THURSDAY, SEPTEMBER 11, 1890.

PRINCIPLES OF ORGANIC CHEMISTRY.

Principles of General Organic Chemistry. By Prof. E. Hjelt, Helsingfors. Translated from the Author's German Edition of the original work by J. Bishop Tingle, Ph.D. (London: Longmans, Green, and Co., 1890.)

THIS work is an English translation of the German edition of a book which originally appeared in Swedish, and its object is stated to be "to give in a short and clear form the most important points of general and theoretical organic chemistry." Paraphrasing a statement recently put forward by a well-known reviewer in these columns, we certainly doubt the propriety of translating German books of this kind into English, regarding the ignorance of German by a chemist as inexcusable, if not criminal: in our opinion, indeed, permission to study the science of chemistry should be contingent on proof being given of a competent knowledge of this language. But our objection does not rest alone on this basis: we should not even have recommended the translation of the work from Swedish, as we hold that its study must have a thoroughly demoralizing effect. It is impossible "to give the most important points of general and theoretical organic chemistry," in accordance with the plan adopted by the author, within so narrow a compass; and such a book can only serve the purposes of the crammer. The uselessness of attempting to construct a cottage from plans prepared for a mansion needs no proof, but it is just such an attempt that is made in the book under notice.

The book is divided into three parts. According to the translator, in Part I. the composition, constitution, and classification of organic compounds are discussed and explained as clearly and concisely as possible. Part II. is devoted to illustrating the connection between the constitution of organic compounds and their chief physical properties. Part III. deals with the chemical behaviour of organic compounds. In illustration of the treatment accorded to the various sections, it may be mentioned, however, that the whole subject of "Geometrical Isomerism," one of the most difficult of modern chemical problems, is dismissed in five pages; that optical properties occupy but five and a half; and that only three and a half are devoted to the discussion of specific gravity and specific volume in their relation to constitution.

Some among us contend that the study of chemical science affords logical training of a very high order, but certainly this would not be the opinion of any intelligent person unacquainted with the subject who chanced to read this book. Thus, what can be the value of such wretched mental pabulum as that supplied on pp. 42–43, where, after the briefest possible reference to the van t' Hoff-Le Bel hypothesis, we read, "Two doubly linked carbon atoms would be represented by a figure consisting of two tetrahedra with one edge in common. Two arrangements are possible of substances of the type $C\,ab = C\,ab$. Fumaric and maleic acids are examples of such compounds"? Then follow the two conventional double tetrahedron figures, and a few lines further comes the dogmatic assertion, "It can be proved that fumaric acid is constituted like Fig. 2, and maleic acid like Fig. 1. It is not possible here to give a systematic account of the principles upon which the discovery of geometrical isomerism is based." Fancy the effect of studying, let us say, Euclid on such principles, and the kindly reception the lad would meet with who told his master in class that "*it can be proved* that any two sides of a triangle are greater than the third," and whose knowledge went no further; yet this is about the position which a reader of this book would be placed in after perusing its fragmentary sentences. If the student be exceptionally intelligent, and be not satisfied with dogmatic assertions, what must, moreover, be his opinion of his teacher when later on he directs his attention to current literature, and finds that the constitution of fumaric and maleic acids is one of the questions which is being hotly contested among chemists; that it is not proved that either acid has the constitution represented by the figures given; that, in fact, it is pure assumption that such is the case; and that the determination of the constitution of these and similar acids is a problem of peculiar difficulty?

The translator tells us that "No pains have been spared in order to bring the work into harmony with the latest researches, though of course, from the very nature of the case, all controversial matter has been excluded." The first part of the sentence is distinctly misleading, and it is difficult to understand the meaning of the latter. Our methods of determining constitution are admittedly in so many cases imperfect and but roughly approximate; so much depends on individual judgment, and the point of view from which the interpretation is given; that, in discussing constitution and the relation of physical properties to structure, "controversy" cannot be excluded. The advancing student has the right to demand a statement of the arguments for and against, and to nourish him on dogma is to do him a grievous injury: his object being to learn to play the game himself later on, he desires to obtain an insight into its rules and moves, and his only chance of learning methods is to become acquainted with the methods and arguments of previous workers. An illustration is afforded by chapter xi., on heat of combustion and heat of formation, which extends to the inordinate length of two pages and a half. In this chapter reference is made to Thomsen's calculations of the thermal values of the different kinds of bonds between carbon atoms, and his conclusions are put forward in such a manner as to lead the student to suppose that they are based on cogent arguments. The author's preface being dated Helsingfors, February 1887, it is excusable that he should have been impressed by the weight of Thomsen's authority; but it is inexcusable that the translator, three years later, should overlook the criticisms that have been passed on Thomsen's work, and should fail to point out that the conclusions which this chemist based on his thermal studies of carbon compounds are frequently in absolute conflict with those deduced from the study of chemical behaviour. The survival at this date of the strange conclusion that in acetylenic compounds the carbon atoms are held together by less than no affinity clearly shows that common-sense after all is an uncommon sense. The concluding paragraph of chapter xi. is one which it is perhaps undesirable to pass without remark :—

> "All researches prove that unsaturated compounds possess a greater heat of combustion than saturated ones ; their heats of formation are therefore less and their energy greater than that of compounds containing carbon atoms linked only by single bonds. The thermal behaviour of unsaturated compounds also shows that the so-called *double bond is a weaker*, *not a stronger*, *form of atomic attraction than the simple bond*."

The first of these sentences is a mere statement of fact ; the second is an unwarrantable and illogical deduction from the facts, and yet the fallacy which it embodies is very generally overlooked. Chemists are persuaded that the ethylenic form of linkage is not the equivalent of *two* paraffinic linkages, but is considerably weaker ; beyond this, however, all is surmise. It is not determined whether or no the carbon atoms in ethylenic compounds are united by more than a single affinity ; and as we have no means at present of calculating the thermal equivalent of even a paraffinic linkage, thermal behaviour cannot enable us to judge which is the stronger form of atomic attraction—the paraffinic or the ethylenic. The greater stability of saturated as compared with unsaturated compounds would appear to be due to the greater readiness with which the latter are acted on. To defeat an enemy it is necessary to approach within striking distance ; and so it is in affairs chemical. The vulnerable points in saturated compounds are few or limited in extent, but in the case of the unsaturated it is easy for the attacking party—the chemical agent—to effect a lodgment.

Our criticisms thus far have had reference chiefly to Parts I. and II. ; but of Part III., which is the more important section of the book and the more novel in plan, we cannot speak in terms much less unfavourable. We can only say : Defend us from the student whose knowledge of the general behaviour of organic compounds has been derived from such a course of study. We wish, in the interests of English chemical students, that the book had remained untranslated.

H. E. A.

THE THEORY OF INTEREST.

Capital and Interest : a Critical History of Economic Theory. By Prof. Eugen von Böhm-Bawerk. Translated by William Smart, M.A. (London : Macmillan and Co., 1890.)

PROF. SMART shares with Mr. James Bonar the honour of introducing to the English public a leader of the important Austrian school of economists. Mr. Bonar, in the *Quarterly Journal of Economics*, transfuses into his own happy style the spirit of Prof. Böhm-Bawerk's theory of value. Prof. Smart translates the same writer's theory of interest, which, to be fully appreciated, should be read in connection with the earlier work. The translation is enhanced by an analysis and a preface, in which the author's theory is, so to speak, "brought down to earth," and adapted, by examples taken from the highway and the market-place, to the comprehension of the wayfaring man. Referring to his own labours, Mr. Smart makes a suggestion which deserves attention :—

> "The time I have given to this work may excuse my suggesting that a valuable service might be rendered to the science, and a valuable training in economics given, if clubs were organized, under qualified professors, to translate, adapt, and publish works which are now indispensable to the economic student."

Mr. Smart should be one of these professors ; for he has proved himself to be eminently qualified, not only to translate, but to adapt an important work.

One quality of this work, about the excellence of which there can be no question, is the learning with which it abounds. The Austrian economists rival their German neighbours of the exclusively "historical" school in laboriousness of research. He must be a ripe scholar to whom many even of the names, as well as matters, in our author's review of theorists and theories are not new. We shall not expose our own ignorance by mentioning the writers of whom we had never heard before. As an instance of one whose name was not unknown, but whose position in economical history was not sufficiently recognized, may be noticed Salmasius. The average English reader is aware that Salmasius was underrated by Milton and his biographer, Dr. Johnson. But it requires Prof. Böhm-Bawerk's acquaintance with economic literature to realize how much Salmasius contributed to the explosion of the old prejudices against interest. Not only does his doctrine

> "indicate an advance, but it long indicates the high-water mark of the advance. . . . There was no essential advance on Salmatius (in respect of the theory of interest) till the time of Smith and Turgot."

J. B. Say, if we remember rightly, has observed that there is not much use in studying the theories of the earlier economists, as they were mostly wrong. Prof. Böhm-Bawerk evidently does not accept this somewhat Philistine conclusion. But we suspect that he does not deny the premiss. For it appears to be the motive of this "Critical History of Economic Theory" to prove that all preceding economists have gone astray, and fallen short of the glory which we fully concede appertains in a special degree to Prof. Böhm-Bawerk as the formulator of the true theory of interest. Now we cannot agree to the negative proposition here implied. Our approbation of Prof. Böhm-Bawerk does not rest upon the censure of his predecessors. Of course it must be admitted that on the theory of interest, as on other economical subjects, a great deal of nonsense has been talked. But—hindered perhaps by the proverbial difficulty of unlearning the lessons of youth—we can hardly believe that the leaders of economic thought, that Ricardo and Senior and J. S. Mill, deserve to be involved in such a sweeping condemnation.

In expressing this doubt we shall shelter ourselves behind the authority of one to whom most readers conversant with economic science will be disposed to defer. In one of the scrupulously weighed notes attached to the epoch-making work which Prof. Alfred Marshall has just published, he thus refers to Prof. Böhm-Bawerk :—

> "The question may be raised whether he has not somewhat exaggerated the difference between his own position and that of his predecessors ; whether the sharp contrasts which he finds between the doctrines of successive schools really existed, and whether those doctrines

were generally as fragmentary and one-sided as he thinks."

Without attempting to add to words so weighty, we shall follow the excellent example of him who had to speak after Mr. Burke, and shall simply "say ditto" to Prof. Marshall.

It is not be supposed that our remarks are calculated to disparage the truth and importance of Prof. Böhm-Bawerk's own theory of interest. It would argue a very slight acquaintance with economical literature to suppose that the worth of an author's own work is to be measured by the worth of his criticisms upon the work of others. Prof. Böhm-Bawerk is not the less right because those from whom he differs are not wrong. We are not precluded from expressing unqualified admiration of the *positive theory* which forms the sequel to this too "critical" history. F. Y. E.

LETTERS TO THE EDITOR.

[*The Editor does not hold himself responsible for opinions expressed by his correspondents. Neither can he undertake to return, or to correspond with the writers of, rejected manuscripts intended for this or any other part of* NATURE. *No notice is taken of anonymous communications.*]

The Soaring of Birds.

In Nature of August 21 (p. 397), a new solution has been offered of the problem of the soaring of birds, which will hardly be accepted as satisfactory; for it is based on the radical misconception that the absolute velocity with which a bird soars, or flies, partly with the air, and partly through the air, can be converted, wholly or in part, into a motion through the air, at a swifter rate than before. This is only possible when the bird passes from one current into another, or the current itself is changed in rate or direction. It is strange that anyone should fail to see that when a body of air is moving uniformly over the land or sea, it can no more sustain a bird flying or gliding within it than if it were motionless.

Referring to your correspondent's first diagram, "It is evident," he says, "that the velocity of the bird at the point *c*, if the initial velocity of the bird and the velocity of the wind are properly adapted" (whatever that may mean) "can be greater than at *a*. He appears to think that the length of the line *a c* is some measure of the velocity; whereas, in fact, this velocity will be the same, or rather greater, indefinitely near to *a* than it is at *c*; the velocity of the bird through the air being then at its maximum, and that of the wind uniform. Nothing is gained by the length of *c a*. A movement in the direction *c d* might be at least as advantageously made close to *a* as further along the line.

It is hardly worth while to press any other objection to the explanation offered. But it may be noted that if the diagrams given are intended to represent the actual facts the soaring bird is being rapidly carried to leeward, which is a misrepresentation. Let me offer what I believe to be an apt illustration. While a billiard ball is rolling across a table, its direction being again and again changed by its rebounds from the cushions, the table is moved forward through space at the rate of about a thousand miles a minute. This movement ought, according to your correspondent, to accelerate or retard the motion of the ball across the table, or at least ought to do so if the two movements were "properly adapted."

Reginald Courtenay.

Tean Vicarage, Stoke-on-Trent, September 1.

[P.S.—In Nature for September 4 (p. 457), just received, are remarks on the soaring of birds, by two of your correspondents, which seem to me to be perfectly just; only I would add that the upward currents of which soaring birds avail themselves are commonly due to obstacles to the uniform motion of the wind. Also, that a soaring bird, if turning abruptly, will in general not merely uplift, but strike once, with the outer wing.]

The Affinities of *Heliopora cærulea.*

Owing to absence from Dublin I have but just seen the correspondence on the affinities of *Heliopora cærulea* in two recent numbers of Nature (pp. 349, 370). Dr. S. J. Hickson has undoubtedly given the true explanation of Mr. Saville Kent's "curious mistake." Knowing that the polyps of this Alcyonarian had never before been observed in expanded condition, I took every opportunity when in Torres Straits of examining living specimens *in situ*. Only on one occasion was I rewarded, and then I distinctly saw the small extruded polyps with their eight flat fringed tentacles; they were nearly colourless, but had a whitish tinge, in fact, they precisely resembled the polyps of the common *Alcyonium digitatum*. I was unable to sketch them at the time, as my bodily position was unfavourable, and the tide was rising. In no case did the polyps exhibit any sign of vitality when kept in a vessel of water in my laboratory. The only published drawing (so far as I remember) purporting to be the polyp of this form is that given by Quoy and Gaimard, but whatever it may be, it represents neither the polyp itself nor the annelid described by Mr. Saville Kent.

Alfred B. Haddon.

Royal College of Science, Dublin.

Occurrence of a Crocodile on Cocos Islands.

With reference to Mr. Ridley's account of the occurrence of a crocodile on the Cocos Islands, I was quartered in Barbados in the beginning of 1885, when a very fine alligator, over 15 feet in length, was washed on shore. As it was on the point of crawling up the beach it was noticed by a sergeant of engineers and some sappers who shot it, and afterwards exhibited it in the town.

The nearest river the alligator could have come from was the Orinoco, a distance of 300 miles.

This is improbable, as the set of the ocean currents would have sent the alligator much to the west of Barbados if it had come from the Orinoco. It is much more probable the alligator came from the mouth of the Amazon or from the Essequibo, many hundred miles further to the east.

Dr. Mitchell, of Trinidad, told me he had seen an alligator on a small log attacked by sharks in the Gulf of Paria.

A. L. Caldwell.

A.S. Corps, Chatham, September 6.

THE BRITISH ASSOCIATION.

Leeds, *Wednesday Morning*.

The Leeds meeting has been small and quiet, the attendance only numbering over 1700. Happily the weather has been excellent, and brilliant sunshine has cast a glow over the ugliness of the place, and rendered the excursions to the Aire and the Wharfe valleys delightful. The usual social accompaniments of British Association meetings have not been so plentiful as at former meetings, but every one seems satisfied with the hospitality displayed.

In the proceedings of the meeting there have been one or two matters of excitement and some marked successes. Sir Frederick Abel considerately cut down an address which was more suited for the study than the platform. It is universally admitted that no more successful lectures have ever been delivered at an Association meeting than those of Mr. Poulton on Friday, on "Mimicry," and Prof. Boys on Monday, on "Quartz Fibres." The large audiences were really entranced.

It can hardly be said that any paper of high and wide scientific importance has been read this year in any of the Sections. There have, however, been several most important discussions on the reorganization of some of the Sections, which attracted much attention, and several changes are to be made.

Next year's meeting of the Association will take place at Cardiff, when Dr. Huggins will preside. The 1892 meeting will be held at Edinburgh, and the 1893 at Nottingham.

The following is the list of grants to be submitted to the meeting of the General Committee to-day :—

A.—*Mathematics and Physics.*

	£
Seismological Phenomena of Japan	10
Electrical Standards	100
Meteorological Observations on Ben Nevis	50
Electrolysis	5
Photographs of Meteorological Phenomena	5
Discharge of Electricity from Points	10
Ultra-Violet Rays of Solar Spectrum	50
Seasonal Variations of Temperature	20

B.—*Chemistry.*

Analysis of Iron and Steel	10
Isomeric Naphthalene Derivatives	25
Formation of Haloid Salts	25
Action of Light upon Dyes	20

C.—*Geology.*

Erratic Blocks	10
Fossil Phyllopoda	10
The Geological Record	100
Photographs of Geological Interest	10
Lias Beds in Northamptonshire	20
Registration of Type Specimens of British Fossils	10
Volcanic Phenomena of Vesuvius	10
Underground Waters	5
Investigation of Elbolton Cave	25

D.—*Biology.*

Marine Biological Association at Plymouth	30
Botanical Station at Peradeniya	50
Improving Deep-sea Tow-net	40
Disappearance of Native Plants	5
Zoology of the Sandwich Islands	100
Zoology and Botany of the West India Islands	100

E.—*Geography.*

Normal Tribes of Asia Minor and Northern Persia	30

G.—*Mechanical Science.*

Action of Waves and Currents in Estuaries	150

H.—*Anthropology.*

New Edition of "Anthropological Notes and Queries"	50
Anthropometric Laboratory	10
North-western Tribes of Canada	200
Habits of Natives of India	10
Corresponding Societies	25
	£1330

SECTION A.

MATHEMATICS AND PHYSICS.

Opening Address by J. W. L. Glaisher, Sc.D., F.R.S., President of the Section.

