive.

There are, however, metamorphoses which do not appear to be adaptive. When the animal, at its various stages of transformation, lives in the same locality and leads the same kind of life, its metamorphoses cannot be regarded as adaptive; and, so far as I see, can be ascribed only to an innate impulse to development. This applies to the metamorphoses of the higher Crustacea (crabs, lobsters, &c.). The earlier transformations here are from one free swimming form to another.

The Crustacea are one of the four classes that constitute the Arthropoda, a great division of the animal kingdom, which precisely coincides with the Linnæan class of insects. The other three classes are the Arachnida, to which the spider and scorpion belong; the Myriopoda, or centipedes and millepedes; and the true or Hexapod Insects, in which class alone wings are developed. Arthropods may be generally defined as segmented animals with jointed appendages. The segmentation is well seen in the centipede; in the spider it appears to be obliterated. The jointed appendages are almost, if not quite, universal among the Arthropoda; they assume various forms—antennæ, jaws, chelate or claw-bearing arms, legs, and swimming feet—all of which are homologous with each other, in the same sense that the arms and legs of man are homologous. It must be observed that, unlike the jaws of Vertebrates, those of Arthropods open horizontally. All the variously modified appendages now mentioned are found in the lobster and prawn. Segmentation is a character which Arthropods share with worms, but the jointed appendages or limbs, from which they derive their name, are, so far as is known at present, altogether peculiar to this division. Both the body and the limbs are constructed on a plan opposite to that of Vertebrates, the hard parts being outside and the soft parts within.

We return to the subject of the metamorphoses of the higher Crustacea.

Fritz Müller, in his "Facts for Darwin," has described the development of a species of Prawn, belonging, or allied to, the genus *Peneus*. Its form, when first hatched, is that called a Nauplius, and bears no more resemblance to its mature form than does a caterpillar to a butterfly. A Nauplius is a minute animal of an oval form, without any trace of segmentation ; it has six swimming legs, but no jaws, and has a single eye placed medially. This form is common as a larval form among the lower Crustacea, but Müller's *Peneus* is the only instance yet known of its occurrence among the higher members of the class. To believers in evolution it will appear certain that orders must be closely akin when their larval forms are almost exactly alike.

So long as the *Peneus* remains in the Nauplius state, there is nothing about it to suggest that it is to develop into an animal of the same order with the lobster. The fact that it has six legs might suggest some affinity with the true or hexapod Insects. This, however, would be an altogether erroneous conjecture, for its legs are not homologous with those of Insects. If their homologues in the Insects can be identified at all, they are not the legs, but the appendages of the head, the antennæ and jaws. In the subsequent metamorphoses of the Nauplius, the first two pairs of its legs are transformed into antennæ, of which the Crustacea have two pairs ; the third pair is transformed into the mandibles or anterior pair of jaws. The part of the body of the Nauplius which bears these appendages becomes the head of the mature prawn ; the tail end remains the tail end, and development proceeds by the growth of segments between these, forming a long tail-like abdomen, which is the corresponding part to that usually, but inaccurately, called the tail of the lobster. New limbs appear, a carapace or shell is developed from the head, and the two eyes of the mature form make their appearance. In this state the animal is called a Zoea. This form is very common among the higher Crustacea ; most crabs appear to leave the egg as Zoeas.

The next stage is what Müller calls the Mysis-form. It differs from the Zoea chiefly in having acquired feet on the newly-formed segments. This changes into the mature form by some of the swimming feet acquiring chelæ or claws, while others posterior to these are changed into walking feet ; and at the same time the respiratory function, which in the Nauplius took place probably through the entire surface, and in the Zoea through the lateral parts of the carapace, is assumed by branchiæ, which are developed on the thorax.*

These changes are perfectly continuous. There is no abrupt change similar to the unfolding of the Insect's wings, nor is there any stage like the pupa or chrysalis stage of many Insects. If the theory of evolution is true, it can scarcely be doubted that as the tadpole represents the fish from which the frog is descended, so the developmental stages of Müller's prawn represents the ancestry of the entire order of Macrurous Crustacea, to which the prawn and the lobster belong. A Nauplius, or some form nearly resembling it, was probably the ancestor of the entire Crustacean class : a Zoea was descended from this, and became the ancestor of all the higher or Malacostracan Crustacea ; a Mysis form was descended from the Zoea, and gave origin to the macrurous or long-tailed order, though not to the crabs, which do not pass through the Mysis stage. The Nauplius stage, it is true, appears to be exceptional among the higher Crustacea, which mostly leave the egg in the Zoea form ; but the fact that the Nauplius form occurs among the higher Crustacea at all is sufficient to prove the affinity of the entire order ; and its absence in most cases only shows that it has dropped out of the chain of successive developmental forms, just as the tadpole stage has been lost

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* See Mr. Dallas's translation of Müller's "Facts for Darwin" (Murray, 1869), pages 58, 59, 60, and 61, whereon are figured the nauplius, two Zoea-stages, and the Mysis-stage of this prawn.

in the case of the land-newt and the Guadaloupe frog. In the case of the lobster the Zoea stage also has dropped out, and the animal leaves the egg in a form resembling the Mysis. Finally, the fresh-water crayfish undergoes no metamorphosis at all.*

The facts of Crustacean metamorphosis, which I have now described in extreme outline, appear to tell very strongly in favour of the general theory of evolution. But I cannot agree with Müller that they at all favour the specially Darwinian form of that theory. Natural selection among spontaneous accidental variations may, at least, help to account for very great changes in the organism to correspond with changed conditions of life. It may, no doubt, account in part for the change in the respiratory and motor systems of the first race of tadpoles that were transformed into air-breathing animals, when the waters in which they lived began to dry up. But it does not follow that the same process is likely to be sufficient while the conditions of life remain unchanged; and this appears to have been the case throughout the greater part of the evolution of the higher Crustacea, because the Nauplius, the Zoea, and the Mysis forms are all freely swimming animals, living under conditions which do not sensibly differ. The minute and random variations which alone Darwin's theory recognises are unlikely to work great changes under unchanging conditions of life; and this for two reasons. In the first place, such spontaneous variations are then less likely to occur, because permanence of circumstances promotes constancy of form, while on the other hand changes of circumstances promote variation; and in the second place, if under such conditions they do occur, they will be less likely to give any sensible advantage to the individuals possessing them than changes of similar magnitude occurring along with changing conditions. I cannot think that the evolution and the metamorphoses now described can be referred to any other cause than a formative impulse impressed at the beginning on living matter by Creative Power.

Besides this general argument, a remarkable special argument on the subject is yielded by Müller's very interesting researches on the development of his prawn. He says† of its Mysis that "the long

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* Stated by Müller (page 47), on the authority of Rathke.

† Page 61.

abdomen, which just before was laboriously dragged along as a useless burden, now, with its powerful muscles, jerks the animal through the water in a series of lively jumps." The Nauplius has no abdomen; this part is acquired when the Nauplius develops into a Zoea, and consists of segments which appear in front of the tail of the Nauplius. Darwin's theory will account only for changes which are immediately beneficial; and Müller's account appears to show that its abdomen is not immediately useful to this Zoea, but is developed for the purpose of subsequently becoming useful as a swimming organ, and developing feet upon its surface. It may be suggested that the abdomen has some physiological function which makes it useful to the Zoea, but this seems scarcely probable.

The metamorphoses of the true Insects present much greater difficulties than those of the Crustacea. Among the Crustacea we have seen that each temporary form worn by the animal during its development probably represents the mature form of one of its remote ancestors. But this does not appear to be true of the Insects, as will appear from a study of their metamorphoses. Insects are the only invertebrate animals that have wings, and their wings resemble nothing else in the animal kingdom. But, though characteristic of the insect class, wings are not universal in it. Some insect orders are wingless, and there are wingless genera in most, if not all, the orders. In many cases the wings are a sexual character, being possessed by the males alone; and in all cases they are acquired by metamorphosis: no insect leaves the egg with wings. These three facts are all mutually connected; characters which are late in development tend to be variable as between species of the same order, and the same is true of characters which belong to one sex only without appertaining to the reproductive system.* It is obvious that any account of the origin of the class of insects must be unsatisfactory, unless it can explain the origin of the wings; for it would be contrary to all analogy to suppose that organs so very peculiar as these, or, indeed, any organs whatever, could at their first origin be suddenly produced; and the wings are developed in a comparatively

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* Such characters are called by Darwin secondary sexual characters.

short time during the last period of larva life, and unfolded, not gradually but all at once, at the final metamorphosis.

All naturalists are now agreed that the wings are morphologically part of the respiratory system. Insects breathe by means of tracheæ or air-tubes, which open on the animal's side and ramify through the body. The wings are formed on the outer termination of the tracheæ; and during the development of the wings and before they come into activity, their veins appear to be tubes which are continuous with the tracheæ. Dr. Duncan says* of the final metamorphosis of the small tortoise-shell butterfly :—"The wings, then scarcely as large as hemp-seeds, are gradually distended at their base, and are perceptibly enlarged at each respiration." The wings appear to be homologous with the external branchiæ of some aquatic larvæ, as the *Cloe bioculata*, the *Ephemera vulgata*, and the *Phryganea clavicornis*.† "The adult insect," says Dr. Duncan, "becomes an air-breather, and spiracles (or mouths of the tracheæ) are developed in its sides exactly in the places where the gills were attached during its fish-like life. In the larvæ of the May-flies (Ephemera) the branchiæ are formed of expansions of the skin, which are very delicate, thin, and variously folded and fringed, and they are attached in pairs to the first seven segments of the abdomen. The tracheæ are included in the folds, and are continued into the body of the larvæ, and they transmit the purified air to it; but the gills disappear during metamorphosis."‡ In *Pteromarcys regalis*, an insect inhabiting damp places, these branchiæ remain through life.§ This is consequently a perennibranchiate insect, and its case is analogous to the perennibranchiate batrachians, which I have described as being permanent tadpoles. In the existing species, as we have seen, these branchiæ are developed on the abdomen, and such a position, for mechanical reasons, would be an impossible one for wings. But, considering the remarkable variability of the respiratory

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* Duncan's Transformation of Insects, page 51.

† See the magnified figures of the larvæ of these species in Dr. Duncan's work, pages 47, 48. *Cloe* is also called *Chloeon*, and is mentioned under that name in a note on p. 77 of this volume.

‡ Same, page 48.

§ Rolleston's *Forms of Animal Life*, introduction, page cx.

organs of aquatic invertebrates generally, there is nothing improbable in the supposition that such branchiæ in one species were developed on the thorax, and came into use as swimming organs, and ultimately as wings. It is mentioned by Sir John Lubbock that the muscles which are attached to the branchiæ of the larvæ of *Cloe* (which he calls *Chloeon*) "in several remarkable points resemble those of the true wings."*

It has been mentioned in support of this hypothesis, that an insect has been lately discovered by Sir John Lubbock, and named *Polynema Natans*, which uses its wings in swimming. But, interesting as is this fact, I do not think it is relevant to the present question: for the *Polynema* belongs to the order *Hymenoptera*, the same order that contains the bee and the ant, which is perhaps the highest of all the insect orders, and does not appear in any way to point to the origin of the class.