No one who is called upon to preside over this Section can fail to be struck by the range of subjects comprehended within its scope. The field assigned to us extends from the most exact of all knowledge, the sciences of number, quantity, and position, to branches of inquiry in which the progress has been so slight that they still consist of little more than collections of observed facts. This breadth of area has obvious disadvantages, but it is not without some compensating advantages. In these days, when science is so much subdivided, it is well that students of subjects even so diverse as those with which we have to deal should occasionally meet on common ground, and have the opportunity of learning from each other's lips the kind of work in which they are engaged. Wide as is our range, we should remember also how closely knit together in various ways are the more important of our subjects; and in the case of mathematics, astronomy, and physics, besides their actual and historical alliance, a mathematician may be permitted to feel that a special bond of union is created by the mathematical processes and language which are essential for their investigation and expression.

It is, I am afraid, unfortunate for my audience, that my own subject should be at one extreme, not only of those dealt with by our Section, but even of the still greater range covered by the Association. I will endeavour, however, in my remarks to confine myself to a few general considerations relating to pure mathematics, which I hope will not be considered out of place on this occasion.

By pure mathematics I do not mean the ordinary processes of algebra, differential and integral calculus, &c., which every worker in the so-called mathematical sciences should have at his command. I refer to the abstract sciences which do not rest upon experiment in the ordinary sense of the term, their fundamental principles being derived from observations so simple as to be more or less axiomatic. To this class belong the theories of magnitude and position, the former including all that relates to quantity, whether discrete or continuous, and the latter including all branches of geometry. The science of continuous magnitude is alone a vast region, containing many beautiful and extensive mathematical theories. Among the more important of these may be mentioned the theories of double and of multiple periodicity, the treatment of functions of complex variables, the transformation of algebraical expressions (modern algebra), and the higher treatment of algebraical and differential equations as distinguished from their mere solution. It is this kind of scientific exploration which fascinates and rewards the pure mathematician, and upon which his best work is most profitably spent. I do not wish to under-estimate the importance of such a subject as finite differences, in which a number of distinct problems are treated with more or less success by interesting methods specially adapted to their solution. Nor would I willingly undervalue the interest of those branches of mathematics which we owe to the mathematical necessities of physical inquiry. But it always appears to me that there is a certain perfection, and also a certain luxuriance and exuberance in the pure sciences which have resulted from the unaided, and I might almost say inspired genius of the greatest mathematicians which is conspicuously absent from most of the investigations which have had their origin in the attempt to forge the weapons required for research in the less abstract sciences. To illustrate my meaning, I may take as an example of a subject of the latter class the theory of Bessel's functions. The object of mathematicians in this case has been to investigate the properties of functions which have already presented themselves in astronomy and physics. Formulæ for their calculation by means of series, continued fractions, definite integrals, &c., have been obtained in profusion, numerous theorems of various kinds and applicable to different purposes have been discovered, extensions and developments have been made in all directions, and, finally, the large body of interesting analysis thus accumulated has been classified and systematized. But, valuable and suggestive as are many of the results and processes, such a collection of facts and investigations is necessarily fragmentary. We do not find the easy flow or homogeneity of form which is characteristic of a mathematical theory properly so called. In such a theory as, for example, the theory of double periodicity (elliptic functions), the subject develops itself naturally as it proceeds; one group of results leads spontaneously to another; new and unexpected prospects open of themselves; ideas the most novel and striking, which penetrate the mind with a charm of their own, spring directly out of the subject itself. We are surprised by the wonderful connections with other subjects which unexpectedly start into existence, and by the widely different methods of arriving at the same truths; in fact, as our knowledge progresses, we continually find that results which seemed to lie far away in the interior of the subject—so remote and concealed that, at first sight, we might think that no other path except the one actually pursued could have reached them—are actually close to its edge when approached from another side, or viewed from another stand-point. We notice, too, that any great theory gives rise to its own special analysis or algebra, frequently connecting together into one whole what were hitherto merely isolated and apparently independent analytical results, and affording a reason for their existence, and also—what is often even more interesting—a reason for the non-occurrence of others, which analogy might have led us to expect. I do not pretend that there are not many branches of mathematics which partake of both these characters, nor do I suppose that the description I have given of a mathematical theory is at all peculiar to pure mathematics. Much of it is common to all scientific research in a fruitful field, though, possibly, we may not find elsewhere such profusion of ideas or perfection of form.

I have been tempted to speak at such length on the objects and aims of the mathematician by the feeling that they are not infrequently misunderstood by the workers in the less abstract sciences. I do not think that mathematical formulæ or processes, merely as such, are much more interesting to the pure than to the applied mathematician. The one studies number, quantity, and position, the other deals with matter and motion; and in both cases the investigations are carried on by means of the same symbolic language.

The order in which the subjects which form an ordinary mathematical course are presented to the student is regulated by the fact that portions of the elements of the pure sciences are required for the explanation and development of any exact science; for example, a knowledge of the elements of trigonometry, analytical geometry, and differential and integral calculus, must necessarily precede any adequate treatment of mechanics, light, or electricity. The majority of students, after mastering a sufficient amount of pure mathematics to enable them to pass on to the physical subjects, continue to devote their attention to the latter, and never know more of the nature of the pure sciences than they can derive from the processes and methods which they learned at the very outset of their mathematical studies. This is necessarily the case with many of the wranglers, as the first part of the Mathematical Tripos includes no true mathematical theory. Most of the mathematical text-books in use at Cambridge are so admirably adapted to the purposes for which they are intended that it seems ungracious to make an adverse criticism of a general kind. But I cannot help feeling regret that their writers have had so much in view the immediate application of the principles of the pure subjects to the treatment of physical problems. In the case of the differential and integral calculus, for example, there seems an increasing tendency to introduce into the book-work and examples propositions which really belong to the physical subjects. This is an important tribute to the growth and influence of physical mathematics in this country, and a zealous physicist might even consider it satisfactory that the student should not be required to encumber himself with knowledge which was not directly applicable to the theory of matter. But from the mathematician's point of view it is unfortunate, for, while shortening by very little the path of the student, it cannot fail to give an incomplete, if not erroneous, idea of the relations of the pure to the applied sciences. How can he help feeling that the former are merely ancillary to the latter when he finds that the mathematical problems which arise naturally in physical investigations have been already dealt with out of their place in the treatises which should have been devoted solely to the sciences of quantity and position?

Perhaps few persons who have not had the matter forced upon their attention fully realize how fragmentary and unsatisfactory is the treatment of even those fundamental subjects in pure mathematics which form the groundwork of any course of mathematical study. Algebra is necessarily the first subject set before the student; it has therefore to be adapted to the beginner, who at that time is only learning the first elements of the language of analysis. It is customary to regard trigonometry as primarily concerned with the solution of triangles; the geometrical definitions of the sine and cosine are therefore adopted, and after the application of the formulæ to practical measurement and calculation a new departure is made with De Moivre's theorem. The elementary portions of the theory of equations, and the differential and integral calculus and differential equations, are valuable collections of miscellaneous principles, processes, and theorems, useful either as results or as instruments of research, but possessing no great interest of their own. Analytical geometry fares the best, for it includes one small subject—curves of the second order—which is treated scientifically and with thoroughness. It is true, however, that the course of reading just mentioned includes one theory which, though itself an imperfect one, receives a tolerably complete development—I mean the theory of singly periodic functions; but it is dispersed in such small fragments among the various subjects that it does not naturally present itself to the mind as a whole. If we could commence this theory by considering analytically the forms and necessary properties of functions of one period (thus obtaining their definitions as series and products), and could then proceed to a detailed discussion of the functions so defined—including their derivatives, the integrals involving them, the representation of functions by their means in series (Fourier's theorem), &c.—we should obtain a connected system of results relating to a definite branch of knowledge which would give a good idea of the orderly development of a mathematical theory; but the fact that the student at the time of his introduction to sines and cosines is supposed to be ignorant of all but the most elementary algebra, places great difficulties in the way of any such systematic treatment of the subject.

Passing now to the consideration of pure mathematics itself, that is to say, of the abstract sciences, which can only be conquered and explored by mathematical methods, it is difficult not to feel somewhat appalled by the enormous development they have received in the last fifty years. The mass of investigation, as measured by pages in Transactions and Journals, which is annually added to the literature of the subject, is so great that it is fast becoming bewildering from its mere magnitude, and the extraordinary extent to which many special lines of study have been carried. To those who believe, if any such there are, that mathematics exists for the sake of its applications to the concrete sciences, it must indeed seem that it has long since run wild, and expanded itself into a thousand useless extravagances. Even the mathematician must sometimes ask himself the question—not infrequently put to him by his friends—"To what is it all tending? What will be the result of it all? Will there be any end?" The last question is readily answered. There certainly can be no end; so wide and so various are the subjects of investigation, so interesting and fascinating the results, so wonderful the fields of research laid open at each succeeding advance—no matter in what direction—that we may be sure that, while the love of learning and knowledge continue to exist in the human mind, there can be no relaxation of our efforts to penetrate still further into the mysterious worlds of abstract truth which lie so temptingly spread before us. The more that is accomplished, the more we see remaining to be done. Every real advance, every great discovery, suggests new fields of inquiry, displays new paths and highways, gives us new glimpses of distant scenery. This wonderful suggestiveness is itself one of the marks of a true theory, one of the signs by which we know that we are investigating the actual, existing truths of Nature, and that our symbols and formulæ are expressing facts quite independent of themselves, though decipherable only by their means. As for the other questions, it is very difficult to render intelligible, even to a mathematician, the kind of knowledge acquired by mathematical research in a new field until he has made himself acquainted with its processes and notation, and we cannot hope to find in the remote regions of an abstract science many results so simple and striking as to appeal forcibly to the imagination of those who are unfamiliar with its conceptions and ideas. It would seem, therefore, that the question, "To what is it all tending?" could never be answered in general terms. I do not think any mathematician could see his way to a reply, or even give definite meaning to the question. He might feel daring enough to predict the probable drift of his own subject, but he could scarcely get a broad-enough view to enable him to indulge his fancy with respect to more than a very minute portion of the field already open to mathematical investigation. To the outsider I am afraid that the subject will continue to present much the same appearance as it does now; it will always seem to be stretching out into limitless symbolic wastes, without producing any results at all commensurate with its expansion.

Instead of attempting to consider the general question of what may be expected to result from the progress of mathematical science, we may restrict ourselves to asking whether the great extension of the bounds of the subject which is taking place in our time will materially add to its powers as a weapon of research in the concrete subjects. This is a question of the highest interest, and one that cannot fail to have occupied the thoughts of every mathematician at some time or another in the course of his work. For my own part, I do not think that the bearing of the modern developments of mathematics upon the physical sciences is likely to be very direct or immediate. It would indeed be rash to assert that there is any branch of mathematics so abstract or so recondite that it might not at any moment find an application in some concrete subject; still it seems to me that if the extension of the pure sciences could only be justified by the value of their applications, it is very doubtful whether a satisfactory plea for any further developments could be sustained. As a rule each subject involves its own ideas and its own special analysis, and it can only occasionally happen that analytical methods devised for the expression and development of one subject will be found to be appropriate for another. It is obvious also that the chance of such applications becomes less and less as we travel farther and farther from the elementary processes and methods which are common to all the exact sciences. There is a general resemblance of style running through much of the analysis required in the physical sciences, but there is no such resemblance in the case of the pure sciences, or between the pure and the physical sciences. It appears likely therefore that, in the future, the mathematical obstacles which present themselves in physical research will have to be overcome, as heretofore, by means of investigations undertaken for the purpose, and that analysis will continue to be enriched by conceptions and results, and even by whole subjects (such as spherical harmonics), which will be entirely due to the concrete sciences. Of course, it will sometimes happen that a differential equation or an integral has already been considered in connection with some other theory, or a whole body of analysis or geometry will suddenly be found to admit of a physical interpretation; but, after all, even the pure sciences themselves exert but an indirect effect upon the perfection of mathematical formulæ and processes, and we must be prepared to find that in general the requirements of physics have to be met by special analytical researches. Having now endeavoured to consider the proposed question impartially, and from a cold and rational standpoint, I cannot refrain from adding that, in spite of all I have said, I believe that every mathematician must cherish in his heart the conviction that at any moment some special analysis, devised in connection with a branch of pure mathematics, may bear wonderful fruit in one of the applied sciences, giving short and complete solutions of problems which could hitherto be treated only by prolix and cumbrous methods. For example, it is difficult to believe that the present unwieldy and imperfect treatment of the lunar theory is the most satisfactory that can be devised. We cannot but hope that some happy discovery in pure mathematics may replace the clumsy and tedious series of our day by simple and direct analytical methods exactly suited to the problem in question. In the different branches of pure mathematics, we find not infrequently that researches connected with one subject incidentally throw a flood of light upon another, and that we are thus led to solutions of problems and explanations of mysteries which would never have yielded to direct attack in the complete absence of any guide to the proper path to be pursued. So, too, in the lunar theory, if the direct attack should fail to supply any better treatment of the subject, we cannot but hope that some day the development of a new branch of mathematics, entirely unconnected with dynamics, may supply the key to the required method. It should be remembered also that dynamics, which differs from the pure sciences only by the inclusion of the laws of motion, is but little removed from them in the character of its more general problems.

It would seem at first sight as if the rapid expansion of the region of mathematics must be a source of danger to its future progress. Not only does the area widen, but the subjects of study increase rapidly in number, and the work of the mathematician tends to become more and more specialized. It is of course merely a brilliant exaggeration to say that no mathematician is able to understand the work of any other mathematician, but it is certainly true that it is daily becoming more and more difficult for a mathematician to keep himself acquainted, even in a general way, with the progress of any of the branches of mathematics except those which form the field of his own labours. I believe, however, that the increasing extent of the territory of mathematics will always be counteracted by increased facilities in the means of communication. Additional knowledge opens to us new principles and methods which may conduct us with the greatest ease to results which previously were most difficult of access; and improvements in notation may exercise the most powerful effects both in the simplification and accessibility of a subject. It rests with the worker in mathematics not only to explore new truths, but to devise the language by which they may be discovered and expressed; and the genius of a great mathematician displays itself no less in the notation he invents for deciphering his subject than in the results attained. There are some theories in which the notation seems to arise so simply and naturally out of the subject itself, that it is difficult to realize that it could have required any creative power to produce it; but it may well have happened that in these very cases it was the discovery of the appropriate notation which gave the subject its first real start, and rendered it amenable to effective treatment. When the principles that underlie a theory have been well grasped, the proper notation almost necessarily suggests itself, if it has not been already discovered; but some sort of provisional notation is required in the early stages of a theory in order to make any progress at all, and the mathematician who first gains a real insight into the nature of a subject is almost sure to be the first to seize upon the right notation. I have great faith in the power of well-chosen notation to simplify complicated theories and to bring remote ones near; and I think it is safe to predict that the increased knowledge of principles and the resulting improvements in the symbolic language of mathematics will always enable us to grapple satisfactorily with the difficulties arising from the mere extent of the subject.

Quite distinct from the theoretical question of the manner in which mathematics will rescue itself from the perils to which it is exposed by its own prolific nature is the practical problem of finding means of rendering available for the student the results which have been already accumulated, and making it possible for a learner to obtain some idea of the present state of the various departments of mathematics. This is a problem which is common to all rapidly moving branches of science, although the difficulties are increased in the case of mathematics by its wide extent and the comparative smallness of the audience addressed. The great mass of mathematical literature will be always contained in Journals and Transactions, but there is no reason why it should not be rendered far more useful and accessible than at present by means of treatises or higher text-books. The whole science suffers from want of avenues of approach, and many beautiful branches of mathematics are regarded as difficult and technical merely because they are not easily accessible. Ten years ago I should have said that even a bad treatise was better than none at all. I do not say that now, but I feel very strongly that any introduction to a new subject written by a competent person confers a real benefit on the whole science. The number of excellent text-books of an elementary kind that are published in this country makes it all the more to be regretted that we have so few that are intended for the more advanced student. As an example of the higher kind of text-book, the want of which is so badly felt in many subjects, I may mention the second part of Prof. Chrystal's "Algebra" published last year, which in a small compass gives a great mass of valuable and fundamental knowledge that has hitherto been beyond the reach of an ordinary student, though in reality lying so close at hand. I may add that in any treatise or higher text-book it is always desirable that references to the original memoirs should be given, and, if possible, short historical notices also. I am sure that no subject loses more than mathematics by any attempt to dissociate it from its history.

There is no more striking feature in the mathematical literature of our day than the numerous republications in a collected form of the writings of the greatest mathematicians. These collected editions not only set before us as a whole the complete works of the masters of our science, but they make it possible for others besides those who reside in the vicinity of large libraries to become acquainted with the principal contributions with which it has been enriched in our century; and, besides being of immense advantage to the science at large, they even go some way towards supplying the want of systematic introductions to the advanced subjects. Among these republications the collected edition of Cayley's works, now in course of publication by the University of Cambridge, is deserving of especial notice. By undertaking this great work, not only in the lifetime of its author, but while in the full vigour of his powers, the University has secured the inestimable advantage of his own editorship, and thus, under the very best auspices, the world is now being placed in full possession of this grand series of memoirs, which already cover a period of nearly fifty years.

Although it may not be possible to contemplate the actual position of pure mathematics in this country with any great amount of enthusiasm, we may yet feel some satisfaction in reflecting that there is more cause for congratulation at present than there has been at any time in the last hundred and fifty years, and that we are far removed from the state of affairs which existed before the days of Cayley and Sylvester. Unfortunately, we cannot point with pride to any distinct school of the pure sciences corresponding to the Cambridge school of mathematical physics, and I am afraid that the old saying that we have generals without armies is as true as ever. For this there is no immediate remedy; a school must grow up gradually of itself, as the study of mathematical physics has grown up at Cambridge. I certainly should not wish, even if it were possible, to obtain more recruits for the pure sciences at the expense of the applied, nor do I desire to see the system of instruction which has found favour in this country so modified that pure mathematics could be carried on by narrow specialists. I should be sorry, for example, that a student, after learning algebra and differential calculus, should pass directly to the theory of curves, and devote himself to research in this field without ever having acquired a general knowledge of other branches of mathematics or of any of its applications. Every person who proposes to engage in mathematical research should be equipped at starting upon his career with some knowledge of at least all the subjects included in the first part of the Mathematical Tripos. From what I have said in an earlier portion of this address it may be inferred that, from the point of view of the pure mathematician, I think that the course of study, and some of the text-books, are capable of improvement, but I am satisfied that a general mathematical training such as the Tripos requires is of the greatest possible value to every student, and that without it he cannot even make a good decision as to the class of subjects to which he is likely to devote his labour with the best effect. If the student were brought by the shortest possible route to the frontier of one of the subjects, where a fruitful field of research was pointed out to him, there is no doubt that the amount of mathematical literature produced might be greatly increased, but I am sure that the advantage to science would not be proportional to this increased amount. I am convinced that no one should devote himself to the abstract sciences unless he feels strongly drawn to them by his tastes. These subjects are treated by means of a powerful symbolic language, and it is the business of the investigator to discriminate between equations and formulæ which represent valuable facts in Nature and those which are merely symbolic relations, deducible from others that are more fundamental, and having no special significance in the subject itself. The mathematician requires tact and good taste at every step of his work, and he has to learn to trust to his own instinct to distinguish between what is really worthy of his efforts and what is not; he must take care not to be the slave of his symbols, but always to have before his mind the realities which they merely serve to express. For these and other reasons it seems to me of the highest importance that a mathematician should be trained in no narrow school; a wide course of reading in the first few years of his mathematical study cannot fail to influence for good the character of the whole of his subsequent work.