If the conclusion is accepted which is here stated as to the probable origin of the Insect's wing, it may appear a necessary inference that the first Insects were water-breathing animals. This, however, does not appear to have been the case; it seems more probable that insects were an air-breathing class from the first; that aquatic respiration was always as exceptional among the Insects as aërial respiration among the Crustacea, and that wings were first formed in one of those exceptional families which took to an aquatic life, and developed branchiæ upon their tracheæ. The reasons for this apparently strange conclusion are as follow:—

As we have seen, the branchiæ, or water-breathing organs, of some larvæ, which appear to be homologous with the wings of mature insects, are developed on the external terminations of the tracheæ or breathing-tubes; and, though in the larvæ in question the tracheæ serve for aquatic respiration, yet tracheæ appear to be essentially and originally air-breathing organs; for air-breathing organs are in general internal, so as to bring the air into the body: while water-breathing organs are in general external, so as to bring the blood out into the water. Consequently, when a water-breathing insect has its branchiæ

* Monograph of the *Collembola and Thysanura*, published by the Ray Society, page 53.

formed in connexion with tracheæ, it appears most probable that the tracheæ are inherited from an air-breathing ancestry; for internal breathing organs like tracheæ could not be formed in a water-breathing race.*

Further, not only is aquatic respiration exceptional among insects, but when it does occur there is no uniformity in the respiratory organs. Sir John Lubbock remarks:—"From the various modes by which respiration is effected among different groups of aquatic insects, we are justified in concluding that the original insect stock was a land animal."† Were the water-breathing insects representatives in that respect of the original stock of the class, then their respiratory organs would resemble their origin and resemble each other; but when we find them unlike in the different water-breathing groups, we conclude them to have been separately developed. In the same way aërial respiration is exceptional among the Crustacea, and the respiratory organs of the various air breathing groups are quite unlike each other, showing that they also have been developed separately.‡

The hypothesis that the branchiæ which have been developed into wings were of later origin than the tracheæ, and of later origin than any other important organ, agrees also with the facts that their presence is very inconstant in the class, and that when they exist they are never developed until the final metamorphosis.

Finally, Sir John Lubbock has given what appears to be strong reasons for thinking that the first insects resembled the *Thysanura*, an order which are all air-breathers and all wingless, and undergo no metamorphosis. He has gone so far as to indicate the genus *Campodea* as that which has probably remained nearest the original form. *Campodea staphylinus*, as figured by him,§ is an insect about a quarter of an inch in length, with strongly-marked segmentation of

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* These reasons are scarcely conclusive, because it may be argued that the tracheæ of the Insects and the Myriopoda (centipèdes) are homologous with the "water-vascular system" of the lower worms or the "segmental organs" of the higher worms or Annelids. But this appears improbable, because the Crustacea, which are the characteristically water-breathing class of Arthropods, have no water-vascular system, and nothing resembling either the tracheæ of Insects or the so-called lungs of spiders.

† *Collembola and Thysanura*, already quoted, page 53.

‡ See Müller's "Facts for Darwin," already quoted.

§ See his work above referred to. See plate 50 of the same work.

the body, no wings, six legs, a pair of jointed antenuæ about one-fourth of the length of the body, and a pair of jointed tail-bristles a little longer than the antenuæ. (In some Thysanura these tail-bristles are used for leaping, whence the name of spring-tails.) *Campodea* has a strong resemblance to the larva of *Cloe* or *Chloeon*, already mentioned; and Sir John Lubbock, in another memoir, states that the metamorphosis of the latter is remarkably continuous and free from abrupt changes, from which he draws what appears to be the reasonable conclusion that it comes tolerably near to representing the original type of insect metamorphosis.

Difficult as is the question of the origin of the insect's wings, the metamorphoses of the parts of the mouth present greater difficulties still. Among some insect orders, as, for instance, the Lepidoptera (moths and butterflies), the mouth of the larva is mandibulate and adapted for biting, while that of the mature form is suctorial. According to Sir John Lubbock, the mouth in the Thysanura is intermediate in structure between the mandibulate and the suctorial types; and he thinks it probable that the first insects had such a mouth, from which the various and more specialised forms of mouth now found in both the larval and the mature forms have been descended. He endeavours to account for the very surprising fact of the larva and the mature insect in many cases having different types of mouth structure, by the suggestion that the larva and the mature insect were placed in circumstances where different forms of mouth were needed by different kinds of food, and that natural selection produced in both cases the forms of mouth that were needed. This, however, seems to be putting on the theory of natural selection a strain that it will not bear. It is, perhaps, possible that natural selection might adopt a mouth to the habitual food; but to suppose that it could afterwards transform and redevelop the same animal's mouth to suit another kind of food, appears not more admissible than to ascribe to natural selection the periodical change of colour in the fur of the ermine.* The transformation of the mouth takes place at the final metamorphosis, together with the development of the wings. While the development of the wings and the development of the

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* See page 7 of this volume.

mouth organs is going on, the insect remains in the pupa or chrysalis state, during which it is quite inactive and does not feed. The necessity for the insect to enter into this state, which may almost be called re-entering into the egg, does not depend on the development of the wings, but on the transformation of the mouth. Many insects, as for instance the Orthoptera (grasshoppers, &c.), acquire wings without the mouth being redeveloped, and they do not enter into the chrysalis state, but develop their wings without any cessation of activity; and others, among which I believe are the wingless working ants, pass through the chrysalis state without ever acquiring wings. It is obvious that such a state is necessary, because a mouth in the act of undergoing transformation from a mandibulate to a suctorial type would be incapable of work, like a machine while under repair. It is remarkable that those insects which pass through this state have the widest distribution, in consequence probably of its being, like the egg state, favourable to dispersion by driftwood and similar means.*

These remarks, however, go no way at all to explain the origin of the chrysalis state, which certainly is among the greatest difficulties of the theory of evolution. The total change from the tadpole to the frog, or from the nauplius to the prawn, is almost, if not quite, as great as the total change from the worm-like larvæ of Hymenoptera or Diptera to the mature winged forms, but the metamorphoses of the Batrachia and the Crustacea are gradual and continuous: they present nothing comparable to the almost sudden development of the insect's wings, and nothing resembling the chrysalis state. Indeed, I believe there is nothing in the entire animal kingdom at all like the latter, except the "encysted" state, which is common among the Protozoa. Sir John Lubbock suggests that the chrysalis state has been produced by the crowding together into a short time of a series of changes, which at first were gradual; and this is probably true, because gradual change is the rule in the animal kingdom, and rapid, almost sudden, change, like that of the chrysalis into the winged insect, is the exception.

Some of the Diptera (two-winged flies) while in the chrysalis state undergo a very remarkable process of almost total redevelop-

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* Rolleston's "Forms of Animal Life." Introduction, page cxiii.

ment. Instead of the tissues of the larva being transformed into those of the perfect insect, they are as it were melted down, except at certain spots, into an almost liquid substance, out of which the tissues of the winged insect are developed. Were it not for the spots which remain undissolved, this process would remind us of some dimorphic substance being dissolved from the crystalline state and crystallised again in a totally different form. Mr. Mivart, in his reply to Darwin, entitled "The Genesis of Species," has based on this fact an argument against Darwin's theory; but I think we know too little of the more obscure laws of life to base on it any argument either one way or the other.

We have seen that among Batrachia and among Crustacea the larval forms probably represent ancestral forms. But this cannot be true in the same sense among insects. We have seen that the frog is probably descended from a tadpole, and the prawn from a nauplius; but the butterfly is not descended from a caterpillar, or the fly from a maggot. In the case of Müller's prawn, the perfect form is descended from a Mysis-like animal, the Mysis form from a Zoea, and the Zoea from a Nauplius. But the winged insect cannot be descended from a chrysalis, because the motionless chrysalis can never have been the mature reproductive state of any species whatever; and it appears impossible that the suctorial butterfly can be descended from the mandibulate caterpillar, because the intermediate stages of mouth structure would be inefficient. It thus appears certain that the "complete metamorphosis" of those insects which pass through the chrysalis state and undergo redevelopment of the mouth parts, unlike the metamorphoses of the Crustacea and the Batrachia, is not original or primitive, but has been acquired.

The resemblance of a caterpillar to a centipede, though obvious enough, is no proof of kindred. The nature of the connection between Insects and Myriopods is a debateable question; but, whatever it may be, insects are certainly not descended from Myriopods. But the resemblance of the grubs, which are the larval forms of Hymenoptera and Diptera, to worms, is of a different nature, and appears to be due to reversion to a worm-like ancestor, from which not insects only, but all the Arthropod classes, are descended. This reversion appears to be due to abundance of food and inactivity of life. Sir John Lubbock says :*—"The larvæ of Lepidoptera live on plants; activity to them would be useless, and they do not possess it. The larvæ of most Hymenoptera (for instance, of the bee, wasp, Cynips, &c.), of Diptera, and of some Coleoptera (beetles), live in circumstances which call for even less locomotion, and have relapsed almost into the condition of their far-distant vermiform ancestor."

This may in some degree explain the metamorphoses of the Sitaris, which are the most anomalous in the whole of the wonderful class of which we are treating. The larval form of a certain beetle, the Sitaris, as described by M. Fabre, is a minute, active insect, furnished with six legs, two long antennæ, and four eyes. These larvæ are hatched in the nest of a bee; and when the male bees emerge in the spring from the burrows, which they do before the females, the larvæ spring on them, and afterwards take an early opportunity of crawling on to the female bees. When the latter lay their eggs, one in each cell, on the surface of the contained honey,† the larva leaps on the egg and devours it. It then undergoes a complete change; its eyes disappear, its legs and antenuæ become rudimentary, and it feeds on honey; so that it now more closely resembles the ordinary larvæ of insects. Ultimately it undergoes further transformations, and finally emerges as a perfect beetle."‡

In conclusion, permit me to make a few remarks on the relation of the Insects to the other Arthropod classes.

All who believe in evolution are probably agreed that the origin of the entire Arthropod division is to be sought among the lower Crustacea, in some form resembling the Nauplius. But beyond this there appears to be no agreement. The best suggestion yet made is, perhaps, that at the conclusion of Müller's "Facts for Darwin":—"For the Insecta alone, the development of the Malacostraca (or higher Crustacea) may, perhaps, present a point of union. Like many Zoeas, the Insecta possess three pairs of limbs serving for the reception of nourishment,§ and three pairs serving for locomotion. Like the

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* *Collembola and Thysauura*, p. 53.