Before leaving this part of my subject I should like to say a few words upon the subject of accuracy of form in the presentation of mathematical results. In other branches of science, where quick publication seems to be so much desired, there may possibly be some excuse for giving to the world slovenly or ill-digested work, but there is no such excuse in mathematics. The form ought to be as perfect as the substance, and the demonstrations as rigorous as those of Euclid. The mathematician has to deal with the most exact facts of Nature, and he should spare no effort to render his interpretation worthy of his subject, and to give to his work its highest degree of perfection. "*Pauca sed matura*" was Gauss's motto.

The Universities are the natural home of mathematics, and to them we chiefly owe its cultivation and encouragement. There is, however, one other much younger body whose services to our science should not be passed over in any survey of its present state—I mean the London Mathematical Society. Twenty-five years ago, upon its foundation, I think the most sanguine mathematician would scarcely have ventured to predict that it would so soon take the position that it has among the scientific institutions of the world. The continuous interest taken by its members in its meetings, and the number and value of the papers published by it, show how steadily the flame of mathematical inquiry is burning among us. I do not presume to assert that the interest taken in the pure sciences can be regarded as an index of the energy and power of a nation, but it is certain that mathematical research flourishes only in a vigorous community. The search after abstract truth for its own sake, without the smallest thought of practical application or return in any form, and the yearning desire to explore the unknown, are signs of the vitality of a people, which are among the first to disappear when decay begins.

In conclusion, I will refer in some detail to one special subject—the Theory of Numbers. It is much to be regretted that this great theory, perhaps the greatest and most perfect of all the mathematical theories, should have been so little cultivated in this country, and that no portion of it should ever have been included in an ordinary course of mathematical study. It may be said to date from the year 1801, when Gauss published his "Disquisitiones Arithmeticæ," so that it is nearly thirty years older than the Theory of Elliptic Functions, to which we may assign the date 1829, the year in which Jacobi's "Fundamenta Nova' appeared. But the latter theory has already found a congenial home among us, while the former is nowhere systematically studied, and is still without a text-book. The chapters in books upon Algebra which bear the title "Theory of Numbers" give a misleading idea of the nature of the subject, the results there given being mainly introductory lemmas of the simplest kind. The theory has nothing to do with arithmetic in the ordinary sense of the word, or numerical tables, or the representation of numbers by figures in the decimal system or otherwise. All its results are actual truths of the most fundamental kind, which must exist *in rerum naturâ*. Its principal branches are the theory of forms and the so-called complex theories. Such a proposition as that every prime number, which when divided by 4 leaves remainder 1, can always be expressed as the sum of two squares, and that this can be done in one way only, affords a good example of a very simple result in the theory of forms. It is entirely independent of any method of representing numbers, and merely asserts that if we have 5, 13, 17, 29, &c., things—let us say marbles, to fix the ideas—we can always succeed in so arranging them as to form them into two squares, and that for each number we can do this in but one way. Simple as such a theorem is to enunciate and comprehend, the demonstration is far from easy. This is characteristic of the whole subject; simple propositions, which we can easily discover by trial, and of the universal truth of which we can feel but little doubt, require for their demonstration a refined and intricate analysis, founded upon the most difficult and imaginative conceptions which mathematics has as yet attained to in its struggles to grapple with the actual problems of the worlds of thought and matter.

The theory of quantity consists of two distinct branches—one relating to discrete quantity, and the other to continuous quantity. To the latter branch belong algebra and all the ordinary subjects of pure mathematics; the former bears the name of the theory of numbers. Its truths are of the most absolute kind, involving only the notions of number and arrangement; in fact, if we imagine all the exact sciences ranged in order, it naturally takes its place at one end of the series. Different sciences appeal to different intellects with very different force, but there are some minds over which the absolute character of the fundamental truths that belong to this theory and the absolute precision of its methods exercise the strongest fascination, and excite an interest which neither the truths of geometry nor the most important discoveries depending upon the constitution of matter are capable of producing.

Many of the greatest masters of the mathematical sciences were first attracted to mathematical inquiry by problems relating to numbers, and no one can glance at the periodicals of the present day which contain questions for solution without noticing how singular a charm such problems still continue to exert. This interest in numbers seems implanted in the human mind, and it is a pity that it should not have freer scope in this country. The methods of the theory of numbers are peculiar to itself, and are not readily acquired by a student whose mind has for years been familiarized with the very different treatment which is appropriate to the theory of continuous magnitude; it is therefore extremely desirable that some portion of the theory should be included in the ordinary course of mathematical instruction at our Universities. From the moment that Gauss, in his wonderful treatise of 1801, laid down the true lines of the theory, it entered upon a new day, and no one is likely to be able to do useful work in any part of the subject who is unacquainted with the principles and conceptions with which he endowed it.

Undoubted the subject is a difficult and intricate one even in its elementary parts, but there can be but little doubt that when the processes which are now only read by specialists on their way to the border become more generally known and studied, they will be found to admit of great simplification. It is in fact a territory where there is quite as much scope for the mathematician in simplifying what has been already won as in securing new conquests. I hope that the apathy of so many years may lead to a splendid awakening in this country, and that our past neglect of this most beautiful theory may be atoned for in the future by special devotion and appreciation.

SECTION D.

BIOLOGY.

OPENING ADDRESS BY PROF. A. MILNES MARSHALL, M.A., M.D., D.SC., F.R.S., PRESIDENT OF THE SECTION.

As my theme for this morning's address I have selected the development of animals. I have made this choice from no desire to extol one particular branch of biological study at the expense of others, nor through failure to appreciate or at least admire the work done and the results achieved in recent years by those who are attacking the great problems of life from other sides and with other weapons.

My choice is determined by the necessity that is laid upon me, through the wide range of sciences whose encouragement and advancement are the peculiar privilege of this Section, to keep within reasonable limits the direction and scope of my remarks; and is confirmed by the thought that, in addressing those specially interested in and conversant with biological study, your President acts wisely in selecting as the subject-matter of his discourse some branch with which his own studies and inclinations have brought him into close relation.

Embryology, referred to by the greatest of naturalists as "one of the most important subjects in the whole round of natural history," is still in its youth, but has of late years thriven so mightily that fear has been expressed lest it should absorb unduly the attention of zoologists, or even check the progress of science by diverting interest from other and equally important branches.

Nor is the reason of this phenomenal success hard to find. The actual study of the processes of development; the gradual building up of the embryo, and then of the young animal, within the egg; the fashioning of its various parts and organs; the devices for supplying it with food, and for ensuring that the respiratory and other interchanges are duly performed at all stages—all these are matters of absorbing interest. Add to these the extraordinary changes which may take place after leaving the egg, the conversion, for instance, of the aquatic gill-breathing tadpole—a true fish as regards all essential points of its anatomy—into a four-legged frog, devoid of tail, and breathing by lungs; or the history of the metamorphosis by which the sea-urchin is gradually built up within the body of its pelagic larva, or the butterfly derived from its grub. Add to these again the far wider interest aroused by comparing the life-histories of allied animals, or by tracing the mode of development of a complicated organ, *e.g.* the eye or the brain, in the various animal groups, from its simplest commencement, through gradually increasing grades of efficiency, up to its most perfect form as seen in the highest animals. Consider this, and it becomes easy to understand the fascination which embryology exercises over those who study it.

But all this is of trifling moment compared with the great generalization which tells us that the development of animals has a far higher meaning; that the several embryological stages and the order of their occurrence are no mere accidents, but are forced on an animal in accordance with a law, the determination of which ranks as one of the greatest achievements of biological science.

The doctrine of descent, or of evolution, teaches us that as individual animals arise, not spontaneously, but by direct descent from pre-existing animals, so also is it with species, with families, and with larger groups of animals, and so also has it been for all time; that as the animals of succeeding generations are related together, so also are those of successive geologic periods; that all animals, living or that have lived, are united together by blood relationship of varying nearness or remoteness; and that every animal now in existence has a pedigree stretching back, not merely for ten or a hundred generations, but through all geologic time since the dawn of life on this globe.

The study of development, in its turn, has revealed to us that each animal bears the mark of its ancestry, and is compelled to discover its parentage in its own development: that the phases through which an animal passes in its progress from the egg to the adult are no accidental freaks, no mere matters of developmental convenience, but represent more or less closely, in more or less modified manner, the successive ancestral stages through which the present condition has been acquired.

Evolution tells us that each animal has had a pedigree in the past. Embryology reveals to us this ancestry, because every animal in its own development repeats this history, climbs up its own genealogical tree.

Such is the recapitulation theory, hinted at by Agassiz, and suggested more directly in the writings of von Baer, but first clearly enunciated by Fritz Müller, and since elaborated by many, notably by Balfour and by Ernst Haeckel.

It is concerning this theory, which forms the basis of the science of embryology, and which alone justifies the extraordinary attention this science has received, that I venture to address you this morning.

A few illustrations from different groups of animals will best explain the practical bearings of the theory, and the aid which it affords to the zoologist of to-day; while these will also serve to illustrate certain of the difficulties which have arisen in the attempt to interpret individual development by the light of past history—difficulties which I propose to consider at greater length.

A very simple example of recapitulation is afforded by the eyes of the sole, plaice, turbot, and their allies. These "flat fish" have their bodies greatly compressed laterally; and the two surfaces, really the right and left sides of the animal, unlike, one being white, or nearly so, and the other coloured. The flat fish has two eyes, but these, in place of being situated, as in other fish, one on each side of the head, are both on the coloured side. The advantage to the fish is clear, for the natural position of rest of a flat fish is lying on the sea bottom, with the white surface downwards and the coloured one upwards. In such a position an eye situated on the white surface could be of no use to the fish, and might even become a source of danger, owing to its liability to injury from stones or other hard bodies on the sea bottom.

No one would maintain that flat fish were specially created as such. The totality of their organization shows clearly enough that they are true fish, akin to others in which the eyes are symmetrically placed one on each side of the head, in the position they normally hold among vertebrates. We must therefore suppose that flat fish are descended from other fish in which the eyes are normally situated.

The recapitulation theory supplies a ready test. On employing it, *i.e.* on studying the development of the flat fish, we obtain a conclusive answer. The young sole on leaving the egg is shaped just as an ordinary fish, and has the two eyes placed symmetrically on the two sides of the head. It is only after the young fish has reached some size, and has begun to approach the adult in shape, and to adopt its habit of resting on one side on the sea bottom, that the eye of the side on which it rests becomes shifted forwards, then rotated on to the top of the head, and finally twisted completely over to the opposite side.

The brain of a bird differs from that of other vertebrates in the position of the optic lobes, these being situated at the sides instead of on the dorsal surface. Development shows that this lateral position is a secondarily acquired one, for throughout all the earlier stages the optic lobes are, as in other vertebrates, on the dorsal surface, and only shift down to the sides shortly before the time of hatching.

Crabs differ markedly from their allies, the lobsters, in the small size and rudimentary condition of their abdomen or "tail." Development, however, affords abundant evidence of the descent of crabs from macrurous ancestors, for a young crab at what is termed the Megalopa stage has the abdomen as large as a lobster or prawn at the same stage.

Molluscs afford excellent illustrations of recapitulation. The typical gastropod has a large spirally-coiled shell; the limpet, however, has a large conical shell, which in the adult gives no sign of spiral twisting, although the structure of the animal shows clearly its affinity to forms wtth spiral shells. Development solves the riddle at once, telling us that in its early stages the limpet embryo has a spiral shell, which is lost on the formation, subsequently, of the conical shell of the adult.

Recapitulation is not confined to the higher groups of animals, and the Protozoa themselves yield most instructive examples. A very striking case is that of Orbitolites, one of the most complex of the porcellanous Foraminifera, in which each individual during its own growth and development passes through the series of stages by which the cyclical or discoidal type of shell was derived from the simpler spiral form.

In *Orbitolites tenuissima*, as Dr. Carpenter has shown,[1] "the whole transition is actually presented during the successive stages of its growth. For it begins life as a Cornuspira, ... its shell forming a continuous spiral tube, with slight interruptions at the points at which its successive extensions commence; while its sarcodic body consists of a continuous coil with slight constrictions at intervals. The second stage consists in the opening out of its spire, and the division of its cavity at regular intervals by transverse septa, traversed by separate pores, exactly as in Peneroplis. The third stage is marked by the subdivision of the 'peneropline' chambers into chamberlets, as in the early forms of Orbiculina. And the fourth consists in the exchange of the spiral for the cyclical plan of growth, which is characteristic of Orbitolites; a circular disk of progressively increasing diameter being formed by the addition of successive annular zones around the entire periphery."

The shells both of Foraminifera and of Mollusca afford peculiarly instructive examples for the study of recapitulation. As growth of the shell is effected by the addition of new shelly matter to the part already existing, the older parts of the shell are retained, often unaltered, in the adult; and in favourable cases, as in *Orbitolites tenuissima*, all the stages of development can be determined by simple inspection of the adult shell.

It is important to remember that the recapitulation theory, if valid, must apply not merely in a general way to the development of the animal body, but must hold good with regard to the formation of each organ or system, and with regard to the later equally with the earlier phases of development.

Of individual organs, the brain of birds has been already cited. The formation of the vertebrate liver as a diverticulum from the alimentary canal, which is at first simple, but by the folding of its walls becomes greatly complicated, is another good example; as is also the development of the vomer in amphibians as a series of toothed plates, equivalent morphologically to the placoid scales of fishes, which are at first separate, but later on fuse together and lose the greater number of their teeth.

Concerning recapitulation in the later phases of development and in the adult animal, the mode of renewal of the nails or of the epidermis generally is a good example, each cell commencing its existence in an indifferent form in the deeper layers of the epidermis, and gradually acquiring the adult peculiarities as it approaches the surface, through removal of the cells lying above it.

The above examples, selected almost haphazard, will suffice to illustrate the theory of recapitulation.

The proof of the theory depends chiefly on its universal applicability to all animals, whether high or low in the zoological scale, and to all their parts and organs. It derives, also, strong support from the ready explanation which it gives of many otherwise unintelligible points.

Of these latter a familiar and most instructive instance is afforded by rudimentary organs, *i.e.* structures which, like the outer digits of the horse's leg, or the intrinsic muscles of the ear of a man, are present in the adult in an incompletely developed form, and in a condition in which they can be of no use to their possessors; or else structures which are present in the embryo, but disappear completely before the adult condition is attained—for example, the teeth of whalebone whales, or the branchial clefts of all higher vertebrates.

Natural selection explains the preservation of useful variations, but will not account for the formation and perpetuation of useless organs; and rudiments such as those mentioned above would be unintelligible but for recapitulation, which solves the problem at once, showing that these organs, though now useless, must have been of functional value to the ancestors of their present possessors, and that their appearance in the ontogeny of existing forms is due to repetition of ancestral characters. Such rudimentary organs are, as Darwin pointed out, of larger relative or even absolute size in the embryo than in the adult, because the embryo represents the stage in the pedigree in which they were functionally active.

Rudimentary organs are extremely common, especially among the higher groups of animals, and their presence and significance are now well understood. Man himself affords numerous and excellent examples, not merely in his bodily structure, but by his speech, dress, and customs. For the silent letter *b* in the word doubt, or the *w* of answer, or the buttons on his elastic side boots are as true examples of rudiments, unintelligible but for their past history, as are the ear muscles he possesses but cannot use, or the gill-clefts, which are functional in fishes and tadpoles, and are present, though useless, in the embryos of all higher vertebrates, which in their early stages the hare and the tortoise alike possess, and which are shared with them by cats and by kings.

Another consideration of the greatest importance arises from the study of the fossil remains of the animals that formerly inhabited the earth. It was the elder Agassiz who first directed attention to the remarkable agreement between the embryonic growth of animals and their palæontological history. He pointed out the resemblance between certain stages in the growth of young fish and their fossil representatives, and attempted to establish, with regard to fish, a correspondence between their palæontological sequence and the successive stages of embryonic development. He then extended his observations to other groups, and stated his conclusions in these words:—[1] "It may therefore be considered as a general fact, very likely to be more fully illustrated as investigations cover a wider ground, that the phases of development of all living animals correspond to the order of succession of their extinct representatives in past geological times."

This point of view is of the utmost importance. If the development of an animal is really a repetition of its ancestral history, then it is clear that the agreement or parallelism which Agassiz insists on between the embryological and palæontological records must hold good. Owing to the attitude which Agassiz subsequently adopted with regard to the theory of natural selection, there is some fear of his services in this respect failing to receive full recognition, and it must not be forgotten that the sentence I have quoted was written prior to the clear enunciation of the recapitulation theory by Fritz Müller.

The imperfection of the geological record has been often referred to and lamented. It is very true that our museums afford us but fragmentary pictures of life in past ages; that the earliest volumes of the history are lost, and that of others but a few torn pages remain to us; but the later records are in far more satisfactory condition. The actual number of specimens accumulated from the more recent formations is prodigious; facilities for consulting them are far greater than they were; the international brotherhood of science is now fully established, and the fault will be ours if the material and opportunities now forthcoming are not rightly and fully utilized.

By judicious selection of groups in which long series of specimens can be obtained, and in which the hard skeletal parts, which alone can be suitably preserved as fossils, afford reliable indications of zoological affinity, it is possible to test directly this correspondence between palæontological and embryological histories, while in some instances a single lucky specimen will afford us, on a particular point, all the evidence we require.

Great progress has already been made in this direction, and the results obtained are of the most encouraging description.

By Alexander Agassiz a detailed comparison was made between the fossil series and the developmental stages of recent forms in the case of the Echinoids, a group peculiarly well adapted for such an investigation. The two records agree remarkably in many respects, more especially in the independent evidence they give as to the origin of the asymmetrical forms from more regular ancestors. The gradually increasing complication in some of the historic series is found to be repeated very closely in the development of their existing representatives; and with regard to the whole group, Agassiz concludes that,[2] "comparing the embryonic development with the palæontological one, we find a remarkable similarity in both, and in a general way there seems to be a parallelism in the appearance of the fossil genera and the successive stages of the development of the Echini."

Neumayr has followed similar lines, and by him, as by other authorities on the group, there seems to be general agreement as to the parallelism between the embryological and palæontological records, not merely for Echini, but for other groups of Echinodermata as well.

The Tetrabranchiate Cephalopoda are an excellent group in which to study the problem, for though no opportunity has yet occurred for studying the embryology of the only surviving mem-

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[1] "On an Abyssal Type of the Genus Orbitolites," Phil. Trans., 1883, Part ii. p. 553.

[1] "Essay on Classification," 1859, p. 115.

[2] "Palæontological and Embryological Development." An Address before the American Association for the Advancement of Science, 1880.

ber of the group, the pearly nautilus, yet owing to the fact that growth of the shell is effected by addition of shelly matter to the part already present, and to the additions being made in such manner that the older part of the shell persists unaltered, it is possible, from examination of a single shell—and in the case of fossils the shells are the only part of which we have exact knowledge—to determine all the phases of its growth; just as in the shell of Orbitolites all the stages of development are manifest on inspection of an adult specimen.

In such a shell as nautilus or ammonites the central chamber is the oldest or first formed one, to which the remaining chambers are added in succession. If, therefore, the development of the shell is a repetition of ancestral history, the central chamber should represent the palæontologically oldest form, and the remaining chambers in succession forms of more and more recent origin. Ammonite shells present, more especially in their sutures, and in the markings and sculpturing of their surface, characters that are easily recognized, and readily preserved in fossils; and the group, consequently, is a very suitable one for investigation from this standpoint.

Würtenberger's admirable and well-known researches[1] have shown that in the Ammonites such a correspondence between historic and embryonic development does really exist; that, for example, in Aspidoceras the shape and markings of the shells in young specimens differ greatly from those of adults, and that the characters of the young shells are those of palæontologically older forms.

Another striking illustration of the correspondence between the palæontological and developmental records is afforded by the antlers of deer, in which the gradually increasing complication of the antler in successive years agrees singularly closely with the progressive increase in size and complexity shown by the fossil series from the Miocene age to recent times.

Of cases where a single specimen has sufficed to prove the palæontological significance of a developmental character, Archæopteryx affords a typical example. In recent birds the metacarpals are firmly fused with one another, and with the distal series of carpals; but in development the metacarpals are at first, and for some time, distinct. In Archæopteryx this distinctness is retained in the adult, showing that what is now an embryonic character in recent birds was formerly an adult one.

Other examples might easily be quoted, but these will suffice to show that the relation between palæontology and embryology, first enunciated by Agassiz, and required by the recapitulation theory, does in reality exist. There is much yet to be done in this direction. A commencement, a most promising commencement, has been made, but as yet only a few groups have been seriously studied from this standpoint.

It is a great misfortune that palæontology is not more generrally and more seriously studied by men versed in embryology, and that those who have so greatly advanced our knowledge of the early development of animals should so seldom have tested their conclusions as to the affinities of the groups they are concerned with by direct reference to the ancestors themselves, as known to us through their fossil remains.

I cannot but feel that, for instance, the determination of the affinities of fossil Mammalia, of which such an extraordinary number and variety of forms are now known to us, would be greatly facilitated by a thorough and exact knowledge of the development, and especially the later development, of the skeleton in their existing descendants, and I regard it as a reproach that such exact descriptions of the later stages of development should not exist, even in the case of our commonest domestic animals.

The pedigree of the horse has attracted great attention, and has been worked at most assiduously, and we are now, largely owing to the labours of American palæontologists, able to refer to a series of fossil forms commencing in the lowest Eocene beds, and extending upwards to the most recent deposits, which show a complete gradation from a more generalized mammalian type to the highly specialized condition characteristic of the horse and its allies, and which may reasonably be regarded as indicating the actual line of descent of the horse. In this particular case, more frequently cited than any other, the evidence is entirely palæontological. The actual development of the horse has yet to be studied, and it is greatly to be desired that it should be undertaken speedily. Klever's[2] recent work on the development of the teeth in the horse may be referred to as showing that important and unexpected evidence is to be obtained in this way.

A brilliant exception to the statement just made as to the want of exact knowledge of the later development of the more highly organized animals is afforded by the splendid labours of Prof. Kitchen Parker, whose recent death has deprived zoology of one of her most earnest and single-minded students, and zoologists, young and old alike, of a true and sincere friend. Prof. Parker's extraordinarily minute and painstaking investigations into the development of the vertebrate skull rank among the most remarkable of zootomical achievements, and afford a rich mine of carefully recorded facts, the full value and bearing of which we are hardly yet able to appreciate.

If further evidence as to the value and importance of the recapitulation theory were needed, it would suffice to refer to the influence which it has had on the classification of the animal kingdom. Ascidians and Cirripedes may be quoted as important groups, the true affinities of which were first revealed by embryology; and in the case of parasitic animals the structural modifications of the adult are often so great that but for the evidence yielded by development their zoological position could not be determined. It is now indeed generally recognized that in doubtful cases embryology affords the safest of all clues, and that the zoological position of such forms can hardly be regarded as definitely established unless their development, as well as their adult anatomy, is ascertained.

It is owing to this recapitulation theory that embryology has exercised so marked an influence on zoological speculation. Thus the formation in most, if not in all, animals of the nervous system and of the sense organs from the epidermal layer of the skin, acquired a new significance when it was recognized that this mode of development was to be regarded as a repetition of the primitive mode of formation of such organs; while the vertebral theory of the skull affords a good example of a view, once stoutly maintained, which received its death-blow through the failure of embryology to supply the evidence requisite in its behalf. The necessary limits of time and space forbid that I should attempt to refer to even the more important of the numerous recent discoveries in embryology, but mention may be very properly made here of Sedgwick's determination of the mode of development of the body cavity in Peripatus, a discovery which has thrown most welcome light on what was previously a great morphological puzzle.

We must now turn to another side of the question. Although it is undoubtedly true that development is to be regarded as a recapitulation of ancestral phases, and that the embryonic history of an animal presents to us a record of the race history, yet it is also an undoubted fact, recognized by all writers on embryology, that the record so obtained is neither a complete nor a straightforward one.

It is indeed a history, but a history of which entire chapters are lost, while in those that remain many pages are misplaced, and others are so blurred as to be illegible; words, sentences, or entire paragraphs are omitted, and worse still, alterations or spurious additions have been freely introduced by later hands, and at times so cunningly as to defy detection.

Very slight consideration will show that development cannot in all cases be strictly a recapitulation of ancestral stages. It is well known that closely allied animals may differ markedly in their mode of development. The common frog is at first a tadpole, breathing by gills, a stage which is entirely omitted by the West Indian Hylodes. A crayfish, a lobster, and a prawn are allied animals, yet they leave the egg in totally different forms. Some developmental stages, as the pupa condition of insects, or the stage in the development of a dogfish in which the œsophagus is imperforate, cannot possibly be ancestral stages. Or again, a chick embryo of say the fourth day is clearly not an animal capable of independent existence, and therefore cannot correctly represent any ancestral condition, an objection which applies to the developmental history of many, perhaps of most animals.

Haeckel long ago urged the necessity of distinguishing in actual development between those characters which are really historical and inherited, and those which are acquired or spurious additions to the record. The former he termed palingenetic or ancestral characters, the latter cenogenetic or acquired. The distinction is undoubtedly a true one, but an exceedingly difficult one to draw in practice. The causes which

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[1] "Studien über die Stammesgeschichte der Ammoniten. Ein geologischer Beweis für die Darwin'sche Theorie" (Leipzig, 1880.)

[2] "Zur Kenntniss der Morphogenese des Equidengebisses," [*Morphologisches Jahrbuch*, xv., 1889, p. 308.

prevent development from being a strict recapitulation of ancestral characters, the mode in which these came about, and the influence which they respectively exert, are matters which are greatly exercising embryologists, and the attempt to determine which has as yet met with only partial success.

The most potent and the most widely spread of these disturbing causes arise from the necessity of supplying the embryo with nutriment. This acts in two ways. If the amount of nutritive matter within the egg is small, then the young animal must hatch early, and in a condition in which it is able to obtain food for itself. In such cases there is of necessity a long period of larval life, during which natural selection may act so as to introduce modifications of the ancestral history, spurious additions to the text.

If, on the other hand, the egg contain within itself a considerable quantity of nutrient matter, then the period of hatching can be postponed until this nutrient matter has been used up. The consequence is that the embryo hatches at a much later stage of its development, and if the amount of food-material is sufficient, may even leave the egg in the form of the parent. In such cases the earlier developmental phases are often greatly condensed and abbreviated; and as the embryo does not lead a free existence, and has no need to exert itself to obtain food, it commonly happens that these stages are passed through in a very modified form, the embryo being, as in a four-day chick, in a condition in which it is clearly incapable of independent existence.

The nutrition of the embryo prior to hatching is most usually effected by granules of nutrient matter, known as food yolk, and embedded in the protoplasm of the egg itself; and it is on the relative abundance of these granules that the size of the egg chiefly depends.

Large size of eggs implies diminution of number of the eggs, and hence of the offspring; aud it can be well understood that while some species derive advantage in the struggle for existence by producing the maximum number of young, to others it is of greater importance that the young on hatching should be of considerable size and strength, and able to begin the world on their own account. In other words, some animals may gain by producing a large number of small eggs, others by producing a smaller number of eggs of larger size—*i.e.* provided with more food yolk.

The immediate effect of a large amount of food yolk is to mechanically retard the processes of development; the ultimate result is to greatly shorten the time occupied by development. This apparent paradox is readily explained. A small egg, such as that of Amphioxus, starts its development rapidly, and in about eighteen hours gives rise to a free-swimming larva, capable of independent existence, with a digestive cavity and nervous system already formed; while a large egg, like that of the hen, hampered by the great mass of food yolk by which it is distended, has, in the same time, made but very slight progress.

From this time, however, other considerations begin to tell. Amphioxus has been able to make this rapid start owing to its relative freedom from food yolk. This freedom now becomes a retarding influence, for the larva, containing within itself but a very scanty supply of nutriment, must devote much of its energies to hunting for, and to digesting its food, and hence its further development will proceed more slowly.

The chick embryo, on the other hand, has an abundant supply of food in the egg itself; it has no occasion to spend time searching for food, but can devote its whole energies to the further stages of its development. Hence, except in the earliest stages, the chick develops more rapidly than Amphioxus, and attains its adult form in a much shorter time.

The tendency of abundant food yolk to lead to shortening or abbreviation of the ancestral history, and even to the entire omission of important stages, is well known. The embryo of forms well provided with yolk takes short cuts in its development, jumps from branch to branch of its genealogical tree, instead of climbing steadily upwards.

Thus the little West Indian frog, Hylodes, produces eggs which contain a larger amount of food yolk than those of the common English frog. The young Hylodes is consequently enabled to pass through the tadpole stage before hatching—to attain the form of a frog before leaving the egg; and the tadpole stage is only imperfectly recapitulated, the formation of gills, for instance, being entirely omitted.

The influence of food yolk on the development of animals is closely analogous to that of capital in human undertakings. A new industry, for example that of pen-making, has often been started by a man working by hand and alone, making and selling his own wares; if he succeed in the struggle for existence, it soon becomes necessary for him to call in others to assist him, and to subdivide the work; hand labour is soon superseded by machines, involving further differentiation of labour; the earlier machines are replaced by more perfect and more costly ones; factories are built, agents engaged, and, in the end, a whole army of work-people employed. In later times a man commencing business with very limited means will start at the same level as the original founder, and will have to work his way upwards through much the same stages, *i.e.* will repeat the pedigree of the industry. The capitalist, on the other hand, is enabled, like Hylodes, to omit these earlier stages, and, after a brief period of incubation, to start business with large factories equipped with the most recent appliances, and with a complete staff of work-people, *i.e.* to spring into existence fully fledged.

There is no doubt that abundance of food-yolk is a direct and very frequent cause of the omission of ancestral stages from individual development; but it must not be viewed as a sole cause. It is quite impossible that any animal, except perhaps in the lowest zoological groups, should repeat all the ancestral stages in the history of the race; the limits of time available for individual development will not permit this. There is a tendency in all animals towards condensation of the ancestral history—towards striking a direct path from the egg to the adult.

This tendency is best marked in the higher, the more complicated members of a group; *i.e.* in those which have a longer and more tortuous pedigree; and though greatly strengthened by the presence of food yolk in the egg, is apparently not due to this in the first instance.

Thus the simpler forms of Orbitolites, as *O. tenuissima*, repeat in their development all the stages leading from a spiral to a cyclical shell; but in the more complicated species, as Dr. Carpenter has pointed out, there is a tendency towards precocious development of the adult characters, the earlier stages being hurried over in a modified form; while in the most complex examples, as in *O. complanata*, the earlier spiral stages may be entirely omitted, the shell acquiring almost from its earliest commencement the cyclical mode of growth. There is no question here of relative abundance of food yolk, but merely of early or precocious appearance of adult characters.

The question of the relations and influence of food yolk, involving as it does the larger or smaller size of the egg, is, however, merely a special side of the much wider question of the nutrition of the embryo, one of the most potent of the disturbing elements affecting development.

Speaking generally, we may say that large eggs are more often met with in the higher than the lower groups of animals. Birds and reptiles are cases in point, and, if mammals do not now produce large eggs, it is because a more direct and more efficient mode of nourishing the young by the placenta has been acquired by the higher forms, and has replaced the food yolk that was formerly present, and is now retained in quantity by Monotremes alone. Molluscs afford another good example, the eggs of Cephalopoda being of larger size than those of the less highly organized groups.

The large size of the eggs of Elasmobranchs, and perhaps that of Cephalopods also, may possibly be associated with the carnivorous habits of the animals; for it is of importance that forms which prey on other animals should hatch of considerable size and strength.

The influence of habitat must also be considered. It has long been noticed as a general rule that marine animals lay small eggs, while their fresh-water allies have eggs of much larger size. The eggs of the salmon or trout are much larger than those of the cod or herring; and the crayfish, though only a quarter the length of a lobster, lay eggs of actually larger size.

This larger size of the eggs of fresh-water forms appears to be dependent on the nature of the environment to which they are exposed. Considering the geological instability of the land as compared with the ocean, there can be no doubt that the fresh-water fauna is, speaking generally, derived from the marine fauna; and the great problem with regard to fresh-water life is to explain why it is that so many groups of animals which flourish abundantly in the sea should have failed to establish themselves in fresh water. Sponges and Cœlenterates abound in the sea, but their fresh-water representatives are extremely few in number; Echinoderms are exclusively marine: there are no fresh-water Cephalopods, and no Ascidians; and of the smaller groups of Worms, Molluscs, and Crustaceans, there are many that do not occur in fresh-water.

Direct experiment has shown that in many cases this distribution is not due to inability of the adult animals to live in fresh water; and the real explanation appears to be that the early larval stages are unable to establish themselves under such conditions. This interesting suggestion, which has been worked out in detail by Prof. Sollas,[1] undoubtedly affords an important clue. To establish itself permanently in fresh water an animal must either be fixed, or else be strong enough to withstand and make headway against the currents of the streams or rivers it inhabits, for otherwise it will in the long run be swept out to sea, and this consideration applies to larval forms equally with adults.

The majority of marine invertebrates leave the egg as minute ciliated larvæ; and such larvæ are quite incapable of holding their own in currents of any strength. Hence, it is only forms which have got rid of the free-swimming ciliated larval stage, and which leave the egg of considerable size and strength, that can establish themselves as fresh-water animals. This is effected most readily by the acquisition of food yolk—hence the large size of the eggs of fresh-water animals—and is often supplemented, as Sollas has shown, by special protective devices of a most interesting nature. For this reason fresh-water forms are not so well adapted as their marine allies for the study of ancestral history as revealed in larval or embryonic development.

Before leaving the question of food yolk, reference must be made to the proposal of the brothers Sarasin, to regard the yolk cells as forming a distinct embryonic layer, the lecithoblast,[2] distinct from the blastoderm. I do not desire to speak dogmatically on a point the full bearings of which are not yet apparent, but I venture to think that this suggestion will not commend itself to embryologists. The distinction between the yolk granules and the cells in which they are embedded is a real and fundamental one; but I see no reason for regarding the yolk cells as other than originally functional endoderm cells in which yolk granules have accumulated to such an extent that they have in extreme cases become devoted solely to the storing of food for the embryo.[3]

Of all the causes tending to modify development, tending to obscure or falsify the ancestral record, food yolk is the most frequent and the most important; its position in the egg determines the mode of segmentation; and its relative abundance affects profoundly the entire embryonic history, and decides at what particular stage, and of what size and form, the embryo shall hatch.

The loss of food yolk is another disturbing element, the full influence of which is as yet imperfectly understood, but the possibility of which must be always kept in mind. It is best known in the case of mammals, where it has led to apparent, though very deceptive, simplification of development; and it will probably not be until the embryology of the large-yolked Monotremes is at length described, that we shall fully understand the formation of the germinal layers in the higher placental mammals.

Amongst invertebrates we know but little as yet concerning the effects of loss of food yolk. It has been suggested that the extraordinary nature of the segmentation of the egg of *Peripatus capensis*, made known to us through Mr. Sedgwick's admirable researches, may be due to loss of food yolk; a suggestion which receives support from the long duration of uterine development in this case.