† It will be perceived that this a different species from the hive-bee.

‡ Darwin's *Origin of Species*, fourth edition, page 530.

§ These three pairs of modified limbs are "a pair of mandibles and two pairs of maxillæ, the hinder pair of which are coalescent, and form the labium."—*Huxley*.

Zoeas, they have an abdomen without appendages: as in all Zoeas, the mandibles are destitute of palpi. Certainly but little in common, compared with the much which separates these two animal forms. Nevertheless, the supposition that the Insecta had for their common ancestor a Zoea which raised itself to a life on land, may be recommended for further examination." To this I would add that a connexion is shown to exist between the Malacostraca and the Insecta, and also between these two and the Arachinda (spiders, scorpions, mites, &c.), by the remarkable fact that in these three groups, when the segmentation can be made out, the segments of which the animal is composed generally number twenty-one, counting the tail end as a segment. The only assignable reason for this is a common ancestry.

But what is the relation of the Myriopoda to the other Arthropod classes? Among the Myriopoda, as among the lower Crustacea or Entomostraca, the number of segments varies greatly. Does not this separate them from those groups in which the number of segments is uniform? We must not answer this question too hastily. The presence of such a common character proves true affinity between groups; but its absence does not necessarily prove the absence of affinity, for it may have been lost by reversion. Nevertheless, when we see such a character as that of having neither more nor less than 21 segments, tolerably constant throughout the three vast groups of the Malacostraca, the Arachnida, and the Insecta, and totally absent in the Myriopoda, it seems difficult to doubt that it points to a true affinity between those groups possessing it, which they do not share with the group that does not possess it. On the other hand, the Myriopoda resemble the Insects in having one pair of antennæ (the Crustacea having two pairs, and the Arachnida none), in the absence of palpi on the mandibles, which the Crustacea and the Arachnida possess, and in the respiration, which is tracheal. Huxley,* than whom there are few if any higher authorities, thinks there is a specially near kindred between the Myriopoda and the Insecta. But against this, besides the argument from the number of the segments, it is to be mentioned that the Myriopoda resemble the Crustacea, and differ from insects and Arachnids, in growing by the intercalation of new segments between

* See the review of Häckel's work in Huxley's *Essays and Critiques.*

those first formed, while Insects and Arachnids do not increase the number of their segments during growth. The resemblance between the tracheal systems of the Myriopoda and the Insecta is no doubt very remarkable; but when we consider the variability of respiratory organs generally, it is perhaps not impossible that these systems may have been separately evolved in the two classes. It appears to be certain that instances do exist of the separate evolution of very similar organs.*

In conclusion, I have only to express a hope that I have done something to make intelligible some of the most wonderful phenomena of the animal kingdom.

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* See page 18 of this volume.

25th March, 1874.

JOSEPH JOHN MURPHY, Esq., F.G.S., President of the Society, in the Chair.

A Paper was read by Professor THOMAS ANDREWS, LL.D., F.R.S., Hon. F.R.S.E., &c.,

ON THE COMPOSITION OF AN INFLAMMABLE GAS ISSUING FROM BELOW THE SILT-BED IN BELFAST.

IN sinking for a well upon the premises of Messrs. Cantrell and Cochrane, in George's Lane, Police Square, Belfast, after having passed through a deposit of silt to the depth of 33 feet, a layer of gravel was reached, seven feet in thickness, and containing a quantity of organic debris. It rested upon a thick deposit of very tenacious clay. On entering the gravel-bed, a large flow of water occurred, which rose to within four feet of the surface of the ground, and interrupted the operation of boring, till a pump, worked by a small steam-engine, was erected, which, so long as it was in action, kept the boring free from water as far as the surface of the gravel-bed. A workman, having lowered a light to examine the bottom of the well, was surprised to see a lambent flame playing over the surface. On examination, this was found to arise from a disengagement of inflammable gas, which had accumulated between the lower surface of the bed of silt and the layer of gravel.

An iron pipe, terminating in a funnel-shaped mouth, about one foot in diameter, was now sunk till it reached the gas stratum, and the water in the well was kept by pumping at such a level that an extra pressure of about one inch of water was maintained upon the gas below. The gas now flowed freely, at the rate of about 40 cubic inches per minute, through the upper end of the iron pipe, and when ignited, burned with a yellow flame, which could scarcely be distinguished from that of ordinary coal gas.

Two portions of the gas were carefully collected by displacement, the stream of gas being allowed to pass till the whole of the atmospheric air in the vessels was completely swept away. The connecting tubes were then carefully sealed, and the gas was afterwards analysed in the laboratory of Queen's College.

A measured volume of the gas, standing over mercury, was exposed to the action first of caustic potash, and afterwards of pyrogallic acid, and the residual gas was afterwards analysed with the following results :—

	V.	*T.*	*B.*	*C.*
Atmospheric Air.	78.7	12.2	770.6	308.8
Residual Gas added..............	120.5	12.4	771.5	272.2
Oxygen added........................	190.0	12.1	771.8	221.8
After Explosion	126.5	13.0	771.7	271.6
Carbonic Acid absorbed........	90.0	11.1	772.0	299.7

In this table *V* is the volume of the gas ; *T* its temperature in centigrade degrees ; *B* the height of the barometer in millimetres ; and *C* the height of the mercury in the tube in which the observations were made. From these data and the results of the previous action of the caustic potash and pyrogallic acid, it follows that the composition of the gas was :—

Marsh gas ($C H_4$) 83.75
Carbonic acid. 2.44
Oxygen 1.06
Nitrogen 12.75

The density of the gas (air = 1) was found to be 0.661, which corresponds nearly to the foregoing composition. The gas was inodorous and contained no compound of carbon and hydrogen except marsh gas.

From this analysis, it is evident that the gas formed in this subterranean sheet of water is in all respects the same as that which is produced in stagnant pools containing leaves and other vegetable matters.

22nd April, 1874.

Professor Everett in the Chair.

A Paper was read by R. LLOYD PATTERSON, Esq.,

entitled :

Notes on some of the Swimming Birds frequenting Belfast Lough.

A few years ago I was in the habit of going out on our bay frequently for the purpose of fishing, or for the combined amusements of sailing and fishing; and in the course of these excursions my attention became gradually directed to the birds that came under notice. The more attention that was bestowed on the subject the more interesting did it become, and after a time I began to take notes of some of the birds we saw and occasionally shot. I now propose to read you some of these notes, interspersed with extracts from the writings of some authorities on the general subject; and if by this paper I could get some of the younger members or visitors to take an interest in such observations, I can assure them that they would find therein a wide and almost inexhaustible field for most interesting observation.

The subject of my paper, or, at all events, the subject of which my paper forms but a very small part, has often been treated of here. If my memory does not deceive me, I have heard our worthy Secretary (Mr. A. O'D. Taylor) lecture on a similar, or allied, subject. But I have not heard the subject brought before us here at all lately, and I am emboldened to bring it forward to-night, partly in the hope that it may assist in redirecting attention to a very attractive, but, amongst us of late, somewhat neglected, study.

Naturalists have agreed in dividing *all* birds into five great families, namely:—

The Raptores, or birds of prey.
,, Insessores (very numerous), or perching birds.
,, Rasores, or scraping birds.
,, Grallatores, or wading birds.
,, Natatores, or swimming birds.

These being subdivided into genera; and these, of course, further subdivided into the individual species.

Anything that I have to say to-night will be confined to only a very few species of the last-named family, the natatores, or swimming birds; but it is interesting to notice by what gradual steps the waders merge into the swimmers. How in the water-rail and the moor-hen the toes are lengthened, so as to enable these birds to walk over floating aquatic plants and to swim; the moor-hen, or water-hen, as it is often called, being a pretty good swimmer, without being web-footed at all. Following these come the lobipedidæ, or lobe-footed birds, such as the coot and the phalaropes, in which the long toes are further provided with membranes almost amounting to a partial web, to assist them in swimming, till we finally arrive at the true swimmers, which are, as everyone knows, completely web-footed.

The swimming birds themselves are divided into five families, some of these being further sub-divided; but, not to trouble you with these minor distinctions, suffice it for our present purpose to name the principal ones, which are—

1st. The "Anatidæ," geese, ducks, swans, widgeon, &c., &c., containing about forty-five British species.

2nd. The "Colymbidæ," or divers, including the grebes, and containing eight species.

3rd. The "Alcadæ," or auks, embracing the puffins and guillemots, containing also eight species.

4th. The "Pelecanidæ," the smallest family of all, having only three species, the gannet and the cormorants.

5th. The "Laridæ," or gulls, including the terns, skuas, and petrels; about thirty-three species.

I have no intention of noticing by any means all the birds that may come before one even in a day's excursion on the lough, only a few of them, and that not in any particular order.

Going out on the lough, let us say in the month of August, we have not gone far till we begin to fall in with the divers, guillemots, many of them with their young, like little balls of white and darkish down, with them, and razor bills. Farther out, the razor bills and guillemots are met with in much larger numbers, and they are wonderfully tame, often not diving till the boat is close on them. When the old bird does dive, the young one is left on the surface alone, in which case it utters a frequent shrill, plaintive cry, which is answered by a hoarser cry from the mother whenever she reappears on the surface. Mother and young then hasten towards one another, the old bird frequently giving the young one a herring fry, or other small fish, into its bill. It is wonderful sometimes to see the number of these young birds, and to fancy where they have all come from, and how such small, feeble, and apparently helpless things have been able to make their way so far. Once out of their nests on the rocky ledges of some sea cliffs, they never return to them, but spend night and day on the water.

Some years ago these birds, as well as the razor-bills, bred in the Gobbin cliffs; but I doubt if they do now, and certainly not in anything approaching the numbers in which I have frequently seen them in this lough, where both species, swimming together in large companies, might sometimes be counted by hundreds, or even thousands, in a day.

The principal breeding haunt for these birds in large numbers hereabouts is Ailsa Craig, to which further reference will be made. Multitudes of the birds of Belfast Bay come from there in Autumn, after the breeding season, migrating South as the winter advances.

They breed also in most suitable localities round the coast, but some individuals do not appear to leave this lough at all, for I think I have seen both it and the razor bill here every month in the year. Thompson speaks of finding them in "vast multitudes" in the limestone cliffs of the Island of Arranmore, off the entrance to Galway Bay, and names numerous other breeding haunts round the coast.

Mr. Waterton, in his account of his visit to the rock-bird breeding localities about Flamborough Head, says the men there assured him that when the young guillemot gets to a certain size it manages to climb upon the back of the old bird, which conveys it down to the ocean; and, from his own observations there, he had no doubt of the correctness of this statement.

These birds, if on land, can make almost no effort to escape; they seemingly cannot rise on wing from the land, and their legs are placed so far back that they can hardly walk, but push themselves on their breast along the ground, using both legs and wings for this purpose. Some idea of the vast numbers of these birds that frequent favorite localities may be formed from a circumstance mentioned by Audubon as coming under his own observation. He says that a boat returned from the Murre Rocks, near Great Macatina Harbour, to the ship in which he was, laden with 25,000 of their eggs.