Our knowledge is very imperfect as to the ease with which food yolk may be acquired or lost; but until our information is more precise on this point, it seems unwise to lay much stress on suggested pedigrees which involve great and frequent alternations in the amount of food yolk present.

Of causes other than food yolk, or only indirectly connected with it, which tend to falsify the ancestral history, many are now known, but time will only permit me to notice the more important. These are distortion, whether in time or space; sudden or violent metamorphosis; a series of modifications, due chiefly to mechanical causes, and which may be spoken of as developmental conveniences; the important question of variability in development; and finally the great problem of degeneration.

Concerning distortions in time, all embryologists have noticed the tendency to anticipation or precocious development of characters which really belong to a later stage in the pedigree. The early attainment of the cyclical form in the shell of *Orbitolites complanata* is a case in point; and Würtemberger has specially noticed this tendency in Ammonites. Many early larvæ show it markedly, the explanation in this case being that it is essential for them to hatch in a condition capable of independent existence, *i.e.* capable, at any rate, of obtaining and digesting their own food.

Anachronisms, or actual reversal of the historical order of development of organs or parts, occur frequently. Thus the joint surfaces of bones acquire their characteristic curvatures before movement of one part on another is effected, and before even the joint cavities are formed.

Another good example is afforded by the development of the mesenterial filaments in Alcyonarians. Wilson has shown in the case of Renilla that in the development of an embryo from the egg the six endodermal filaments appear first, and the two long ectodermal filaments at a later period; but that in the formation of a bud this order of development is reversed, the ectodermal filaments being the first formed. He suggests, in explanation, that, as the endodermal filaments are the digestive organs, it is of primary importance to the free embryo that they should be formed quickly. The long ectodermal filaments are chiefly concerned with maintaining currents of water through the colony; in bud-development they appear before the endodermal filaments, because they enable the bud during its early stages to draw nutrient matter from the body fluid of the parent; while the endodermal filaments cannot come into use until the bud has acquired both mouth and tentacles.

The completion of the ventricular septum in the heart of higher vertebrates before the auricular septum is a well-known anachronism, and every embryologist could readily furnish many other cases.

A curious instance is afforded by the development of the teeth in mammals, if recent suggestions as to the origin of the milk dentition are confirmed, and the milk dentition prove to be a more recent acquisition than the permanent one.[1]

But the most important cases in reference to distortion in time concern the reproductive organs. If development were a strict and correct recapitulation of ancestral history, then each stage would possess reproductive organs in a mature condition. This is not the case, and it is clearly of the greatest importance that it should not be. It is true that the first commencement of the reproductive organs may occur at a very early larval stage, or even that the very first step in development may be a division of the egg into somatic and reproductive cells; and it is possible that, as maintained by Weismann, this latter condition is a primitive one. Still, even in these cases the reproductive organs merely commence their development at these early stages, and do not become functional until the animal is adult.

Exceptionally in certain animals, and as a normal occurrence in others, precocious maturation of the reproductive organs takes place, and a larval form becomes capable of sexual reproduction. This may lead to arrest of development, either at a late larval period, as in the Axolotl, or at successively earlier and earlier stages, as in the gonophores of the Hydromedusæ, until finally the extreme condition seen in Hydra is produced.

We do not know the causes that determine the period, whether late or early, at which the reproductive organs ripen, but the question is one of great interest and importance and deserves careful attention. The suggestion has been made that entire groups of animals, such as the Mesozoa, are merely larvæ, arrested through such precocious acquiring of reproductive power, and it is conceivable that this may be the case. Mesozoa are a puzzling group in which the life-history, though known with tolerable completeness, has as yet given us no reliable clue concerning their affinities to other animals—a tantalizing distinction that is shared with them by Rotifers and Polyzoa.

Distortion of a curious kind is seen in cases of abrupt metamorphosis, where, as in the case of many Echinoderms, of Phoronis, and of the metabolic insects, the larva and the adult differ greatly in form, habits, mode of life, and very usually in

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[1] "On the Origin of Freshwater Faunas," Scientific Transactions of the Royal Dublin Society, vol. iii. Ser. II, 1886.

[2] "Ergebnisse naturwissenschaftlicher Forschungen auf Ceylon," Bd. ii. Heft. iii., 1889.

[3] *Cf.* E. B. Wilson, "The Development of Renilla," Phil. Trans., 1883, p. 755.

[1] *Cf.* Thomas Oldfield, "On the Homologies and Succession of the Teeth in the Dasyuridæ, with an attempt to trace the history of the evolution of the Mammalian teeth in general," Phil. Trans., 1887.

the nature of their food and the mode of obtaining it; and the transition from one stage to the other is not a gradual but an abrupt one, at any rate so far as external characters are concerned.

Sudden changes of this kind, as from the free-swimming Pluteus to the creeping Echinus, or from the sluggish leaf-eating caterpillar to the dainty butterfly, cannot possibly be recapitulatory, for even if small jumps are permissible in Nature, there is no room for bounds forward of this magnitude. Cases of abrupt metamorphosis may always be viewed as due to secondary modifications, and rarely, if ever, have any significance beyond the particular group of animals concerned. For example, a Pluteus larva may be recognized as belonging to the group of Echinoidea before the adult urchin has commenced to be formed within it, and the Lepidopteran caterpillar is already an unmistakable insect. Hence, for the explanation of the metamorphoses in these cases it is useless to look outside the groups of Echinoidea and Insecta respectively.

Abrupt metamorphosis is always associated with great change in external form and appearance, and in mode of life, and very usually in mode of nutrition. A gradual transition in such cases is inadmissible, because in the intermediate stages the animal would be adapted to neither the larval nor the adult condition; a gradual conversion of the biting mouth parts of the caterpillar to the sucking proboscis of a moth would inevitably lead to starvation. The difficulty is evaded by retaining the external form and habits of one particular stage for an unduly long period, so that the relations of the animal to the surrounding environment remain unchanged, while internally preparations for the later stages are in progress. Cinderella and the princess are equally possible entities, each being well adapted to her environment. The exigencies of the situation do not permit, however, of a gradual change from one to the other: the transformation, at least as regards external appearance, must be abrupt.

Kleinenberg has recently directed attention to cases in which the larval and adult organs develop independently; the larval nervous system, for instance, aborting completely and forming no part of that of the adult. I am not sure that I fully understand Kleinenberg's argument, but it seems very possible that such cases, which are probably far more numerous than is yet admitted, may be due to what may be termed the telescoping of ancestral stages one within another, which takes place in actual development, and may accordingly be grouped under the head of developmental convenience. Undue prolongation of an early ancestral stage, as in cases of abrupt metamorphosis, must involve modification, especially in the muscular and nervous systems; in such cases a telescoping of ancestral stages takes place, as we have seen, the adult being developed within the larva. Such telescoping must distort the recapitulatory history, and as the shape of the larva and adult may differ widely, an independent origin of organs, especially the muscular and nervous systems, may be acquired secondarily.

The stage in the development of Squilla, in which the three posterior maxillipedes disappear completely, to reappear at a later stage in a totally different form, is not to be interpreted as meaning that the adult maxillipedes are entirely new structures unconnected historically with those of the larva. Neither is the annual shedding of the antlers of deer to be regarded as the repetition of an ancestral hornless condition intercalated historically between successive stages provided with antlers. In both cases the explanation is afforded by convenience, whether of the embryo or adult.

Many embryological modifications or distortions may be attributed to mechanical causes, and may fairly be considered under the head of developmental conveniences.

The amnion of higher vertebrates is a case in point, and is probably rightly explained as due in the first instance to sinking or depression of the embryo into the yolk, in order to avoid distortion through pressure against a hard unyielding eggshell. A similar device is employed, presumably for the same reason, in the early development of many insect embryos; and the depression of the Tænia head within the cyst is a phenomenon of very similar nature.

Restriction of the space within which development occurs often causes displacement or distortion of organs, whose growth, restricted in its normal direction, takes place along the lines of least resistance. The telescoping of the limbs and other organs within the body of an insect larva is a simple case of such distortion; and a more complicated example, closely comparable in many ways to the invagination of the Tænia head, is afforded by the remarkable inversion of the germinal layers in rodents, first described by Bischoff in the guinea-pig, and long believed to be peculiar to that animal, but subsequently and simultaneously discovered by three independent observers—Kupffer, Selenka, and Fraser—to occur in varying degrees in rats, mice, and in other rodents.

One of the most recent attempts to explain developmental peculiarities as due to mechanical causes is Mr. Dendy's suggestion with regard to the pseudogastrula stage in the development of the calcareous sponges. It is well known that, while the larva is in the amphiblastula stage, and still embedded in the tissues of the parent, the granular cells become invaginated within the ciliated cells, giving rise to the pseudogastrula stage. At a slightly later stage, when the larva becomes free, the invaginated granular cells become again everted, and the larva spherical in shape; while still later invagination occurs once more, the ciliated cells being this time invaginated within the granular cells. The significance of the pseudogastrula stage has hitherto been undetermined, but Mr. Dendy points out that the larva always occupies a definite position with reference to the parental tissues; that the ciliated half of the larva is covered by a soft and yielding wall, while the opposite half, composed of the granular cells, is covered by a layer stiffened with rigid spicules; and his observations on the growth of the larva lead him to think that the pseudogastrula stage is brought about mechanically by flattening of the granular cells through pressure against this rigid wall of spicules.

Embryology supplies us with many unsolved problems, and it is not to be wondered at that this should be the case. Some of these may fairly be spoken of as mere curiosities of development, while others are clearly of greater moment. I do not propose to catalogue these, but will merely mention two or three which I happen to have recently run my head against, and remember vividly.

The solid condition of the œsophagus, in Elasmobranch embryos, first noticed by Balfour, is a very curious point. The œsophagus has at first a well-developed lumen, like the rest of the alimentary canal; but at an early period, stage K of Balfour's nomenclature, the part of the œsophagus overlying the heart, and immediately behind the branchial region, becomes solid, and remains solid for a long time, the exact date of reappearance of the lumen not being yet ascertained.

Mr. Bles and myself have recently noticed that a similar solidification of the œsophagus occurs in tadpoles of the common frog. In young free-swimming tadpoles the œsophagus is perforate, but in tadpoles of about 7½ mm. length it becomes solid and remains so until a length of about 10½ mm. has been attained. The solidification occurs at a stage closely corresponding with that in which it first appears in the dogfish, and a curious point about it is that in the frog the œsophagus becomes solid just before the mouth-opening is formed, and remains solid for some little time after this important event.

This closing of the œsophagus clearly cannot be recapitulation, but the fact that it occurs at corresponding periods in the frog and dogfish suggests that it may possibly, as Balfour hinted, "turn out to have some unsuspected morphological bearing."

Another developmental curiosity is the duplication of the gill-slits by growth downwards of tongues from their dorsal margins; a duplication which is described as occurring in Amphioxus and in Balanoglossus, but in no other animal; and the occurrence of which, in apparently closely similar fashion, is one of the strongest arguments in favour of a real affinity between these two forms. It is hardly possible that such a modification should have been acquired independently twice over.

A much more litigious question is the significance of the neurenteric canal of vertebrates, that curious tubular communication between the central canal of the nervous system and the hinder end of the alimentary canal that is conspicuously present in the embryos of lower vertebrates, and retained in a more or less disguised condition in the higher groups as well.

The neurenteric canal was discovered by that famous embryologist Kowalevsky in Ascidians and in Amphioxus. He drew special attention to the occurrence of a stage in both Ascidians and in Amphioxus in which the larva is free-swimming and in which the sole communication between the alimentary cavity and the exterior is through the neurenteric canal and the central canal of the nervous system; and suggested[1] that animals may

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[1] "Weitere Studien über die Entwickelungs-Geschichte des *Amphioxus lanceolatus*" (*Archiv für mikroskopische Anatomie*, Bd. xiii., 1877, p. 201).

have existed or may still exist in which the nerve tube fulfilled a non-nervous function, and possibly acted as part of the alimentary canal, a suggestion that has recently been revived in a somewhat extravagant form.

A passage of food particles into the alimentary cavity through the neural tube has not yet been seen, and probably does not occur, as the larva still possesses sufficient food yolk to carry it on in its development. It is therefore permissible to hold that the neurenteric canal may be a mere embryological device, and devoid of any deep morphological significance.

The question of variation in development is one of very great importance, and has perhaps not yet received the attention it deserves. We are in some danger of assuming tacitly that the mode of development of allied animals will necessarily agree in all important respects or even in details, and that if the development of one member of a group be known, that of the others may be assumed to be similar. The more recent progress of embryology is showing us that such inferences are not safe, and that in allied genera or species, or even in different individuals of the same species, variations of development may occur affecting important organs and at almost any stage in their formation.

Great individual variations in the earliest processes of development, *i.e.* the segmentation of the egg, have been described by different writers.

In Renilla, Wilson found an extraordinary range of variation in the segmentation of eggs from which apparently identical embryos were produced. In some cases the egg divided into two in the normal manner; in other cases it divided at once into eight, sixteen, or thirty-two segments, which in different specimens were approximately equal or markedly unequal in size. Sometimes a preliminary change of form occurred without any further result, the egg returning to its spherical shape, and pausing for a time before recommencing the attempt to segment. Segmentation sometimes commenced at one pole, as in telolecithal eggs, with the formation of four or five small segments, the rest of the egg breaking up later, either simultaneously or progressively, into segments about equal in size to those first formed; while lastly, in some instances segmentation was very irregular, following no apparent law.

It is noteworthy that the variability in the case of Renilla is apparently confined to the earliest stages, for whatever the mode of segmentation, the embryos in their later stages were indistinguishable from one another.

Similar modifications in the segmentation of the egg have been described in the oyster by Brooks, in Anodon and other Mollusca, in Hydra, and in Lumbricus, in which last Wilson has recently shown that marked differences occur in the eggs even of the same individual animal. In the different species of Peripatus there appear also to be considerable variations in the details of segmentation.

In the early embryonic stages after the completion of segmentation very considerable variation may occur in allied species or genera. Among Cœlenterates, for instance, the mode of formation of the hypoblast presents most perplexing modifications: it may arise as a true gastrula invagination; as cells budded off from one pole of the blastula into its cavity; as cells budded off from various parts of the wall of the blastula; by delamination or actual division of each cell of the blastula wall; or it may be present from the start as a solid mass of cells inclosed by the epiblast cells. It is in connection with these variations that controversy has arisen as to the primitive mode of development of the gastrula, a point to which I shall return later on.

Among the higher Metazoa or Cœlomata the extraordinary modifications in the position and in every conceivable detail of formation of the mesoblast in different and often in closely allied forms have given rise to ardent discussion, and have led to the proposal of theory after theory, each rejected in turn as only affording a partial explanation, and now culminating in Kleinenberg's protest against the use of the term mesoblast at all, at any rate in a sense implying any possibility of comparison with the primary layers, epiblast and hypoblast, of Cœlenterata.

This is not the place to attempt to decide so difficult and technical a point, even were I capable of so doing, but we may well take warning from this extraordinary diversity of development, the full extent of which I believe we as yet realize most imperfectly, that in our attempts to reconstruct ancestral history from ontogenetic development we have taken in hand no light task. To reconstruct Latin from modern European languages would in comparison be but child's play.

Of the readiness with which special developmental characters are acquired by allied animals the brothers Sarasin[1] have given us evidence in the extraordinary modifications presented by the embryonic and larval respiratory organs of Amphibians.

Confining ourselves to those forms which do not lay their eggs in water, and in which consequently development takes place within the egg, we find that Ichthyophis and Salamandra have three pairs of specially modified external gills. Nototrema has two pairs; Alytes and Typhlonectes have only a single pair, which in the latter genus take the form of enormous leaf-like outgrowths from the sides of the neck. In Hylodes and Pipa there are no gills, the tail acting as the larval respiratory organ; and in *Rana opisthodon*, according to Boulenger, larval respiration is effected by nine pairs of folds of the skin of the ventral surface of the body.

Most of these extraordinarily diversified organs are clearly secondarily acquired structures; it is possible that they all are, and that external gills, as was suggested by Balfour for Elasmobranchs, are to be regarded as embryonal respiratory organs acquired by the larvæ, and of no ancestral value. The point, however, cannot be considered settled, for on this view the external gills of Elasmobranchs and Amphibians would be independently acquired and not homologous structures, a view contradicted by the close agreement in their relations in the two groups, as well as by the absence of any real break between external and internal gills in Amphibians.

It is well known that the frog and the newt differ greatly in important points of their development. The two-layered condition of the epiblast in the frog is a marked point of difference, which involves further changes in the mode of formation of the nervous system and sense organs. The kidneys and their ducts differ considerably in their development in the two forms, as do also the blood-vessels.

Concerning the early development of the blood-vessels, there are considerable differences even between allied species of frogs. In *Rana esculenta* Maurer finds that there is at first in each branchial arch a single vessel or aortic arch, running directly from the heart to the aorta: from the cardiac end of this aortic arch a vessel grows out into the gill as the afferent branchial vessel, the original aortic arch losing its connection with the heart, and becoming the efferent branchial vessel. Afferent and efferent branchial vessels become connected by capillaries in the gill, and the course of the circulation, so long as gill-breathing is maintained, is from the heart through the truncus arteriosus to the afferent branchial vessel, then through the gill capillaries to the efferent branchial vessel, and then on to the aorta. When the pulmonary circulation is thoroughly established, the branchial circulation is cut off by the efferent vessel reacquiring its connection with the heart, when the blood naturally takes the direct passage along it to the aorta, and so escapes the gill capillaries.

In *Rana temporaria* the mode of development is very different: the afferent and efferent vessels arise in each arch independently and almost simultaneously: the afferent vessel soon acquires connection with the heart; but, unlike *R. esculenta*, the efferent vessel has no connection with the heart until the gills are about to atrophy.

In other words, the continuous aortic arch, from heart to aorta, is present in *R. esculenta* prior to the development of the gills: it becomes interrupted while the gills are in functional use, but is re-established when these begin to atrophy. In *R. temporaria*, on the other hand, there is no continuous aortic arch until the gills begin to atrophy.