The *black* guillemot is not nearly so common as the other species alluded to. It is a much more wary bird than the common species, and on the approach of a boat it almost invariably seeks safety in *flight*—not in diving, like others of its family. I shot one of these birds on the 1st of May, a few years ago, in a very pretty and interesting plumage, intermediate between the young and the adult bird. It was a bird of the previous year. The adult black guillemot, with its jet black plumage all over, except the large perfectly white spot on each wing, black eyes, black bill, and vermillion colored legs, is a very funny-looking little fellow. I have never seen its young.

Last summer, when out yachting, I observed on several occasions a solitary black guillemot in full plumage about the same place in the centre of the bay, equidistant from Greypoint and Carrickfergus. From the first time I observed this bird to the last there was a period of about a month, during which I saw it several times.

I mention this circumstance now in connexion with this species, but intend referring hereafter to the fact of single diving birds apparently frequenting the same place for a length of time together.

The razor bill so closely resembles the common guillemot in size, color, habits, and haunts, as to require but little separate notice.

Speaking of it, Thompson says that it "was found in countless numbers on the northern shores of the Island of Rathlin." He mentions its appearance far up the Bay of Belfast. On this subject I have a note that, on 25th March, 1871, I shot two of them near Holywood lighthouse. On the same day I saw what is a very unusual thing so far up the bay—two porpoises, and several gannets fishing. In October I have seen the razor bill within a mile to a mile and-a-half of the quays of the town ; and, on one occasion in February, I saw one in the channel between the point of Thompson's Bank and the Twin Islands. One of the best specimens I have was shot in Ballyholme Bay early in May last, an adult bird in full summer plumage.

This bird is so common as to be well known to every one that ever ventures upon the water, and really requires almost no notice at my hands now. It and the guillemots are generally classed together by the fishermen here, and spoken of collectively, but only when on the wing, as "cutties," a word of the origin of which, in this connexion, I have no idea, except it be the peculiar short, "bunty" appearance they present when flying—the word "cutty" being used in Scotland to signify something short. A "cutty pipe" is a term commonly applied to a short pipe. Both species are commonly called "puffins"—of course a misnomer, for the true puffin is quite a distinct species, known locally to the fishermen and boatmen of this lough as "Ailsa cock." I see Thompson mentions this name for it also.

The puffin, having been mentioned, may now come under review. It is by no means so common as either the guillemots or razor bills, and, indeed, in several years I have not noticed it at all. Although boating every year more or less, I have no note of seeing the true puffin from August, 1866, to the same month in 1871, and have the following note with regard to its appearance then :—

"*9th August, 1871.*—Out in the 'Amba' from Bangor, fishing mackerel (of which we caught 225, besides sixteen nowds, or grey gurnards). I shot two puffins, and saw a great number of them—far more than I had ever seen in one day before. It is very remarkable that for the last few years, although I had been boating so much at all seasons of the year, I had not seen a single example of the puffin, while I saw during this period thousands of guillemots and razor bills. To-day the puffin was nearly as numerous as either of the other species ; but these, again, were not so numerous as is usual at this season. We did not see less than sixty or eighty puffins to-day."

This is a singular and singularly impudent looking bird. Its well-defined dark (almost black) and white plumage, rounded head, whitish cheeks, and huge bill, render its identity unmistakable.

My brother Richard told me that, crossing with some friends going to their shooting in Argyleshire, from Belfast to Campbeltown, on 10th August, 1873, he saw outside and near the Mull of Cantyre, and by Sanda Island, multitudes, estimated at many thousands, of these birds.

I see Thompson and other authors state that the young birds leave the nest regularly on or close to the 12th of August.

In a very interesting account of a visit to Horn Head, in Donegal, the breeding haunt of vast multitudes of almost all species of the natatores, Mr. Thompson devotes considerable space to the puffin. It deposits its single large egg in a rabbit burrow, if there are any available for the purpose; failing which, the birds excavate a burrow for themselves, in which they hatch their young, the period of incubation lasting one month.

Yarrel and Selby both speak of their burrowing. The former author says:—"Rabbit warrens are not unfrequent on the coast, and where this is the case the puffins often contend with the rabbits for the possession of some of the burrows."

Mr. Selby remarks:—"Many puffins resort to the Fern Islands, selecting such as are covered with a stratum of vegetable mould, and here they dig their own burrows, from there not being any rabbits to dispossess upon the particular islets they frequent. They commence this operation about the first week in May, and the hole is generally excavated to the depth of three feet, often in a curving direction, and occasionally with two entrances. When engaged in digging, which is principally performed by the males, they are sometimes so intent upon their work as to admit of being taken in the hand, and the same may be done during incubation." Mr. Selby goes on to say that he has taken them at this time by thrusting his arm down the burrow and seizing them on the nest, though at the risk of a severe bite from the powerful and sharp bill of the old bird.

A gentleman from Moravia, an Austrian province in the very centre of Europe, who was with us in the "Amba" on the occasion lately referred to, would fully endorse this statement of Mr. Selby's as to the biting powers of the puffin. One of the specimens procured that day was only wounded; and, being caught by the punt, we handed it up into the yacht to the Austrian, whose loud cries, when it fastened on him like a vice, produced, I am bound to admit, more laughter than sympathy, and whose marked fingers will certainly be to him a lasting remembrance of the only day's mackerel fishing he ever had in his life.

Mr. Folkard, in the "Wild Fowler," is my authority for the following :—

"A singular method of fowling is used in Hirta, which is chiefly performed by females, with the assistance of dogs specially trained to the pursuit. The only birds they capture in the manner about to be described are puffins, which burrow under ground with their beaks, and there deposit and hatch their eggs.

"The maids of Hirta make early morning excursions on the beach, attended by a dog, which hunts the holes at the foot of the rocks and about the shore. Some of these dogs are so well trained that they never pass a hole containing a puffin's nest but they smell it out, and capture the old bird without killing it or breaking the eggs. In the cold weather, when the birds sit closely huddled together in large numbers in the deep holes and clefts of the rocks, on one of the little dogs being sent in, it seizes the first bird by its wing, and proceeds to drag it out. The bird, to save itself from persecution, lays hold with its powerful beak of the wing of another, which, to save itself, seizes the next ; this, in like manner, clings to its nearest neighbour, and so on, the dog continuing to drag them out steadily. In this way a whole string of puffins falls into the hands of the fowler, as every bird, from first to last, grasps the one nearest to it, and so all are dragged out one after another, as if linked together. Thus the wife or daughter of a family in the short time of an hour or less secures sufficient provision to supply for one day or more all the inmates of the household. The family subsist on the eggs of the birds during the egging season, and their flesh at others ; the dog faring sumptuously on the bones. Every family throughout the island has one at least of these little fowling dogs. The breed of the animal is simply a mixture of the terrier and water-spaniel, and is sometimes so regularly trained to its duties that it is sent unattended in search of puffins, when it goes about its business with the same sagacity as if its young mistress accompanied it. On a dog being sent on an errand of this kind, it generally returns in a few minutes with a live puffin in its mouth ; then, if required, it is sent on a second and third excursion, and so on until sufficient are caught for the day's subsistence. The feathers and down of these birds are of great use and value both for domestic comforts and as an article of commerce."

Other localities are mentioned where this method of fowling is also practised.

In the "Cruise of the Kate," by Middleton, he speaks of the puffin breeding in vast numbers on Skomer Island, off the coast of Pembrokeshire, and of the guillemots, kittiwakes, and oyster-catchers, frequenting the headland called the "Wick" in that island in "countless thousands."

The puffins, he says, are at continual war with the rabbits, and are, particularly since the passing of the "Sea-birds Preservation Act," having decidedly the best of it, they increasing and the rabbits diminishing in numbers.

In his "Cruise of the Betsy," Hugh Miller speaks of this bird in a very different locality—namely, the Island of Eigg, one of the "small isles" of the "inner Hebrides" lying between Mull and Skye. "The puffin," he says, "a comparatively rare bird in the inner Hebrides, builds in great numbers in the continuous line of precipice which sweeps round the Bay of Luig."

He found a curious tradition about this bird, which he calls an "apocryphal piece of the natural history of the puffin," current among the inhabitants of this island. "The puffin," he continues, "feeds its young, say the islanders, on an oily scum of the sea, which renders it such an unwieldy mass of fat that about the time when it should be beginning to fly it becomes unable to get out of its hole. The parent bird, not in the least puzzled, however, treats the case medicinally, and, like mothers of another two-legged genus, who, when their daughters get over-stout, put them through a course of reducing acids to bring them down, feeds it on sorrel leaves for several days together, till, like a boxer under training, it gets thinned to the proper weight, and becomes not only able to get out of its cell, but also to employ its wings." This supposed feeding on sorrel leaves is referred to by Thompson, p. 223, and others also. Last June I was fortunate enough to visit these waters, and although we coasted close along the shore of Eigg, I only saw two or three birds of this species altogether, and but few of the commoner species first mentioned.

The other recorded and well-known breeding haunts of this peculiar little bird are pretty numerous, and do not require detailed mention, being found at Tory Island, the Skelligs, and numerous other places in Ireland, and also in many suitable localities in England and Scotland.

I shall next notice the cormorants. Sitting stock-still on some of the parts of the wreck of the "City of Lucknow;" off Rockport, on the floating breakwater in Helen's Bay; on the perch to mark the dangerous reef of rocks known as the North Briggs, sometimes called the "Pot Feet," near Whitehead; or on any other rocks, buoys, or perches in the lough, large dark-coloured birds may often be observed. In summer, when they, in common with almost all of the natatores, depart to their breeding haunts, they are but seldom observed; some individuals, however, remain the whole summer. I refer to the cormorants, both the common and the green (or crested) species—a bird much smaller than the one first named. These birds become more numerous in autumn; and, as winter approaches and advances, they appear to come farther and farther up the lough; till, in mid-winter, I mean December, January, and February, I have seen them, and on one occasion, shot one within less than a mile of the quays of the town. A few years ago they were but seldom seen in any numbers near Holywood; but some posts having been put up of late years to mark the channel leading up to the new pier, the cormorants find these apparently most convenient resting places; for, on stormy mornings, I have sometimes counted not less than six or eight individuals here. I have many notes of this species, the great cormorant; the smaller or crested species not coming so far up the lough, and, consequently, not coming so prominently or frequently under notice.