The difference is an important one, for it is a matter of considerable morphological interest to determine whether the continuous aortic arch is primitive for vertebrates: *i.e.* whether it existed prior to the development of gills. This point could be practically settled if we could decide which of the two frogs, *R. esculenta* and *R. temporaria*, has most correctly preserved its ancestral history in this respect.

About this there can be little doubt. The development of the vessels in the newts, a less modified group than the frogs, agrees with that of *R. esculenta*, and interesting confirmation is afforded by a single aberrant specimen of *R. temporaria*, in which Mr. Bles and myself found the vessels developing after the type of *R.*

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[1] "Ergebnisse naturwissenschaftlicher Forschungen auf Ceylon," vol. ii. chap. i. pp. 24-38.

esculenta, i.e. in which a complete aortic arch was present before the gills were formed.

We are therefore justified in concluding that as regards the development of the branchial blood-vessels, *R. esculenta* has retained a primitive ancestral character which is lost in *R. temporaria*, and it is interesting to note that were our knowledge of the development of amphibians confined to the common frog, the most likely form to be studied, we should, in all probability, have been led to wrong conclusions concerning the ancestral condition of the blood-vessels in a point of considerable importance.

A matter which at present is attracting much attention is the question of degeneration.

Natural selection, though consistent with and capable of leading to steady upward progress and improvement, by no means involves such progress as a necessary consequence. All it says is that those animals will, in each generation, have the best chance of survival which are most in harmony with their environment, and such animals will not necessarily be those which are ideally the best or most perfect.

If you go into a shop to purchase an umbrella, the one you select is by no means necessarily that which most nearly approaches ideal perfection, but the one which best hits off the mean between your idea of what an umbrella should be and the amount of money you are prepared to give for it: the one, in fact, that is on the whole best suited to the circumstances of the case, or the environment for the time being. It might well happen that you had a violent antipathy to a crooked handle, or else were determined to have a catch of a particular kind to secure the ribs, and this might lead to the selection, *i.e.* the survival, of an article that in other and even in more important respects was manifestly inferior to the average.

So it is also with animals: the survival of a form that is ideally inferior is very possible. To animals living in profound darkness the possession of eyes is of no advantage, and forms devoid of eyes would not merely lose nothing thereby, but would actually gain, inasmuch as they would escape the dangers that might arise from injury to a delicate and complicated organ. In extreme cases, as in animals leading a parasitic existence, the conditions of life may be such as to render locomotor, digestive, sensory, and other organs entirely useless; and in such cases those forms will be best in harmony with their surroundings which avoid the waste of energy resulting from the formation and maintenance of these organs.

Animals which have in this way fallen from the high estate of their forefathers, which have lost organs or systems which their progenitors possessed, are commonly called degenerate. The principle of degeneration, recognized by Darwin as a possible, and, under certain conditions, a necessary consequence of his theory of natural selection, has been since advocated strongly by Dohrn, and later by Lankester in an evening discourse delivered before the Association at the Sheffield meeting in 1879. Both Dohrn and Lankester suggested that degeneration occurred much more widely than was generally recognized.

In animals which are parasitic when adult, but free-swimming in their early stages, as in the case of the Rhizocephala, whose life-history was so admirably worked out by Fritz Müller, degeneration is clear enough: so also is it in the case of the solitary Ascidians, in which the larva is a free-swimming animal with a notochord, an elongated tubular nervous system, and sense organs, while the adult is fixed, devoid of the swimming tail, with no notochord, and with a greatly reduced nervous system and aborted sense organs.

In such cases the animal, when adult, is, as regards the totality of its organization, at a distinctly lower morphological level, is less highly differentiated than it is when young, and during individual development there is actual retrograde development of important systems and organs.

About such cases there is no doubt; but we are asked to extend the idea of degeneration much more widely. It is urged that we ought not to demand direct embryological evidence before accepting a group as degenerate. We are reminded of the tendency to abbreviation or to complete omission of ancestral stages of which we have quoted examples above; and it is suggested that if such larval stages were omitted in all the members of a group we should have no direct evidence of degeneration in a group that might really be in an extremely degenerate condition.

Supposing, for instance, the free larval stages of the solitary Ascidians were suppressed, say through the acquisition of food yolk, then it is urged that the degenerate condition of the group might easily escape detection. The supposition is by no means extravagant; food yolk varies greatly in amount in allied animals, and cases like Hylodes, or amongst Ascidians Pyrosoma, show how readily a mere increase in the amount of food yolk in the egg may lead to the omission of important ancestral stages.

The question then arises whether it is not possible, or even probable, that animals which now show no indication of degeneration in their development are in reality highly degenerate, and whether it is not legitimate to suppose such degeneration to have occurred in the case of animals whose affinities are obscure or difficult to determine.

It is more especially with regard to the lower vertebrates that this argument has been employed; and at the present day, zoologists of authority, relying on it, do not hesitate to speak of such forms as Amphioxus and the Cyclostomes as degenerate animals, as wolves in sheep's clothing, animals whose simplicity is acquired and deceptive rather than real and ancestral.

I cannot but think that cases such as these should be regarded with some jealousy; there is at present a tendency to invoke degeneration rather freely as a talisman to extricate us from morphological difficulties; and an inclination to accept such suggestions, at any rate provisionally, without requiring satisfactory evidence in their support.

Degeneration of which there is direct embryological evidence stands on a very different footing from suspected degeneration, for which no direct evidence is forthcoming; and in the latter case the burden of proof undoubtedly rests with those who assume its existence.

The alleged instances among the lower vertebrates must be regarded particularly closely, because in their case the suggestion of degeneration is admittedly put forward as a means of escape from difficulties arising through theoretical views concerning the relation between vertebrates and invertebrates.

Amphioxus itself, so far as I can see, shows in its development no sign of degeneration, except possibly with regard to the anterior gut diverticula, whose ultimate fate is not altogether clear. With regard to the earlier stages of development, concerning which, thanks to the patient investigations of Kowalevsky and Hatschek, our knowledge is precise, there is no animal known to us in which the sequence of events is simpler or more straightforward. Its various organs and systems are formed in what is recognized as a primitive manner; and the development of each is a steady upward progress towards the adult condition. Food yolk, the great cause of distortion in development, is almost absent, and there is not the slightest indication of the former possession of a larger quantity. Concerning the later stages our knowledge is incomplete, but so much as has been ascertained gives no support to the suggestion of general degeneration.

Our knowledge of the conditions leading to degeneration is undoubtedly incomplete, but it must be noticed that the conditions usually associated with degeneration do not occur. Amphioxus is not parasitic, is not attached when adult, and shows no evidence of having formerly possessed food yolk in quantity sufficient to have led to the omission of important ancestral stages. Its small size as compared with other vertebrates is one of the very few points that can be referred to as possibly indicating degeneration, and will be considered more fully at a later point in my address.

A consideration of much less importance, but deserving of mention, is that in its mode of life Amphioxus not merely differs as already noticed from those groups of animals which we know to be degenerate, but agrees with some, at any rate, of those which there is reason to regard as primitive or persistent types. Amphioxus, like Balanoglossus, Lingula, Dentalium, and Limulus, is marine, and occurs in shallow water, usually with a sandy bottom, and, like the three smaller of these genera, it lives habitually buried almost completely in the sand, into which it burrows with great rapidity.

I do not wish to speak dogmatically. I merely wish to protest against a too ready assumption of degeneration; and to repeat that, so far as I can see, Amphioxus has not yet, either in its development, in its structure, or in its habits, been shown to present characters that suggest, still less that prove, the occurrence in it of general or extensive degeneration.

In a sense, all the higher animals are degenerate; that is, they can be shown to possess certain organs in a less highly developed condition than their ancestors, or even in a rudimentary state.

Thus a crab as compared with a lobster is degenerate in the matter of its tail, a horse as compared with Hipparion in regard to its outer toes; but it is neither customary nor advisable to speak of a crab as a degenerate animal compared to a lobster; to do so would be misleading. An animal should only be spoken of as degenerate when the retrograde development is well marked, and has affected not one or two organs only, but the totality of its organization.

It is impossible to draw a sharp line in such cases, and to limit precisely the use of the term degeneration. It must be borne in mind that no animal is at the top of the tree in all respects. Man himself is primitive as regards the number of his toes, and degenerate in respect to his ear muscles; and between two animals even of the same group it may be impossible to decide which of the two is to be called the higher and which the lower form.

Thus, to compare an oyster with a mussel. The oyster is more primitive than the mussel as regards the position of the ventricle of the heart and its relations to the alimentary canal; but is more modified in having but a single adductor muscle; and almost certainly degenerate in being devoid of a foot.

Care must also be taken to avoid speaking of an animal as degenerate in regard to a particular organ merely because that organ is less fully developed than in allied animals. An organ is not degenerate unless its present possessor has it in a less perfect condition than its ancestors had.

A man is not degenerate in the matter of the length of his neck as compared with a giraffe, nor as compared with an elephant in respect of the size of his front teeth, for neither elephant nor giraffe enters into the pedigree of man. A man is, however, degenerate, whoever his ancestors may have been, in regard to his ear muscles; for he possesses these in a rudimentary and functionless condition, which can only be explained by descent from some better equipped progenitor.

Closely connected with the question of degeneration is that of the size of animals, and its bearing on their structure and development; a problem noticed by many writers, but which has perhaps not yet received the attention it merits.

If we are right in interpreting the eggs of Metazoa as representing the unicellular or protozoan stage in their ancestry, then the small size of the egg may be viewed as recapitulatory.

But the gradual increase in size of the embryo, and its growth up to the adult condition, can only be regarded as representing in a most general way, if at all, the actual or even the relative sizes of the intermediate ancestral stages of the pedigree.

It is quite true that animals belonging to the lower groups are, as a general rule, of smaller size than those of higher grade; and also that the giants are met with among the highest members of each division. Cephalopoda are the highest molluscs, and the largest cephalopods greatly exceed in size any other members of the group; decapods are at once the highest and the largest crustaceans; and whales, the hugest animals that exist, or, so far as we know, that ever have existed, belong to the highest group of all, the mammalia. It would be easy to quote exceptions, but the general rule obtains admittedly.

However, although there may be, and probably is, a general parallelism between the increase in size from the egg to the adult, and the historical increase in size during the passage from lower to higher forms; yet no one could maintain that the sizes of embryos represent at all correctly those of the ancestors; that, for instance, the earliest birds were animals the size of a chick embryo at a time when avian characters first declared themselves, or that the ancestral series in all cases presented a steady progression in respect of actual magnitude.

In the lower animals, *e.g.*, in Orbitolites, the actual size of the several ancestral stages is probably correctly recapitulated during the growth of the adult; and it is very possible that it is so also in such forms as the solitary sponges. In higher animals, except in the early stages of those forms which are practically devoid of food yolk, and which hatch as pelagic larvæ, this certainly does not obtain.

This is clear enough, but is worth pointing out, for if, as most certainly is the case, the embryos of animals are actually smaller than the ancestral forms they represent, it is possible that the smallness of the embryo may have had some influence on its organization, and be responsible for some of the modifications in the ancestral history; and more especially for the disappearance of ancestral organs in free-swimming larvæ.

In adult animals the relation between size and structure has been very clearly pointed out by Herbert Spencer. Increased size involves by itself increased complexity of structure; the determining consideration being that while the surface area of the body increases as the squares of the linear dimensions, the mass of the body increases as their cubes.

If, for example, we imagine two animals of similar shape and proportions, but of different size; for the sake of simplicity, we may suppose them to be spherical, and that the diameter of one is twice that of the other; then the larger one will have four times the extent of surface of the smaller, but eight times its mass or bulk: and it is quite possible that while the extent of surface, or skin, in the smaller animal might suffice for the necessary respiratory and excretory interchanges, it would be altogether insufficient in the larger animal, in which increased extent of surface must be provided by foldings of the skin, as in the form of gills.

To take an actual instance; Limapontia is a minute nudibranchiate, or sea-slug, about the sixth of an inch in length; it has a smooth body, totally devoid of respiratory processes, while forms allied to it, but of larger size, have their extent of surface increased by branching processes, which often take the form of specialized gills.

This is a peculiarly instructive case, because Limapontia in its early developmental stages possesses a large spirally-coiled shell, and shows other evidence of descent from forms with specialized breathing organs. We are certainly right in associating the absence of respiratory organs in the adult with the small size of the animal; and comparison with allied forms suggests very strongly that there has been in its pedigree an actual reduction of size, which has led to the degeneration of the respiratory organs.

This is an important conclusion: it is a well-known fact that the smaller members of a group are, as a rule, more simply organized than the larger members, especially with regard to their respiratory and circulatory systems; but if we are right in concluding that reduction in size may be an actual cause of simplification or degeneration in structure, then we must be on our guard against assuming hastily that these smaller and simpler animals are necessarily primitive in regard to the groups to which they belong. It is possible, for instance, that the simplification or even absence of respiratory organs seen in Pauropus, in the Thysanura, and in other small Tracheata, may be a secondary character, acquired through reduction of size.

An interesting illustration of the law discussed above is afforded by the brains of mammals; it has been noticed by many anatomists that the extent of convolution, or folding of the surface of the cerebral hemispheres in mammals, is related not to the degree of intelligence of the animal, but to its actual size, a beaver having an almost smooth brain and a cow a highly complicated one. Jelgersma, and, independently of him, Prof. Fitzgerald,[1] have explained this as due to the necessity of preserving the due proportion between the outer layer of grey matter or cortex, which is approximately uniform in thickness, and the central mass of white matter. But for the foldings of the surface the proportion of white matter to grey matter would be far higher in a large than in a small brain.

It must not be forgotten, on the other hand, that many zoologists hold the view, in favour of which the evidence is steadily increasing, that the primitive or ancestral members of each group were of small size. Thus Fürbringer remarks, with regard to birds, that on the whole small birds show more primitive and simpler conditions of structure than the larger members of the same group. He expresses the opinion that the first birds were probably smaller than Archæopteryx, and notes that reptiles and mammals also show in their earlier and smaller types more primitive features than do their larger descendants. Finally, Fürbringer concludes that "it is therefore the study of the smaller members within given groups of animals which promises the best results as to their phylogeny."

Again, one of the most striking points with regard to the pedigree of the horse, as agreed on by palæontologists, is the progressive reduction in size which we meet with as we pass backwards in time from stage to stage. The Pliocene Hipparion was smaller than the existing horse, in fact about the size of a

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[1] Cf. Nature, June 5, 1890, p. 125.

donkey; the Miocene Mesohippus about equalled a sheep; while Eohippus, from the Lower Eocene deposits, was no larger than a fox. Not only is there good reason for holding that, as a rule, larger animals are descended from ancestors of smaller size, but there is also much evidence to show that increase in size beyond certain limits is disadvantageous, and may lead to destruction rather than to survival. It has happened more than once in the history of the world, and in more than one group of animals, that gigantic stature has been attained immediately before extinction of the group—a final and tremendous effort to secure survival, but a despairing and unsuccessful one. The Ichthyosauri, Plesiosauri, and other extinct reptilian groups, the Moas, and the huge extinct Edentates, are well-known examples, to which before long will be added the elephants and the whales, and, it may be, ironclads as well.

The whole question of the influence of size is of the greatest possible interest and importance, and it is greatly to be hoped that it will not be permitted to remain in its present uncertain and unsatisfactory condition.

It may be suggested that Amphioxus is an animal which has undergone reduction in size, and that its structural simplicity may, like that of Limapontia, be due, in part at least, to this reduction. Such evidence as we have tells against this suggestion; the first system to undergo degeneration in consequence of a reduction in size is the respiratory, and the respiratory organs of Amphioxus, though very simple, are also, for a vertebrate, unusually extensive.

We have now considered the more important of the influences which are recognized as affecting developmental history in such a way as to render the recapitulation of ancestral stages less complete than it might otherwise be, which tend to prevent ontogeny from correctly repeating the phylogenetic history. It may at this point reasonably be asked whether there is any way of distinguishing the palingenetic history from the later cenogenetic modifications grafted on to it—any test by which we can determine whether a given larval character is or is not ancestral.

Most assuredly there is no one rule, no single test, that will apply in all cases; but there are certain considerations which will help us, and which should be kept in view.

A character that is of general occurrence among the members of a group, both high and low, may reasonably be regarded as having strong claims to ancestral rank; claims that are greatly strengthened if it occurs at corresponding developmental periods in all cases; and still more if it occurs equally in forms that hatch early as free larvæ, and in forms with large eggs, which develop directly into the adult. As examples of such characters may be cited the mode of formation and relations of the notochord, and of the gill clefts of vertebrates, which satisfy all the conditions mentioned.

Characters that are transitory in certain groups, but retained throughout life in allied groups, may, with tolerable certainty, be regarded as ancestral for the former: for instance, the symmetrical position of the eyes in young flat fish, the spiral shell of the young limpet, the superficial positions of the madreporite in Elasipodous Holothurians, or the suckerless condition of the ambulacral feet in many Echinoderms.

A more important consideration is that if the developmental changes are to be interpreted as a correct record of ancestral history, then the several stages must be possible ones, the history must be one that could actually have occurred, *i.e.* the several steps of the history as reconstructed must form a series, all the stages of which are practicable ones.

Natural selection explains the actual structure of a complex organ as having been acquired by the preservation of a series of stages, each a distinct, if slight, advance on the stage immediately preceding it—an advance so distinct as to confer on its possessor an appreciable advantage in the struggle for existence. It is not enough that the ultimate stage should be more advantageous than the initial or earlier condition, but each intermediate stage must also be a distinct advance. If, then, the development of an organ is strictly recapitulatory, it should present to us a series of stages, each of which is not merely functional, but a distinct advance on the stage immediately preceding it. Intermediate stages, *e.g.* the œsophagus of the tadpole, which are not and could not be functional, can form no part of an ancestral series—a consideration well expressed by Sedgwick[1] thus: "Any phylogenetic hypothesis which presents difficulties from a physiological standpoint must be regarded as very provisional indeed."