The common cormorant is found in great variety of plumage, according to age, sex, and season. Among several individuals that I have shot at different seasons of the year in this lough, I have retained three in my own collection: one, a male bird, shot on 12th October, off Rockport, is of a jetty shining black all over, not a white or lightish colored feather in it; another, shot on 3rd March, off Macedon Point, is a female, and in very beautiful and perfect plumage. The entire body, breast, and back shining metallic black, with a greenish shimmer through it; the triangular white mark on the thigh, or "the watch that it carries under the wing," as it is sometimes called by the fowlers, quite perfect and well defined; the upper part of the head and neck ornamented with longish hair like white feathers. The back of the head and the neck are ornamented with a fine crest of black feathers, and its *toute ensemble* is that of a fine, bold, handsome bird. My third specimen was shot about half-a-mile off Cultra quay, on 19th February. This was the largest cormorant I ever saw, and weighed 8 lbs. It was a bird of immense strength and power, and struggled hard to escape; exerting its powers of diving, which in all the family are really wonderful, to a most extraordinary extent. However, finally, after a long chase, a long shot from my double No. 8 breech-loader, charged with a 2 oz. wire cartridge of heavy shot, laid him low, and the prize was secured. The breast and lower part of the body of this bird are light colored, varying from an olive green on the neck to a lighter color on the breast, and nearly pure white below. Its wings, sides, neck, and back all jet black, with the least appearance of the white thigh mark just beginning to show in a little "tick" here and there through the black feathers. Examples that I procured on two occasions in the month of December (1870 and '72) were similar in plumage to the one last described, except for the white mark beginning to show, this clearly indicating the advance of the season.

M'Skimmin, in his "History of Carrickfergus," remarks of cormorants:—"Those here set off almost every morning for Lough Neagh, and return again the same evening. On one being shot, just as it arrived from Lough Neagh, in its crop was found fourteen pollans," "sufficient evidence certainly," adds Thompson, "that this individual had been fishing there, for nowhere else, nearer than Lough Erne, could this species of fish have been obtained." Mr. Thompson continues—"A scientific friend visiting Massareene Deerpark, on the borders of Lough Neagh, on the 3rd December, 1847, was attracted by the singular appearance of about a hundred cormorants perched on trees (probably thirty feet in height), on a low wooded island of the lake, where they remained for two hours, or so long as he had an opportunity of observing them. The country people there believe that these birds daily visit the sea, and that they would die if they did not get a drink of salt water within the twenty-four hours."

Mr. Thompson also mentions having seen them in the west and south of Ireland, and at the lakes of Killarney. Of their appearance at Killarney I have noted that in August, 1871, I saw eleven individuals sitting on the small points of rock that rise out of the water in front of Innisfallen Island, looking towards the Victoria Hotel. This group, to judge from the difference of size they exhibited, seemed to have examples of both species among its numbers; but I could not speak with certainty on this point, neither was I near enough to have been able to remark anything about their plumage.

I again quote Mr. Thompson, who says (of the common cormorant) :—

"The most favourable opportunity I have had of observing it is alluded to in a general description of the birds of Horn Head, under "Puffin," p. 225 :— 'The gamekeeper there stated that he had seen salmon of from two to five pounds weight in their nests ; but this must be over estimated. They are considered so destructive to this valuable fish that a reward of fourpence is paid to him for the head of every cormorant of this species he can procure.'

In a note in M'Skimmin's "Carrickfergus" it is added :—"Rewards were formerly paid at assize for destroying these birds. In the records of the County Antrim, in 1729, mention is made of a person called Jemfrey, in Island Magee, who had killed ninety-six cormorants in one season."

When the plumage of a cormorant has become quite saturated with water, from long continued diving, the bird is frequently seen to stand on a post or other projection with its wings outspread to dry, often fanning the wings rapidly as if to assist the drying process Its attitude and appearance on these occasions are really most ludicrous. Sir Wm. Jardine, Thompson, and other authors mention this peculiarity ; Mr. Thompson mentioning, on one occasion, at Strangford Lough, seeing fifteen of them, after a very heavy shower of rain, standing together in a line, apparently on the water, though in reality on a sunken rock which did not rise to the surface, with their wings outstretched to dry, inferring that a wetting by rain induces the expansion of the wings as well as a wetting by sea water.

Cormorants are gifted with a rather high order of intelligence, and are easily reconciled to captivity. Instances are on record of their becoming domesticated ; not only that, but quite attached to their masters, following them about wherever they went. Montagu speaks of one that became so tame and attached as never to seem happy except when permitted to remain by the side of its owner.

They were formerly trained to catch fish and bring them to hand, a "cast" of cormorants being spoken of in the same sense as a "cast" of hawks. Pennant is my authority for stating that fishing with trained cormorants was a regularly recognised sport in England in the time of Charles the First, mention being made of a Mr. Wood, who was "Master of the Corvorants" to that monarch. In China this practice is followed to a very large extent even at the present day, and that not for sport but for profit.

Sir George Staunton, in his account of his embassy to China, describes the place where the "Luetze," a species of cormorant, is bred, and trained to fish. He speaks of a large lake, on which there are *thousands* of small boats and rafts, built for, and occupied entirely in, this fishery, each boat having a crew of two men, and being supplied with ten or a dozen cormorants. These birds are so well trained as not to require any ring or strap round the throat to prevent them swallowing the fish they capture, which they bring at once to their owners, nor are they secured or fastened in any way to prevent their escape.

Attempts have been made at various times to reintroduce cormorant fishing into this country. Twenty or thirty years ago some tame birds were brought over from Holland, where they had been trained by a person who had seen the use made of them in the China seas. A ring was placed round their necks, which prevented their swallowing any but very small fish; and it is said that the rapidity and activity of their movements under water in pursuit of fish could be compared to nothing so appropriate as a swallow darting after a fly.

I don't think it is more than three or four years since I read in the *Field* newspaper a most interesting series of papers describing the revival then, near London, of the ancient British sports of hawking, or falconry, and fishing with cormorants; but I have not heard of its continuance. Mr. Thompson mentions the weight of one large specimen that came under his notice as 7 lbs. 6 oz., so that my 8 lbs. bird, already mentioned, *is* an unusually large one.

Mr. Glennon, of Dublin, publishes the following note in the "Dublin Penny Journal":—

"Several years ago I took a pair of these birds from a nest among the rocks of Howth, and kept them for nearly two years, by which time they had attained their full growth. They were pleasant pets enough, unless when pressed by hunger, but then they became most outrageous, and screamed most violently; when satisfied with food they slept, roosting on a large stone trough placed for holding water. But woe to the man or beast that attempted to approach them when hungry. It happened once that a gentleman's servant went to look at them while in this state. He wore a pair of red plush breeches, that immediately caught the attention of the birds, which I had been in the habit of feeding with livers and lights. The consequence was, they made such a furious charge that I had to run to his assistance with a stick, and, even so, did not beat them off without difficulty. Their attack on dogs, cats, and poultry, if unprotected, was always fatal. They fought at once with their bills, wings, and claws, screaming frightfully all the time. In fact the cause of my parting with them was their having destroyed a fine Spanish pointer. He had incautiously strayed into the place where I kept them, and they immediately flew and attacked him in front and rear. His loud howlings brought me to his aid. I was astonished to find they had got him down, and, before I could rescue him from their fury, they had greatly injured him in one of his shoulders, so much so, that he afterwards died of the wound."

The virtues of the common and green cormorants as food are not much enhanced by the note from the late Mr. G. Mathews: "that they were both eaten by the Norwegian sailors *when they had nothing else*." In this connexion I may say that I have often wondered at reading of old customs in England of such birds as cormorants and herons being always produced at great feasts as delicacies. Herons must have been bad and rank enough, but cormorants surely far worse. Even for years after they are stuffed they retain a strong smell, like a mixture of musk and ammonia; so I can fancy the correctness of Kingsley's description of "squab pies," at a great Cornish feast in the eleventh century. "Fat," he says, "was the feasting and loud was the harping in the halls of Alef, King of Gweek. Savoury was the smell of fried pilchard and hake; more savoury still that of roast porpoise; most savoury of all that of fifty huge squab pies, built up of layers of apples, bacon, onions, and mutton, and at the bottom of each a squab or young cormorant, which diffused both through the pie and through the ambient air a delicate odour of mingled guano and polecat."

The notices of the attacks of cormorants on animals, birds, and even on man, mentioned by Thompson and other authors, would not lead one to expect much display of affection from them; yet Yarrell says:—"Sir Robert Shafto Adair told me that a pair of cormorants took to and brought up a nest of young ravens, the natural parents of which had both been destroyed. The gamekeeper was desired to watch the proceedings, and reported that the cormorants brought a constant supply of fish."

Thompson has mentioned a flock of above one hundred having been seen on one occasion in this bay. He mentions other occasions when flocks of from fifteen to seventeen were seen, and I think they must have been more numerous here then than now, as the largest number that I have noted as having been seen here on any one occasion was seventeen, and this was during a snowstorm, on 25th February, 1873.

I have dwelt thus at length on the common cormorant, as it is a bird that may very frequently be seen round our coasts, and a little attention to its habits will well repay the observer with interest for his trouble. They are bold, powerful birds. Their strength, powers of endurance, cunning when wounded, and tenacity of life, are extraordinary, and their diving powers, although perhaps equalled by some, are only surpassed, in my experience, by one species of the true divers, the "great Northern," to be noticed hereafter.

The "green" or crested cormorant is a rarer bird than the other. It is of smaller size, and more solitary in its habits, although I have exceptionally seen (on 10th May, 1873) nine of them sitting together on the floating breakwater in "Helen's Bay." When fired at, these birds fall like plummets instantaneously into the water; and I have seen half-a-dozen of them fall, plunge and disappear simultaneously, and afterwards emerge at intervals of time and space all round you in a most puzzling way, keeping their bodies submerged, and showing nothing but their neck and small fine head above water. In diving they are quite as expert as their larger congeners, but not so powerful, and do not remain so long under water; but, when they do rise to the surface, they present a much smaller mark than the other species.

I shall now, with your permission, notice the gannet, or, as it is called by some, the solan goose; and a most interesting bird it is. To most of us the gannet is at least known, and to many it is familiar.

According to Thompson, and any other authorities also to which I have had access, the gannet has only one breeding haunt in Ireland —one of the Skellig islands, off the coast of Kerry. Their number here was estimated at 500 pair. Mr. J. F. Townsend wrote to Mr. Thompson that these birds also frequented the "Stags of Broadhaven," huge insulated rocks, "towering over the ocean at a considerable distance from the shore" (the coast of Mayo). Visiting these rocks one year in the month of July, he mentions having seen "hundreds of young gannets and vast numbers of old ones;" and he adds, "There cannot be the least doubt that the gannet breeds at Broadhaven," but this statement lacks confirmation. According to both Yarrell and Thompson, Lundy Island, in the Bristol Channel, is their only breeding station in England, both authors mentioning four such stations in Scotland.

Ailsa Craig, in the Clyde; the Bass Rock, in the Frith of Forth; and St. Kilda, out in the Atlantic Ocean, are well-known haunts of the gannet, and that, too, in very large numbers. The two first-named localities are comparatively easy of access, and have been frequently visited by naturalists; the latter is very difficult of access, and is but seldom visited. Some accounts of visits to this remarkable rock, the habits of its few inhabitants, and the important part that the gannet plays in their domestic economy, are very interesting. To the above-named localities Mr. Yarrell adds "Souliskerry;" and, on the authority of M'Culloch, the author of the "Western Isles," Mr. Thompson mentions "Soulisker"—two different names, and neither of them quite correct, for the same place. The place meant is pronounced "Suliskere," but spelt "Sula Sgeir"—"Sula" meaning gannet, and "Sgeir" rock—the "Gannet's Rock," a most appropriate name, as I shall presently show. This rock is situated in the Atlantic Ocean, about thirty-five miles north of the Butt of Lewis, as the northern extremity of that island is called. The fifth locality frequented by these birds, and that, too, in large numbers, is not mentioned by any authority whom I have consulted: I refer to the "Stack," a lofty isolated rock in the Atlantic Ocean, about thirty miles north of Cape Wrath in Sutherlandshire, the north-western point of Scotland. Sula Sgeir and the Stack are uninhabited, save by the gannets and other sea-fowl.

In the course of a very delightful trip to the Hebrides, which the kindness of my friend Mr. Wm. Valentine enabled me to take part in last summer, we visited, among other places, Stornoway in Lewis, where I met Mr. M'Donald, Commander of H.M. cruiser "Vigilant," a tidy, able-looking schooner, then in the bay. Her duty is to look after some of the Scotch fisheries; and, as in this capacity her captain has unrivalled facilities for getting accurate information on such points, I think I am justified in accepting his statements about the gannet, and also about the fisheries, as substantially correct.

To him, then, I am indebted for the following information. He first startled some of our company by the statement that there were spread nightly during the season, on the east coast of Scotland alone, a length of herring nets that would span the Atlantic twice ; and from what I have since seen, taken from official returns, I am satisfied Mr. M'Donald's estimate on this point, startling as it may seem, is certainly under, rather than over, the mark. One of our party replied that, if that apparently exaggerated statement were true, the poor herrings had but a bad chance of escape ; to which Mr. M'Donald replied, that *all* the herrings taken in *all* the Scotch fisheries were as nothing—were as a mere drop in the ocean, as he expressed it—compared with the countless myriads of them that surround our coasts ; and that the total catch of herrings, although when reduced to figures seemed immense, was really never missed out of the numerous enormous shoals from which they are taken. "Talk about the herrings *we* are able to catch," said he ; "why, there is one *bird* in Scotch waters that *alone* captures and consumes more herrings than are taken in the *whole* Scotch fisheries." "The gannet?" I said. "Yes," he replied, "the gannet ;" and then he gave me the following astounding figures, stating that he could vouch for their accuracy. He said there were five breeding stations of the gannet in Scotland, or at least in Scotch waters ; one in Ireland, and one in England. All of these have been already named.

Passing over the English and Irish stations as of but little account, he said estimates had been formed of the number of gannets inhabiting the Scotch stations ; and, having asked him to kindly mention numbers, I took down from his dictation the following :—

AILSA CRAIG	is said to be inhabited and frequented by about	12,000	gannets.
THE BASS ROCK		12,000	,,
ST. KILDA		50,000	,,
THE STACK		50,000	,,
SULA SGEIR		300,000	,,
Total, ...		424,000	,,

Each of these birds would consume about a dozen herrings in the day, if it could get them ; and, assuming that they must sometimes put up with short commons, he estimated the daily average consumption at six herrings for each gannet. The multiple of 6 on 424,000, multiplied again by 365 for the days of the year, produces 928,560,000 (nine hundred and twenty-eight million five hundred and sixty thousand) herrings ; and this divided by 800, for the number of herrings in a barrel, leaves an equivalent of 1,160,700 (one million one hundred and sixty thousand seven hundred) barrels. The total take of 1872 being only 750,000 barrels, the quantity captured by the birds was thus about one-half more than the total catch by man ! I have not seen the complete returns for 1873 yet, but it was estimated that that year would show better results than any of its predecessors, it being expected that the total cure would amount to 950,000 barrels ; but, even with this enormous take, the gannets still beat the fishermen by some couple of hundred thousand barrels, or 160,000,000 of herrings !

That the gannet is capable of eating a dozen of herrings in the day I have not a shadow of a doubt. Mr. M'Donald said that having frequently taken the young birds off their nests, and hand fed them, they regularly consumed this quantity, and would have taken more if they had been given to them.

Thompson mentions, on the authority of the Rev. Mr. Black, of Annalong, that "one which happened to be caught asleep on the water, which is often the case during the mackerel season, was brought on board the boat, and tied by the left leg to one of the thafts. To test its appetite some fish were thrown to it, when, without 'drawing breath,' it swallowed four full-grown mackerel, and would have disposed of more had not the fishermen thought it had had enough at least for one meal." A friend of my own (Mr. Henry Atkinson) speaking of the same locality, told me of having himself captured gannets in the same way, and when brought on board the boat they have bolted as many as six whole mackerel as fast as they could be thrown to them.

In an old book shown me lately I find mention of a gannet, gorged with food, unable to rise from the water, and so captured alive, vomiting up twenty-nine herrings !

Speaking of the gannet in pursuit of its prey, Mr. Thompson says :

"To witness the fishing of the gannet, is not only a beautiful but a grand spectacle, more so to my mind than even the swoop of the golden eagle or the peregrine falcon at its 'quarry', in which amazing power of flight and keenness of vision are manifested. These chase their prey in their own element, the ambient air, and if the pursued touch but the surface of the water, it proves an altar of safety against the assailant; but the gannet procures its food not only in another element, but, from a great elevation in the air, perceives it far beneath the surface of the sea, majestically poises itself, and, direct as a plummet, shoots into the deep with an impetus that forces a jet of water into the air, conspicuous from a great distance."

"The more intelligent fishermen of Belfast Bay always like to see the gannet when they are herring fishing, as they set their nets accordingly to the height above the water into which it plunges; the greater the elevation of the birds in the air, the lower in the water the nets are sunk."

I quite agree with this. Last summer at Castlerock, Co. Derry, I was much interested in watching the gannets fishing. Out at sea they struck from various but always considerable heights, but close in shore, and when the waves were breaking on the land, and the water not more than two or three feet deep, the gannets flew leisurely along, only a few feet above the surface, and as the breaking waves would disturb the sand-eels, exposing them to view, the gannets would strike down in a slanting direction, and would not more than disappear for a moment below the surface, when they would again emerge.

Speaking of the great depth to which the gannets can plunge in pursuit of prey, Mr. Thompson says that the extreme depth of water in which they can see their prey from a height, must be somewhat conjectural; but that numbers of these birds have been taken in nets at a depth of 180 feet, is fully proven. On this subject he contributed the following notes to Charlesworth's Magazine of Natural History.

"Having heard from two friends, who were grouse shooting in the neighbourhood of Ballantrae, that they had seen great numbers of gannets lying in a state of decay in holes on the beach, and that these birds had been taken at extraordinary depths in the fishermen's nets. I made particular enquiry on the subject from a worthy resident of my acquaintance (postmaster, &c., of the village), and received the following reply:—'Gannets are very commonly caught about Ballantrae (chiefly in the month of March), in the fisherman's nets, which are generally sunk from nine to twenty, but sometimes to the depth of thirty fathoms, just as the fish are lying. They are taken at all these depths, when the water is rough as well as smooth, and in both the cod and turbot nets (respectively five and seven inches wide in the mesh.) Of the greatest quantity taken at one time, John, son of old Alexander Coulter, can make oath that he took ninety-four gannets from one net at a single haul, a few years ago. The net was about sixty fathoms long, a cod net, wrought in a five inch scale. The birds brought up the net, with the sinkers and fish to the top, where such as were not drowned made a sad struggle to escape. There were four nets in this train ; but the above ninety-four were in one of the nets, and there were thirty-four additional birds in the other part of the train, being one hundred and twenty-eight gannets in all."

"Were these facts not simply attested," adds Thompson, "I would be incredulous about the depths which the gannet sounds ; but the information furnished in writing, the truth of which, it is stated, may be implicitly relied on, is precisely what was related to my friends, and the singularity of which prompted my inquiry. The vicinity of Ailsa Craig, the great breeding haunt of the gannet in this quarter, must be recollected in connection with what is here related."

Mr. M'Gillivray says that—

"The force with which the gannet plunges from on wing in pursuit of a fish is astonishingly great. The following story, illustrating this point, was related to me by more than one person, and I believe it to be true. Several years ago an open boat was returning from St. Kilda to Harris, and a few herrings happened to be lying in the bottom, close to the edge of the ballast. A gannet passing overhead, stopping for a moment, suddenly darted down upon the fish, and passed through the bottom of the boat, as far as the middle of the body, which, being retained in that position by one of the crew, effectually stopped the leak until they had reached their destination."

Another fatal mistake is sometimes made by the gannet attempting to swallow a fish too large or unsuited to its capacity. I saw a very fine specimen of a gannet brought into Holywood which had been found by some fishermen quite dead, with a grey gurnard sticking in its throat. The fish was head foremost in the bird's throat, and, its spines lying the wrong way, it could not be ejected.

An Irish Naturalist, O'Flaherty, writing in the year 1684, says—

"Here the gannet soares high to espy his prey in the sea under him, at which he casts himself headlong into the sea, and swallows up whole herrings in a morsel. This bird flys through ship's sailes piercing them with his beak."

St. Kilda being an inhabited island, while the other principal resorts of the gannet are uninhabited, save, at all events, by a caretaker or two, is best known in connexion with this bird. Several authors and naturalists have visited it, although it is difficult of access, and have given most interesting descriptions of it. The estimates of some of these visitors of the number of herrings annually consumed by the gannets of St. Kilda *alone* vary from 95 to 105 millions, and these estimates corroborate the figures furnished by Mr. M'Donald; for, counting it out on his basis, we arrive at 109½ millions.

In Mr. Folkard's delightful book, the "Wild Fowler," I find (p. 357), a chapter on "Rock-fowling in St. Kilda," from which I extract the following:—

"The Island of St. Kilda has always been a favorite place of resort for sea-fowl, the numbers frequenting the cliffs and rocks of that locality at certain seasons being truly astonishing. During summer the natives subsist chiefly on the birds captured by the rock-fowlers, and on the eggs of the various species which build in the rocks. It has been affirmed that, during the fowling and egging seasons, out of the abundance of fowl and eggs which are taken on the island, there is a sufficient surplus, after amply supplying all the natives, to support *two thousand* persons besides! * * * * * * * * When the fowling season commences in St. Kilda the native fowlers have a merry-making, and feast together, as of one fraternity, over the first productions of their adventures. At this meeting they arrange themselves into distinct parties (generally each of four persons), for the purpose of fowling. Each party has at least one fowling-rope, which should be about thirty fathoms in length.