A good example of an embryological series fulfilling these conditions is afforded by the development of the eye in the higher Cephalopoda. The earliest stage consists in the depression of a slightly modified patch of skin; round the edge of the patch the epidermis becomes raised up as a rim; this gradually grows inwards from all sides, so that the depressed patch now forms a pit, communicating with the exterior through a small hole or mouth. By further growth the mouth of the pit becomes still more narrowed, and ultimately completely closed, so that the pit becomes converted into a closed sac or vesicle; at the point at which final closure occurs, formation of cuticle takes place, which projects as a small transparent drop into the cavity of the sac; by formation of concentric layers of cuticle, this drop becomes enlarged into the spherical transparent lens of the eye, and the development is completed by histological changes in the inner wall of the vesicle, which convert it into the retina, and by the formation of folds of skin around the eye, which become the iris and the eyelids respectively.

Each stage in this developmental history is a distinct advance, physiologically, on the preceding stage, and, furthermore, each stage is retained at the present day as the permanent condition of the eye in some member of the group Mollusca.

The earliest stage, in which the eye is merely a slightly depressed and slightly modified patch of skin, represents the simplest condition of the Molluscan eye, and is retained throughout life in Solen. The stage in which the eye is a pit, with widely open mouth, is retained in the limpet; it is a distinct advance on the former, as through the greater depression the sensory cells are less exposed to accidental injury.

The narrowing of the mouth of the pit in the next stage is a simple change, but a very important step forwards. Up to this point the eye has served to distinguish light from darkness, but the formation of an image has been impossible. Now, owing to the smallness of the aperture, and the pigmentation of the walls of the pit which accompanies the change, light from any one part of an object can only fall on one particular part of the inner wall of the pit or retina, and so an image, though a dim one, is formed. This type of eye is permanently retained in the Nautilus.

The closing of the mouth of the pit by a transparent membrane will not affect the optical properties of the eye, and will be a gain, as it will prevent the entrance of foreign bodies into the cavity of the eye.

The formation of the lens by deposit of cuticle is the next step. The gain here is increased distinctness and increased brightness of the image, for the lens will focus the rays of light more sharply on the retina, and will allow a greater quantity of light, a larger pencil of rays from each part of the object, to reach the corresponding part of the retina. The eye is now in the condition in which it remains throughout life in the snail and other gastropods. Finally the formation of the folds of skin known as iris and eyelids provides for the better protection of the eye, and is a clear advance on the somewhat clumsy method of withdrawal seen in the snail.

The development of the vertebrate liver is another good but simpler example. The most primitive form of the liver is that of Amphioxus, in which it is present as a simple saccular diverticulum of the intestinal canal, with its wall consisting of a single layer of cells, and with blood-vessels on its outer surface. The earliest stage in the formation of the liver in higher vertebrates—the frog, for instance—is practically identical with this. In the frog the next stage consists in folding of the wall of the sac, which increases the efficiency of the organ by increasing the extent of surface in contact with the blood-vessels. The adult condition is attained simply by a continuance of this process; the foldings of the wall becoming more and more complicated, but the essential structure remaining the same—a single layer of epithelial cells in contact on one side with blood-vessels, and bounding on the other directly or indirectly the cavity of the alimentary canal.

It is not always possible to point out the particular advantage gained at each step even when a complete developmental series is known to us, but in such cases, as, for instance, in Orbitolites, our difficulties arise chiefly from ignorance of the particular conditions that confer advantage in the struggle for existence in the case of the forms we are dealing with.

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[1] "On the Early Development of the Anterior Part of the Wolffian Duct and Body in the Chick" (*Quarterly Journal of Microscopical Science*, vol. xxi., 1881, p. 456).

The early larval stages in the development of animals, and more especially those that are marine and pelagic in habit, have naturally attracted much attention, since in the absence, probably inevitable, of satisfactory palæontological evidence, they afford us the sole available clue to the determination of the mutual relations of the large groups of animals, or of the points at which these diverged from one another.

In attempting to interpret these early ontogenetic stages as actual ancestral forms, beyond which development at one time did not proceed, we must keep clearly in view the various disturbing causes which tend to falsify the ancestral record, such as the influence of food yolk, or of habitat, and the tendency of diminution in size to give rise to simplification of structure, a point of importance if it be granted that these free larvæ are of smaller size than the ancestral forms to which they correspond.

If, on the other hand, in spite of these powerful modifying causes, we do find a particular larval form occurring widely and in groups not very closely akin, then we certainty are justified in attaching great importance to it, and in regarding it as having strong claims to be accepted as ancestral for these groups.

Concerning these larval forms, and their possible ancestral significance, our knowledge has made no great advance since the publication of Balfour's memorable chapter on this subject; and I propose merely to allude briefly to a few of the more striking instances.

The earliest, the most widely spread, and the most famous of larval forms is the gastrula, which occurs in a simple or in a modified form in some members of each of the large animal groups. It is generally admitted that its significance is the same in all cases, and the evidence is very strong in favour of regarding it as a stage ancestral for all Metazoa. The difficulty arising from its varying mode of development in different forms is, however, still unsolved, and embryologists are not yet agreed whether the invaginate or delaminate form is the more primitive. In favour of the former is its much wider occurrence; in favour of the latter the fact that it is easy to picture a series of stages leading gradually from a unicellular protozoon to a blastula, a diblastula, and ultimately a gastrula, each stage being a distinct advance, both morphological and physiological, on the preceding stage; while in the case of the invaginate gastrula it is not easy to imagine any advantage resulting from a flattening or slight pitting in of one part of the surface, sufficient to lead to its preservation and further development.

Of larval forms later than the gastrula, the most important by far is the Pilidium larva, from which it is possible, as Balfour has shown, that the slightly later Echinoderm larva, as well as the widely spread Trochosphere larva, may both be derived. Balfour concludes that the larval forms of all Cœlomata, excluding the Crustacea and vertebrates, may be derived from one common type, which is most nearly represented now by the Pilidium larva, and which "was an organism something like a Medusa, with a radial symmetry." The tendency of recent phylogenetic speculations is to accept this in full, and to regard as the ancestor of Turbellarians and of all higher forms, a jelly-fish or ctenophoran, which, in place of swimming freely, has taken to crawling on the sea bottom.

Of the two groups excluded above, the Crustacea and the Vertebrata, the interest of the former centres in the much discussed problem of the significance of the Nauplius larva. There is now a fairly general agreement that the primitive Crustacea were types akin to the phyllopods, *i.e.* forms with elongated and many-segmented bodies, and a large number of pairs of similar appendages. If this is correct, then the explanation of the Nauplius stage must be afforded by the phyllopods themselves, and it is no use looking beyond this group for it. A Nauplius larva occurs in other Crustacea merely because they have inherited from their phyllopod ancestors the tendency to develop such a stage, and it is quite legitimate to hold that higher crustaceans are descended from phyllopods, and that the Nauplius represents in more or less modified form an earlier ancestor of the phyllopods themselves.

As to the Nauplius itself, the first thing to note is that, though an early larval form, it cannot be a very primitive form, for it is already an unmistakable crustacean; the absence of cilia, the formation of a cuticular investment, the presence of jointed schizopodous limbs, together with other anatomical characters, proving this point conclusively. It follows, therefore, either that the earlier and more primitive stages are entirely omitted in the development of Crustacea, or else that the Nauplius represents such an early ancestral stage, with crustacean characters, which properly belong to a later stage, thrown back upon it and precociously developed.

The latter explanation is the one usually adopted; but before the question can be finally decided, more accurate observations than we at present possess are needed concerning the stages intermediate between the egg and the Nauplius.

The absence of a heart in the Nauplius may reasonably be associated with the small size of the larva.

Concerning the larval forms of vertebrates, it is only in Amphioxus and the Ascidians that the earliest larval stages are free-living, independent animals. In both groups the most characteristic larval stage is that in which a notochord is present, and a neural tube, open in front, and communicating behind through a neurenteric canal with the digestive cavity, which has no other opening to the exterior. This is a very early stage, both in Amphioxus and Ascidians; but, so far as we know, it cannot be compared with any invertebrate larva. It is customary, in discussions on the affinities of vertebrates, to absolutely ignore the vertebrate larval forms, and to assume that their peculiarities are due to precocious development of vertebrate characteristics. It may turn out that this view of the matter is correct; but it has certainly not yet been proved to be so, and the development of both Amphioxus and Ascidians is so direct and straightforward that evidence of some kind may reasonably be required before accepting the doctrine that this development is entirely deceptive with regard to the ancestry of vertebrates.

Zoologists have not quite made up their minds what to do with Amphioxus: apparently the most guileless of creatures, many view it with the utmost suspicion, and not merely refuse to accept its mute protestations of innocence, but regard and speak of it as the most artful of deceivers. Few questions at the present day are in greater need of authoritative settlement.

That ontogeny really is a repetition of phylogeny must, I think, be admitted, in spite of the numerous and various ways in which the ancestral history may be distorted during actual development.

Before leaving the subject, it is worth while inquiring whether any explanation can be found of recapitulation. A complete answer can certainly not be given at present, but a partial one may, perhaps, be obtained.

Darwin himself suggested that the clue might be found in the consideration that at whatever age a variation first appears in the parent, it tends to reappear at a corresponding age in the offspring; but this must be regarded rather as a statement of the fundamental fact of embryology than as an explanation of it.

It is probably safe to assume that animals would not recapitulate unless they were compelled to do so: that there must be some constraining influence at work, forcing them to repeat more or less closely the ancestral stages. It is impossible, for instance, to conceive what advantage it can be to a reptilian or mammalian embryo to develop gill-clefts which are never used, and which disappear at a slightly later stage, or how it can benefit a whale, that in its embryonic condition it should possess teeth which never cut the gum, and which are lost before birth.

Moreover, the history of development in different animals or groups of animals, offers to us, as we have seen, a series of ingenious, determined, varied, but more or less unsuccessful efforts to escape from the necessity of recapitulating, and to substitute for the ancestral process a more direct method.

A further consideration of importance is that recapitulation is not seen in all forms of development, but only in sexual development, or, at least, only in development from the egg. In the several forms of asexual development, of which budding is the most frequent and most familiar, there is no repetition of ancestral phases; neither is there in cases of regeneration of lost parts, such as the tentacle of a snail, the arm of a starfish, or the tail of a lizard; in such regeneration it is not a larval tentacle, or arm, or tail, that is produced, but an adult one.

The most striking point about the development of the higher animals is that they all alike commence as eggs. Looking more closely at the egg and the conditions of its development, two facts impress us as of special importance: first, the egg is a single cell, and therefore represents morphologically the Protozoan, or earliest ancestral phase; secondly, the egg, before it can develop, must be fertilized by a spermatozoon, just as the stimulus of fertilization by the pollen-grain is necessary before the ovum of a plant will commence to develop into the plant-embryo.

The advantage of cross-fertilization in increasing the vigour of the offspring is well known, and in plants devices of the most varied and even extraordinary kind are adopted to ensure that such cross-fertilization occurs. The essence of the act of cross-fertilization, which is already established among Protozoa, consists in combination of the nuclei of two cells, male and female, derived from different individuals. The nature of the process is of such a kind that two individual cells are alone concerned in it; and it may, I think, be reasonably argued that the reason why animals commence their existence as eggs, *i.e.* as single cells, is because it is in this way only that the advantage of cross-fertilization can be secured, an advantage admittedly of the greatest importance, and to secure which natural selection would operate powerfully.

The occurrence of parthenogenesis, either occasionally or normally, in certain groups is not, I think, a serious objection to this view. There are very strong reasons for holding that parthenogenetic development is a modified form, derived from the sexual method. Moreover, the view advanced above does not require that cross-fertilization should be essential to individual development, but merely that it should be in the highest degree advantageous to the species, and hence leaves room for the occurrence, exceptionally, of parthenogenetic development.

If it be objected that this is laying too much stress on sexual reproduction, and on the advantage of cross-fertilization, then it may be pointed out in reply that sexual reproduction is the characteristic and essential mode of multiplication among Metazoa: that it occurs in all Metazoa, and that when asexual reproduction, as by budding, &c., occurs, this merely alternates with the sexual process which, sooner or later, becomes essential.

If the fundamental importance of sexual reproduction to the welfare of the species be granted, and if it be further admitted that Metazoa are descended from Protozoa, then we see that there is really a constraining force of a most powerful nature compelling every animal to commence its life-history in the unicellular condition, the only condition in which the advantage of cross-fertilization can be obtained; *i.e.* constraining every animal to begin its development at its earliest ancestral stage, at the very bottom of its genealogical tree.

On this view the actual development of any animal is strictly limited at both ends: it must commence as an egg, and it must end in the likeness of the parent. The problem of recapitulation becomes thereby greatly narrowed; all that remains being to explain why the intermediate stages in the actual development should repeat the intermediate stages of the ancestral history.

Although narrowed in this way, the problem still remains one of extreme difficulty.

It is a consequence of the theory of natural selection that identity of structure involves community of descent: a given result can only be arrived at through a given sequence of events: the same morphological goal cannot be reached by two independent paths. A negro and a white man have had common ancestors in the past; and it is through the long-continued action of selection and environment that the two types have been gradually evolved. You cannot turn a white man into a negro merely by sending him to live in Africa: to create a negro the whole ancestral history would have to be repeated; and it may be that it is for the same reason that the embryo must repeat or recapitulate its ancestral history in order to reach the adult goal.

I am not sure that we can at present get much further; but the above considerations give opportunity for brief notice of what is perhaps the most noteworthy of recent embryological papers, Kleinenberg's remarkable monograph on Lopadorhynchus.

Kleinenberg directs special attention to what is known to evolutionists as the difficulty with regard to the origin of new organs, which is to the effect that although natural selection is competent to account for any amount of modification in an organ after it has attained a certain size, and become of functional importance, yet that it cannot account for the earlier stages in the formation of an organ before it has become large enough or sufficiently developed to be of real use. The difficulty is a serious one: it is carefully considered by Mr. Darwin, and met completely in certain cases; but, as Kleinenberg correctly states, no general explanation has been offered with regard to such instances.

As such general explanation Kleinenberg proposes his theory of the development of organs by substitution. He points out that any modification of an organ or tissue must involve modification, at least in functional activity, of other organs. He then continues by urging that one organ may replace or be substituted for another, the replacing organ being in no way derived morphologically from the replaced or preceding organ, but having a genetic relation to it of this kind:—that it can only arise in an organism so constituted, and is dependent on the prior existence of the replaced organ, which supplies the necessary stimulus for its formation.

As an example he takes the axial skeleton of vertebrates. The notochord, formed by change of function from the wall of the digestive canal, is the sole skeleton of the lowest vertebrates, and the earliest developmental phase in all the higher forms. The notochord gives rise directly to no other organ, but is gradually replaced by other and unlike structures by substitution. The notochord is an intermediate organ, and the cartilaginous skeleton which replaces it is only intelligible through the previous existence of the notochord; while, in its turn, the cartilaginous skeleton gives way, being replaced, through substitution, by the bony skeleton.

The successive phases in the evolution of weapons might be quoted as an illustration of Kleinenberg's theory. The bow and arrow is a better weapon than a stick or stone; it is used for the same purpose, and the importance or need for a better weapon led to the replacement of the sling by the bow; the bow does not arise by further development or increasing perfection of the sling; it is an entirely new weapon, towards the formation of which the older and more primitive weapons have acted as a stimulus, and which has replaced these latter by substitution, while the substitution at a later date of firearms for the bow and arrow is merely a further instance of the same principle.

It is too early yet to realize the full significance of Kleinenberg's most suggestive theory; but if it be really true that each historic stage in the evolution of an organ is necessary as a stimulus to the development of the next succeeding stage, then it becomes clear why animals are constrained to recapitulate. Kleinenberg suggests further that the extraordinary persistence in embryonic life of organs which are rudimentary and functionless in the adult may also be explained by his theory, the presence of such organs in the embryo being indispensable as a stimulus to the development of the permanent structures of the adult.

It would be easy to point out difficulties in the way of the theory. The omission of historic stages in the actual ontogenetic development, of which almost all groups of animals supply striking examples, is one of the most serious; for if these stages are necessary as stimuli for the succeeding stages, then their omission requires explanation; while, if such stimuli are not necessary, the theory would appear to need revision.

Such objections may, however, prove to be less serious than they appear at first sight; and in any case Kleinenberg's theory may be welcomed as an important and original contribution, which deserves—indeed demands—the fullest and most careful consideration from all morphologists, and which acquires special interest from the explanation which it offers of recapitulation as a mechanical process, through which alone is it possible for an embryo to attain the adult structure.

That recapitulation does actually occur, that the several stages in the development of an animal are inseparably linked with and determined by its ancestral history, must be accepted. "To take any other view is to admit that the structure of animals and the history of their development form a mere snare to entrap our judgment."

Embryology, however, is not to be regarded as a master-key that is to open the gates of knowledge and remove all obstacles from our path without further trouble on our part; it is rather to be viewed and treated as a delicate and complicated instrument, the proper handling of which requires the utmost nicety of balance and adjustment, and which, unless employed with the greatest skill and judgment, may yield false instead of true results.

Embryology is indeed a most powerful and efficient aid, but it will not, and cannot, provide us with an immediate or complete answer to the great riddle of life. Complications, distortions, innumerable and bewildering, confront us at every step, and the progress of knowledge has so far served rather to increase the number and magnitude of these pitfalls than to teach us how to avoid them.

Still, there is no cause for despair—far from it; if our difficulties are increasing, so also are our means of grappling with them; if the goal appears harder to reach than we thought for, on the other hand its position is far better defined, and the means of approach, the lines of attack, are more clearly recognized.

One thing above all is apparent, that embryologists must not work single-handed, and must not be satisfied with an acquaintance, however exact, with animals from the side of development only; for embryos have this in common with maps, that too close and too exclusive a study of them is apt to disturb a man's reasoning power.

Embryology is a means, not an end. Our ambition is to explain in what manner and by what stages the present structure of animals has been attained. Towards this embryology affords most potent aid; but the eloquent protest of the great anatomist of Heidelberg must be laid to heart, and it must not be forgotten that it is through comparative anatomy that its power to help is derived.

What would it profit us, as Gegenbaur justly asks, to know that the higher vertebrates when embryos have slits in their throats, unless through comparative anatomy we were acquainted with forms now existing in which these slits are structures essential to existence? Anatomy defines the goal, tells us of the things that have to be explained; embryology offers a means, otherwise denied to us, of attaining it.