"A fowling-rope is an indispensable requisite for the operation, and was formerly considered the most valuable implement a man of substance could be possessed of in the island. It was looked upon almost in the character of an heir-loom, and descended through the family from generation to generation. It formed the first subject of bequest in the will of a St. Kildian, and on intestacy fell to the share of the eldest son. In default of male issue, on falling to a daughter's portion, it was reckoned equal in value to two of the best cows in the island."

The manufacture of such a rope from salted and dressed cow-hides, and the mode of using it, are then described, the author continuing:—

"The operations of rock-fowling are chiefly performed in the night-time, but the egging is done by daylight. The method in which the fowler captures his birds by night is very ingenious. It is as follows:—He clothes himself in garments as nearly resembling the colour of the rocks as possible, but upon his breast he bears a broad piece of white linen; when, having descended, by aid of the bird-rope, to some shelf on the rock where he has obtained a footing, he places himself in a position with his back to the rock near the roosts of the birds, where he remains perfectly still. The birds, mistaking the white on the fowler's breast for a resting-place in the rock, fly directly towards it, and endeavour to cling to it, when the fowler immediately takes them with his hand, and, after wringing their necks, suspends them to his girdle, or throws them in a heap at his feet. The fowler generally continues these operations throughout the whole night, and sometimes with astounding success, as many as four hundred fowl being sometimes taken by an expert fowler in one night.

* * * * * * * * *

"St. Kilda is also a well-known resort of the solan geese [gannets], and the St. Kildian fowlers are particularly expert in capturing them; but to such persecution are these birds subject, that it is almost astonishing that there are any left in the island. They are the objects of the fowler's attacks at all seasons of the year. From the month of March, just before they begin to lay, the rock fowlers seek them in the night time, and creep upon them so stealthily that they snatch them from their roosts, without disturbing others which may be roosting beside them. The fowler employs besides, the very cunning stratagem of depositing the first captive goose, as soon as killed, among the living companions; the latter immediately begin to mourn over their departed friend with much grief and groaning; when the fowler taking advantage of the mournful ceremony secures many captives from among the mourners."

* * * * * * * * *

"In the month of May the fowlers climb and scale the rocks in the same way, in pursuit of the eggs of the solan geese; and about August and September they take the young ones (called goug) which are then just ready to fly, and in prime condition for the table; being so redundantly fat, from the constant feeding of the parent birds, that they are, just at that particular time and season of the year, larger and heavier than the old birds. Macauley asserts that the fat on their breasts at that time is three inches in thickness. They are also well covered with valuable down, of which they are stripped after being killed, and they are then sent to market."

Speaking of the Bass Rock, Mr. Selby says:—"This precipitous rock is rented from the proprietor at sixty or seventy pounds per annum, and as the proceeds chiefly depend upon the produce of the gannets, great care is taken to protect the old birds, which the tenant is enabled to do from the privilege possessed by the proprietor of preventing any person from shooting or otherwise destroying them within a certain limited distance of the island. From the accounts I have received from the resident there, it appears that the gannet is a very long-lived bird, as he has recognised, from particular and well-known marks, certain individuals for upwards of forty years that invariably returned to the same spot to breed. He also confirmed to me the time required for this bird to attain maturity—namely, four years; and pointed out several in the different garbs they assume during that period, stating also that until fully matured they have never been known to breed. During incubation, in consequence of being unmolested, they become very tame; and where the nests are easily accessible, upon the flat surface of the rock on the south-west side of the island, will allow themselves to be stroked by the hand without resistance, or any show even of impatience, except a low, guttural note."

I recollect reading somewhere that in some parts of America gannets are captured in very large numbers, the flesh of their breasts being used as bait for cod fish.

I may conclude my notice of the gannet with an extract from a poem called "Ardglass," published in the year 1802. The heroic measure of the poem forms a ludicrous contrast to the every day occurrences it describes, and yet the descriptions are wonderfully true to nature :—

"Herrings, the food of Mona's greedy sons,
Who eat them up as fast as buttered buns,
As lions eat up kids, the bones and marrow,
Or hungry hawks devour the little sparrow!"

* * * * *

"When the huge body and enormous shoal
Of numerous herrings quit the frozen pole;
Desert their northern clime for temperate climes,
Like Goths and Vandals in the barb'rous times,
To British seas, long wished, at length resort,
And yield our anxious poor a kind support:
Then various birds, with wonder we survey,
Attend the pilgrim on their watery way.
Of these the gull and gannet are the chief,
Who eat them up as glutton would roast beef.
The gull, like diver, rides the waves secure,
As huntsman rides the courser o'er the moor,
Yet ne'er descends within the briny flood,
But on the surface takes the finny brood.
With vent'rous wing the gannet mounts on high,
And darts straight downward from the vaulted sky,
Pierces to wondrous depth the liquid plain,
Seizes his prey, and then ascends again.

But, should the hog* with open mouth assail,
Adown his throat they run as thick as hail :
Now here and there, from side to side he'd pass,
And thus collect them to a solid mass.
Then downward dive and in the middle rise,
Devour, disperse, and raise them to the skies ;
Yet boats and nets he'd shun with cautious care,
And flimsy texture ne'er disturb nor tear.

The few species of birds that I have been speaking of are nearly all commonly observed, either from the number in which they are found, from their own size or plumage, from some peculiarity in their habits, or something else to attract attention to them ; and of course there are very many others, equally deserving of notice, which the limited time at one's disposal in the course of a necessarily short paper like the present compels me to pass over. Of these the most numerous are the various species of gulls and the scoters, and scaup ducks, two species which I have occasionally in the winter months, and particularly in frosty weather, seen in vast numbers—flocks of them, I should say, consisting of thousands in our bay. About a month ago, crossing over from Dover to Ostend, on approaching the Belgian coast, I observed the common or black scoter in immense flocks, and some few pairs of the velvet scoter among them. I remarked particularly, that while the velvet scoters seemed to be paired the common species did not.

At the same time and place I observed a considerable number of the red-throated diver, singly and in pairs, with a very brief notice of which species, and of its larger and more distinguished relative, the great northern diver, I shall conclude.

The first note I have of the great northern diver is that down the lough on 1st May, 1869, in a small steam launch, we fell in with a large diving bird off Greenisland, and chased it unsuccessfully for above an hour. We were near enough to see the rings round the neck, but it was such an accomplished diver it eluded our efforts to kill or capture it, ducking the flash when fired at. Later in the day we fell in with another of the same species in Ballyholme Bay ; and after a long chase, having wounded it at the first shot, and followed

* The "hog," a local name for the bottle-nosed whale.

it up very closely afterwards, I secured it; and it was a very good specimen, in full summer plumage.

I have other notes of seeing this species in this lough on five or six different occasions—all, with one exception (October last), in May, my latest recorded date being 20th May. On 14th May last year I chased one off Cultra, and another off Ballymacormick Point, both of which individuals I had previously observed in the same places, and which I went in search of for the reason already alluded to, of remarking that diving birds frequent the same place for a long time if not disturbed. This winter, for instance, for several weeks in succession, I saw five golden-eye ducks fishing off Greg's Battery, between Holywood and Marino.

With regard to the Great Northern Diver, which I pursued unsuccessfully on 14th May last, the following is my original note:—

"Wednesday, 14th May, 1873, off Cultra, I saw the large bird which I had seen there on Saturday, and we went after it. One time it rose about forty to fifty yards off, at all events sufficiently near to see distinctly the neck rings and marking of the great northern diver. I got a shot at it this time, and, although the shot seemed to go all round the bird, it dived apparently none the worse. It rose again pretty soon, about one hundred yards off, and gave a loud harsh cry, flapped its wings and dived again. We now chased the bird for fully half-an-hour, but it was such an expert diver, staying so long under water, and going such distances, and generally appearing in a direction different to what we expected, that we never got near it again, and finally had to give up the chase. I remarked particularly that the bird did not dive with a jerk, like the puffins and guillemots, throwing their tail into the air as if turning a half summersault before disappearing below the surface; but it seemed simply to bend its head forward, and shoot beneath the surface, apparently without an effort. Again, on the same day, outside Ballymacormick Point we saw the other great northern diver, and gave chase for fifteen or twenty minutes, but it got away from us and out of our sight altogether, and we had to give it up."

These birds, and any that I had previously noticed, were in full summer plumage.

The only instance in which I saw one here in winter plumage was on the 18th October last, regarding which I have the following note.

"From the Shaddock (a sunken wreck) we stood into Ballyholme Bay, and there fell in with a great northern diver, which we chased for fully half an hour, quite ineffectually, never getting a chance of a fair shot at it, so wary was it, and such an accomplished diver. I did finally fire a shot at it at about 120 yards, with a B.B. cartridge, and saw the shot strike the water all round it, but the only effect this had was to make the bird dive, and this time disappear altogether."*

I saw two of them hanging up in a poulterer's shop in Manchester in January last, and heard, on inquiry, that they had been sent to him for sale from Scotland. The locality was not mentioned.

Mr. Thompson gives to this noble bird the prominence it deserves in a long and interesting description, and I regret that time will not permit me to read some extracts from it. He says, speaking of the appearance of an individual of this species in the same locality for a length of time together—"They appear to have favourite haunts, as what was believed to be the same bird was seen week after week in the same place." The driver of the mail car from Glenarm to Cushendall regarded the appearance of a bird of this species at a particular spot as a daily occurrence, remarking that he knew it well as a frequenter of the place for two years—these observations confirming my own.

In January, a couple of years ago, I saw one of these birds near Glenarm, in winter plumage, of course. The red-throated species is much commoner, my notes of it being so numerous as not to require detailed mention, the only one worth repeating being that on the 23rd March last year, I saw twenty-three red-throated divers in a flock off Seapark, between Greenisland and Carrickfergus. They were a good deal scattered at first, but drew together as the boat approached them, and finally all took wing at once.

Both these species are mentioned by Thompson in the note I already read under "Gannet" as being taken in fisherman's nets, sometimes at great depths (p. 259).

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* NOTE.—Since this was written I shot a fine specimen of the Northern Diver, in winter plumage, on 25th April last. I saw two or three others, some of them in summer plumage, to-day.

DESCRIPTIVE CATALOGUE

OF

SKULLS AND CASTS OF SKULLS,

FROM VARIOUS IRISH SOURCES,

COLLECTED BY THE LATE JOHN GRATTAN, ESQ.,

Now the property of the Belfast Natural History and Philosophical Society.

[A series of Drawings on Stone, by J. Howard Burgess, Esq., illustrating the Skulls described in the foregoing catalogue, and the Round Towers from which some of them were obtained, have been mounted, and are now for exhibition in the Belfast Museum.]

1 Cast of Skull, from small tumulus, Phœnix Park, Dublin, presented by the late Dr. Ball. Original in University Museum. No notice nor any information respecting this tumulus could be obtained by Mr. Grattan, except that Dr. Ball told him it was bee-hive shaped.

2 Cast of Skull, from Ristoren, Donaghmore, County Tyrone, presented by J. Grattan, Esq. The cast was made by Mr. Grattan from the skull then in the possession of Mr. Bell of Dungannon, but subsequently, it is believed, presented by him to Sir W. Wilde. An urn of baked clay was found in the cist with the skull, and an inquest was about being held upon the remains, when, fortunately for the reputation alike of the county and the constabulary, Mr. Bell interfered.

3 Cast of Skull of one of the skeletons found in the large tumulus, Phœnix Park, Dublin, presented by Dr. Ball. Original in Royal Irish Academy. See its Catalogue of Antiquities, page 81.

4 Cast from second skull of same finder, also presented by Dr. Ball.

5 Cast from fragments of a skull presented by Dr. Ball, and marked by him "very ancient from Railway cutting," but without any further particulars.

6 to 14, Skulls or Casts of Skulls from ancient sepulchral mound, Mount Wilson, King's Co. This mound was examined by Mr. Grattan in May 1873, with the permission and assistance of George Newsom, Esq., of Mount Wilson, on whose property it was situated. The spot itself is nameless, and, so far as can be ascertained, is unassociated with any local tradition or superstition whatever, nor was it even suspected of being the depository of human remains until some years before, when Mr. Newsom commenced removing it for agricultural purposes, its material being a coherent loamy gravel, well adapted for the improvement of reclaimed moorland. At that time 16 or 17 skeletons were removed and reburied in another locality. Originally the mound may have had a diameter at its basis of 90ft. ; but at the time Mr. Grattan visited it, probably one half of it had been removed or disturbed. The graves lay parallel to each other, at irregular intervals of from 2 to 3 feet ; were excavated out of the otherwise undisturbed subsoil of the field ; and rarely exceeded 4 feet in depth from the surface of the mound. They contained no traces either of wood or metal, nor was any work of art whatsoever found either in or about them. All the interments bore evidence of having been made about the same period, not a bone having been disturbed or displaced. Such crania as could be removed were without exception removed in fragments, which, when they became dry, were restored as far as practicable. Owing to the perishable condition of the bones, it was not possible to recover a perfect skeleton, so as to ascertain its exact length ; but the dimensions of some of the thigh bones would seem to indicate an original stature of 5ft. 6in. to 5ft. 8in. at the utmost. The individuals were of both sexes, and of ages varying from 6 or 8 years up to 70 or 80. In even the very youngest the teeth were much worn as if by the attrition of some very hard description of food, the progress of degradation curiously keeping pace with the age as indicated by the teeth themselves. Mr. Newsom was of opinion that fully 30 skeletons must have been disturbed from time to time before Mr. Grattan and he examined the mound, and they met with 10 skulls, only 5 of which, however, could be removed. Three fragments of the jaws of animals were found, and four or five detached teeth. They were portions of the upper jaw of a small ox, and of the lower jaws of a boar and of a goat. See "Ulster Journal of Archæology," vol. 1, page 276.

6	SKULL,	No. 1.	Presented by John Grattan, Esq.
7	SKULL,	,, 2,	ditto.
8	CAST OF SKULL,	,, 3,	ditto.
9	CAST OF SKULL,	,, 4,	ditto.
10	CAST OF SKULL,	,, 5,	ditto.
11	SKULL,	,, 6,	ditto.
12	Vacant,	,, 7.	*See note.

* 8, 9, 10, and 12 were procured by the Marchioness of Downshire, and entrusted for some time to Mr. Grattan, who made careful tracings and measurements of them while in his possession, and subsequently made castings of 8, 9, and 10, before forwarding them to St. George's Hospital, London, to the Museum of which institution her ladyship presented them. 14, from the same tumulus, was subsequently presented by her ladyship.

13 Skull, ,, 8. Presented by John Grattan, Esq.

14 Skull, ,, 9, by Lady Downshire.

15 *a* Skull, child's, imperfect, by John Grattan, Esq.

b Fragments of adult skulls, ditto.

c Fragments of adult skulls, by Lady Downshire.

d Ditto. ditto.

e Lower Jaw of adult. ditto.

16 Skull, No. 1, presented by the late Lord Dungannon.

17 Skull, ,, 2, ditto.

16 and 17 are from the ancient sepulchral chamber, Ballynahatty, County Down.

In this sepulchral chamber, situated in a field almost adjoining the great circular embankment known as the Giant's Ring, three methods of interment, all contemporaneously adopted, were observed—cremation, with urn burial; cremation, without urn burial; and the entombment of unburnt portions of the dismembered body. It is stated that in the same piece of ground indications of extensive interments have been discovered at various periods, vast quantities of human bones having been turned up by the plough; and in a mound which was removed when the present dwelling house was built, and in several other parts of the field, short coffins, formed of stone slabs, and generally containing urns and burnt bones, have been found. See "Ulster Journal of Archælogy," vol. 3, page 258.

Various fragments of skulls, jaws, burnt bones, and small bits of sepulchral urns belonging to this find are preserved in a box. The larger fragments of the urns were presented by Lord Dungannon to the Royal Irish Academy.

18 to 27 are from the Round Towers of Ulster, and the stone-roofed chapel of Devenish.

These towers, the date of whose erection Dr. Petrie assigns to a period extending somewhere between the 5th and 13th centuries, were examined by the late Edmund Getty, Esq., John Grattan, Esq., W. Thompson, Esq., and several other gentlemen. Notices of the examinations will be found in the "Ulster Journal of Archælogy," vol. 3, p. 110; vol. 4, p. 62; vol. 5, p. 110; vol. 4, p. 173; vol. 8, p. 292; vol 4, p. 178. In all of the towers, except Trummary, one uniform class of phenomena was observed. After removing a greater or lesser depth of heterogenous materials, evidently the slow accumulations of ages, a flooring of lime more or less thick was reached, from which downwards the offsets that constituted the foundations of the tower extended; the interior being filled up with soil similar in all respects, except compactness, to the natural till or virgin soil upon which the foundation rested ; and in this soil and under this lime floor, without any exception whatever, it was that the remains when present were found. Trummary, according to Dr. Petrie, of comparatively recent erection, differed remarkably from all the others by having its skeleton contained in a carefully constructed stone chamber. The skulls obtained, with the one exception of Drumbo, were in so frail and perishable a condition that they could only be removed in almost hopeless fragments. These were afterwards saturated with glue, and cemented together by Mr. Grattan. Of the ten towers examined five contained human remains, four exhibited no trace of them whatever, and one had been previously disturbed. The tower of Devenish contained no remains, but the small contiguous and probably contemporaneous stone-roofed chapel did. In it the skull No. 27 was found.

18 SKULL from interior of Drumo Round Tower, Co. Antrim. Presented by the Revd. Mr. Maunsell, incumbent of the parish.

19 SKULLS from the interior of the Round Tower of Clones. Presented by the late Edmund Getty, Esq.

20 SKULL 2, from Clones, ditto.

21 SKULL 3, ditto. ditto.

22 SKULL 4, ditto. ditto.

23 SKULL 5, fragment of child's ditto. ditto.

Various other fragments connected with these are preserved in box.

24 SKULL, imperfect from Drumlane Round Tower, Co. Cavan. Presented by Edmund Getty, Esq.

25 SKULL from Armoy Round Tower, Co. Antrim. Presented by Edmund Getty, Esq.

e FRAGMENT of skull from ditto.

26 FRAGMENT of skull from Round Tower of Trummary, Co. Antrim. Presented by Edmund Getty, Esq.

27 SKULL from stone-roofed chapel, Devenish, Co. Fermanagh. Presented by Edmund Getty, Esq.

28 SKULL from old cathedral, Downpatrick. Presented by the Rev. Mr. Macauley, P.P. For accounts of these skulls see "Ulster Journal of Archæology," vol. 6, page 220.

29 SKULL from the old castle of Belfast, obtained when sinking the foundations for Mr. Gunning's buildings in Donegall Place. Presented by Mr. Gunning.

30 31 32 CASTS from skulls found deeply imbeded along with several canoes in the bed of the Blackwater, Co. Armagh, when being deepened by the board of works. Casts made by Mr. Grattan, with the obliging permission of William Kelly, Esq., Stipendiary Magistrate, in whose possession the skulls were. Casts presented by John Grattan, Esq.

33 34 35 SKULLS from ruins of Church, Island Mahee, Strangford Lough, Co. Down. Presented by the Rev. Dr. Reeves.' See Reeves' Ecclesiastical Antiquities, page 195.

36 FRAGMENT of Skull from Ballykinler, Co. Down.

37 CAST from reputed Skull of Carolan, the Irish Bard. Anthenticity very questionable. Made and presented by John Grattan, Esq.

38 SKULL discovered in the bed of the Boyne when it was being deepened by the board of works. Abnormal shape; suicidal type. Presented by Lady Downshire.

39 Imperfectly restored Skull from St. John's Point, Co. Down, formerly a Preceptory of the Knights' Templar. Presented by Dr. Hodges.

40 SKULL from ancient burial ground, Aghadoe, Co. Derry. Abnormal macrocephalic. Presented by John Grattan, Esq.

41 SKULLS from Armagh Cathedral burial ground. Presented by G. B. Allen, Esq.

42 SKULL from Armagh, ditto.

43 SKULLS from Inniskeen, Co. Monaghan. Preserved and presented by J. Grattan, Esq.

44 SKULL from Inniskeen, ditto.

45 SKULL from Buttevant, Co. Cork, ditto.

46 SKULL ditto. ditto.

47 SKULL from Aghadoe, Co. Derry, ditto.

48 SKULL from ditto. ditto.

49 SKULL from Arran, Galway Bay, ditto.

50 SKULL ditto. ditto.

51 SKULL from Armagh. Presented by J. B. Allen, Esq.

52 SKULL ditto. ditto.

53 SKULL ditto. ditto.

54 SKULL from Inniskeen. Presented by J. Grattan, Esq.

55 SKULL from Ancient Burial Ground, Co. Wicklow. Presented by Mr. Powell.

56 SKULL from Buttevant, Co. Cork. Presented by John Grattan, Esq.

57 SKULL ditto., ditto.

58 SKULL from Rock of Cashel, ditto.

59 SKULL from Aghadoe, ditto.

60 SKULL from Belfast Old Poor House (cholera burial ground), ditto.

61 SKULL from Buttevant, County Cork; probably young female. Presented by John Grattan, Esq.

62 SKULL from Buttevant, ditto.

63 SKULL ditto. Type questionable; breadth much above average; forehead broader; a low organization in any case; may have been an extreme departure from the Celtic form, or of foreign origin.

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