Comparative anatomy and palæontology must be studied most earnestly by those who would turn the lessons of embryology to best account, and it must never be forgotten that it is to men like Johannes Müller, Stannius, Cuvier, and John Hunter, the men to whom our exact knowledge of comparative anatomy is due, that we owe also the possibility of a science of embryology.

SECTION E.

GEOGRAPHY.

Opening Address by Lieutenant-Colonel Sir R. Lambert Playfair, K.C.M.G., H.M. Consul-General in Algeria, President of the Section.

The Mediterranean, Physical and Historical.

When the unexpected honour was proposed to me of presiding over your deliberations, I felt some embarrassment as to the subject of my address. Geography as a science and the necessity of encouraging a more systematic study of it, had been treated in an exhaustive manner during previous meetings. The splendid discoveries of Stanley and the prolonged experiences of Emin have been amply illustrated by the personal narrative of the former. The progress of geography during the past year has been fully detailed in the annual address of the President of the Royal Geographical Society in June last; so that it would be a vain and presumptuous endeavour for me to compress these subjects into the limits of an opening address. Closely connected with them are the magnificent experiments for opening out Africa which are being made by our merchant princes, amongst whom the name of Sir William Mackinnon stands pre-eminent, and by our missionary societies of various churches, all acting cordially in unison, and sinking, in the dark continent, the differences and heartburnings which divide Christianity at home; I have thought it better, however, not to discuss matters so closely connected with political questions which have not yet passed into the realm of history.

In my perplexity I applied for the advice of one of the most experienced geographers of our Society, whose reply brought comfort to my mind. He reminded me that it was generally the custom for Presidents of Sections to select subjects with which they were best acquainted, and added: "What more instructive and captivating subject could be wished than The Mediterranean, Physical and Historical?"

For nearly a quarter of a century I have held an official position in Algeria, and it has been my constant delight to make myself acquainted with the islands and shores of the Mediterranean, in the hope of being able to facilitate the travels of my countrymen in that beautiful part of the world.

I cannot pretend to throw much new light on the subject, and I have written so often about it already that what I have to say may strike you as a twice-told tale: nevertheless, if you will permit me to descend from the elevated platform occupied by more learned predecessors, I should like to speak to you in a familiar manner of this "great sea," as it is called in sacred Scripture, the *Mare Internum* of the ancients, "our sea," *Mare nostrum* of Pomponius Mela.

Its shores include about three million square miles of the richest country on the earth's surface, enjoying a climate where the extremes of temperature are unknown, and with every variety of scenery, but chiefly consisting of mountains and elevated plateaux. It is a well-defined region of many parts, all intimately connected with each other by their geographical character, their geological formation, their flora, fauna, and the physiognomy of the people who inhabit them. To this general statement there are two exceptions—namely, Palestine, which belongs rather to the tropical countries lying to the east of it, and so may be dismissed from our subject; and the Sahara, which stretches to the south of the Atlantic region—or region of the Atlas—but approaches the sea at the Syrtis, and again to the eastward of the Cyrenaica, and in which Egypt is merely a long oasis on either side of the Nile.

The Mediterranean region is the emblem of fertility and the cradle of civilization, while the Sahara—Egypt, of course, excepted—is the traditional panther's skin of sand, dotted here and there with oases, but always representing sterility and barbarism. The sea is in no sense, save a political one, the limit between them; it is a mere gulf, which, now bridged by steam, rather unites than separates the two shores. Civilization never could have existed if this inland sea had not formed the junction between the three surrounding continents, rendering the coasts of each easily accessible, whilst modifying the climate of its shores.

The Atlas range is a mere continuation of the south of Europe. It is a long strip of mountain land, about 200 miles broad, covered with splendid forests, fertile valleys, and in some places arid steppes, stretching eastward from the ocean to which it has given its name. The highest point is in Morocco, forming a pendant to the Sierra Nevada of Spain; thence it runs, gradually decreasing in height, through Algeria and Tunisia, it becomes interrupted in Tripoli, and it ends in the beautiful green hills of the Cyrenaica, which must not be confounded with the oases of the Sahara, but is an island detached from the eastern spurs of the Atlas, in the ocean of the desert.

In the eastern part the flora and fauna do not essentially differ from those of Italy; in the west they resemble those of Spain; one of the noblest of the Atlantic conifers, the *Abies pinsapo*, is found also in the Iberian peninsula and nowhere else in the world, and the valuable alfa grass or esparto (*Stipa tenacissima*), from which a great part of our paper is now made, forms one of the principal articles of export from Spain, Portugal, Morocco, Algeria, Tunisia, and Tripoli. On both sides of the sea the former plant is found on the highest and most inaccessible mountains, amongst snows which last during the greater part of the year, and the latter from the sea-level to an altitude of 5000 feet, but in places where the heat and drought would kill any other plant, and in undulating land where water cannot lodge.

Of the 3000 plants found in Algeria by far the greater number are natives of Southern Europe, and less than 100 are peculiar to the Sahara. The *macchie* or maquis of Algeria in no way differs from that of Corsica, Sardinia, and other places; it consists of lentisk, arbutus, myrtle, cistus, tree-heath, and other Mediterranean shrubs. If we take the commonest plant found on the southern shores of the Mediterranean, the dwarf palm (*Chamærops humilis*), we see at once how intimately connected is the whole Mediterranean region, with the exception of the localities I have before indicated. This palm still grows spontaneously in the south of Spain, and in some parts of Provence, in Corsica, Sardinia, and the Tuscan Archipelago, in Calabria and the Ionian Islands, on the continent of Greece, and in several of the islands in the Levant, and it has only disappeared from other countries as the land has been brought under regular cultivation. On the other hand, it occurs neither in Palestine, Egypt, nor in the Sahara.

The presence of European birds may not prove much, but there are mammalia, fish, reptiles, and insects common to both sides of the Mediterranean. Some of the larger animals, such as the lion, panther, jackal, &c., have disappeared before the march of civilization in the one continent, but have lingered, owing to Mohammedan barbarism, in the other. There is abundant evidence of the former existence of these, and of the other large mammals which now characterize tropical Africa, in France, Germany, and Greece; it is probable that they only migrated to their present habitat after the upheaval of the great sea which in Eocene times stretched from the Atlantic to the Indian Ocean, making Southern Africa an island continent like Australia. The original fauna of Africa, of which the lemur is the distinctive type, is still preserved in Madagascar, which then formed part of it.

The fish fauna is naturally the most conclusive evidence as to the true line of separation between Europe and Africa. We find the trout in the Atlantic region, and in all the snow-fed rivers falling into the Mediterranean; in Spain, Italy, Dalmatia; it occurs in Mount Olympus, in rivers of Asia Minor, and even in the Lebanon, but nowhere in Palestine south of that range, in Egypt, or in the Sahara. This fresh-water salmonoid is not exactly the same in all these localities, but is subject to considerable variation, sometimes amounting to specific distinction. Nevertheless, it is a European type found in the Atlas, and it is not till we advance into the Sahara, at Tuggurt, that we come to a purely African form in the Chromidæ, which have a wide geographical distribution, being found everywhere between that place, the Nile and Mozambique.

The presence of newts, tailed batrachians, in every country round the Mediterranean, except again in Palestine, Egypt, and the Sahara, is another example of the continuity of the Mediterranean fauna, even though the species are not the same throughout.

The Sahara is an immense zone of desert which commences on the shores of the Atlantic Ocean, between the Canaries and Cape de Verde, and traverses the whole of North Africa, Arabia, and Persia, as far as Central Asia. The Mediterranean portion of it may be said roughly to extend between the 15th and 30th degrees of north latitude.

This was popularly supposed to have been a vast inland sea in very recent times, but the theory was supported by geological facts wrongly interpreted. It has been abundantly proved by the researches of travellers and geologists that such a sea was neither the cause nor the origin of the Libyan Desert.

Rainless and sterile regions of this nature are not peculiar to North Africa, but occur in two belts which go round the world in either hemisphere, at about similar distances north and south of the equator. These correspond in locality to the great inland drainage areas from which no water can be discharged into the ocean, and which occupy about one-fifth of the total land surface of the globe.

The African Sahara is by no means a uniform plain, but forms several distinct basins containing a considerable extent of what may almost be called mountain land. The Hoggar Mountains in the centre of the Sahara are 7000 feet high, and are covered during three months with snow. The general average may be taken at 1500. The physical character of the region is very varied; in some places, such as at Tiout, Moghrar, Touat, and other oases in or bordering on Morocco, there are well-watered valleys, with fine scenery and almost European vegetation, where the fruits of the north flourish side by side with the palm tree. In others there are rivers like the Oued Guir, an affluent of the Niger, which the French soldiers, who saw it in 1870, compared to the Loire. Again, as in the bed of the Oued Rir, there is a subterranean river, which gives a sufficient supply of water to make a chain of rich and well-peopled oases equal in fertility to some of the finest portions of Algeria. The greater part of the Sahara, however, is hard and undulating, cut up by dry water-courses, such as the Igharghar, which descends to the Chott Melghigh, and almost entirely without animal or vegetable life.

About one-sixth of its extent consists of dunes of moving sand, a vast accumulation of detritus washed down from more northern and southern regions—perhaps during the glacial epoch—but with no indication of marine formation. These are difficult and even dangerous to traverse; but they are not entirely destitute of vegetation. Water is found at rare but well-known intervals, and there is an abundance of salsolaceous plants which serve as food for the camel. This sand is largely produced by wind action on the underlying rocks, and is not sterile in itself, it is only the want of water which makes it so. Wherever water does exist, or artesian wells are sunk, oases of great fertility never fail to follow.

Some parts of the Sahara are below the level of the sea, and here are formed what are called *chotts* or *sebkhas*, open depressions without any outlets, inundated by torrents from the southern slopes of the Atlas in winter and covered with a saline efflorescence in summer. This salt by no means proves the former existence of an inland sea; it is produced by the concentration of the natural salts, which exist in every variety of soil, washed down by winter rains, with which the unevaporated residue of water becomes saturated.

Sometimes the drainage, instead of flooding open spaces and forming chotts, finds its way through the permeable sand till it meets impermeable strata below it, thus forming vast subterranean reservoirs where the artesian sound daily works as great miracles as did Moses' rod of yore at Meribah. I have seen a column of water thrown up into the air equal to 1300 cubic metres per diem; a quantity sufficient to redeem 1800 acres of land from sterility and to irrigate 60,000 palm trees. This seems to be the true solution of the problem of an inland sea; a sea of verdure and fertility caused by the multiplication of artesian wells, which never fail to bring riches and prosperity in their train.

The climate of the Sahara is quite different from that of what I have called the Mediterranean region, where periodical rains divide the year into two seasons. Here, in many places, years elapse without a single shower; there is no refreshing dew at night, and the winds are robbed of their moisture by the immense continental extents over which they blow. There can be no doubt that it is to these meteorological, and not to geological, causes that the Sahara owes its existence.

Reclus divides the Mediterranean into two basins, which, in memory of their history, he calls the Phœnician and the Carthaginian, or the Greek and Roman seas, more generally known to us as the Eastern and Western Basins, separated by the island of Sicily.

If we examine the submarine map of the Mediterranean, we see that it must at one time have consisted of two enclosed or inland basins, like the Dead Sea. The western one is separated from the Atlantic by the Straits of Gibraltar, a shallow ridge, the deepest part of which is at its eastern extremity, averaging about 300 fathoms; while on the west, bounded by a line from Cape Spartel to Trafalgar, it varies from 50 to 200 fathoms. Fifty miles to the west of the Straits the bottom suddenly sinks down to the depths of the Atlantic, while to the east it descends to the general level of the Mediterranean, from 1000 to 2000 fathoms.

The Western is separated from the Eastern Basin by the isthmus which extends between Cape Bon in Tunisia and Sicily, known as the "Adventure Bank," on which there is not more than from 30 to 250 fathoms. The depth between Italy and Sicily is insignificant, and Malta is a continuation of the latter, being only separated from it by a shallow patch of from 50 to 100 fathoms; while to the east and west of this bank the depth of the sea is very great. These shallows cut off the two basins from all but superficial communication.

The configuration of the bottom shows that the whole of this strait was at one time continuous land, affording free communication for land animals between Africa and Europe. The palæontological evidence of this is quite conclusive. In the caves and fissures of Malta, amongst river detritus, are found three species of fossil elephants, a hippopotamus, a gigantic dormouse, and other animals which could never have lived in so small an island. In Sicily, remains of the existing elephant have been found, as well as the *Elephas antiquus*, and two species of hippopotamus, while nearly all these and many other animals of African type have been found in the Pliocene deposits and caverns of the Atlantic region.

The rapidity with which such a transformation might have occurred can be judged by the well-known instance of Graham's Shoal, between Sicily and the island of Pantellaria; this, owing to volcanic agency, actually rose above the water in 1832, and for a few weeks had an area of 3240 feet in circumference and a height of 107 feet.

The submersion of this isthmus no doubt occurred when the waters of the Atlantic were introduced through the Straits of Gibraltar. The rainfall over the entire area of the Mediterranean is certainly not more than 30 inches, while the evaporation is at least twice as great; therefore, were the Straits to be once more closed, and were there no other agency for making good this deficiency, the level of the Mediterranean would sink again till its basin became restricted to an area no larger than might be necessary to equalize the amount of evaporation and precipitation. Thus not only would the strait between Sicily and Africa be again laid dry, but the Adriatic and Ægean Seas also, and a great part of the Western Basin.

The entire area of the Mediterranean and Black Seas has been estimated at upwards of a million square miles, and the volume of the rivers which are discharged into them at 226 cubic miles. All this and much more is evaporated annually. There are two constant currents passing through the Straits of Gibraltar, superimposed on each other; the upper and most copious one flows in from the Atlantic at a rate of nearly three miles an hour, or 140,000 cubic metres per second, and supplies the difference between the rainfall and evaporation, while the under-current of warmer water, which has undergone concentration by evaporation, is continually flowing out at about half the above rate of movement, getting rid of the excess of salinity; even thus, however, leaving the Mediterranean salter than any other part of the ocean except the Red Sea.

A similar phenomenon occurs at the eastern end, where the fresher water of the Black Sea flows as a surface current through the Dardanelles, and the salter water of the Mediterranean pours in below it.

The general temperature of the Mediterranean from a depth of fifty fathoms down to the bottom is almost constantly 56°, whatever may be its surface elevation. This is a great contrast to that of the Atlantic, which at a similar depth is at least 3° colder, and which at 1000 fathoms sinks to 40°.

This fact was of the greatest utility to Dr. Carpenter in connection with his investigations regarding currents through the Straits, enabling him to distinguish with precision between Atlantic and Mediterranean water.

For all practical purposes the Mediterranean may be accepted as being, what it is popularly supposed to be, a tideless sea, but it is not so in reality. In many places there is a distinct rise and fall, though this is more frequently due to winds and currents than to lunar attraction. At Venice there is a rise of from one to two feet in spring tides, according to the prevalence of winds up or down the Adriatic, but in that sea itself the tides are so weak that they can hardly be recognized, except during the prevalence of the Bora, our old friend *Boreas*, which generally raises a surcharge along the coast of Italy. In many straits and narrow arms of the sea there is a periodical flux and reflux, but the only place where tidal influence, properly so called, is unmistakably observed is in the Lesser Syrtis, or Gulf of Gabes; there the tide runs at the rate of two or three knots an hour, and the rise and fall varies from three to eight feet. It is most marked and regular at Djerba, the Homeric island of the Lotophagi; one must be careful in landing there in a boat, so as not to be left high and dry a mile or two from the shore. Perhaps the companions of Ulysses were caught by the receding tide, and it was not only a banquet of dates, the "honey-sweet fruit of the Lotus," or the potent wine which is made from it, which made them "forgetful of their homeward way."

The Gulf of Gabes naturally calls to mind the proposals which were made a few years ago for inundating the Sahara, and so restoring to the Atlantic region the insular condition which it is alleged to have had in prehistoric times. I will not allude to the English project for introducing the waters of the Atlantic from the west coast of Africa; that does not belong to my subject. The French scheme advocated by Commandant Roudaire, and supported by M. de Lesseps, was quite as visionary and impracticable.

To the south of Algeria and Tunis there exists a great depression stretching westward from the Gulf of Gabes to a distance of about 235 miles, in which are several *chotts* or salt lakes, sometimes only marshes, and in many places covered with a saline crust strong enough to bear the passage of camels. Commandant Roudaire proposed to cut through the isthmuses which separated the various chotts, and so prepare their basins to receive the waters of the Mediterranean. This done, he intended to introduce the sea by a canal, which should have a depth of one metre below low-water level.

This scheme was based on the assumption that the basin of the chotts had been an inland sea within historic times; that, little by little, owing to the difference between the quantity of water which entered and the amount of evaporation and absorption, this interior sea had disappeared, leaving the chotts as an evidence of the former condition of things; that, in fact, this was none other than the celebrated Lake Triton, the position of which has always been a puzzle to geographers.

This theory, however, is untenable; the isthmus of Gabes is not a mere sandbank; there is a band of rock between the sea and the basin of the chotts, through which the former never could have penetrated in modern times. It is much more probable that Lake Triton was the large bight between the island of Djerba and the mainland, on the shores of which are the ruins of the ancient city of Meninx, which, to judge by the abundance of Greek marble found there, must have carried on an important commerce with the Levant.

The scheme has now been entirely abandoned; nothing but the mania for cutting through isthmuses all over the world which followed the brilliant success achieved at Suez can explain its having been started at all. Of course, no mere mechanical operation is impossible in these days, but the mind refuses to realize the possibility of vessels circulating in a region which produces nothing, or that so small a sheet of water in the immensity of the Sahara could have any appreciable effect in modifying the climate of its shores.

The Eastern Basin is much more indented and cut up into separate seas than the Western one; it was therefore better adapted for the commencement of commerce and navigation; its high mountains were landmarks for the unpractised sailor, and its numerous islands and harbours afforded shelter for his frail barque, and so facilitated communication between one point and another.

The advance of civilization naturally took place along the axis of this sea, Phœnicia, Greece, and Italy being successively the great nurseries of human knowledge and progress. Phœnicia had the glory of opening out the path of ancient commerce, for its position in the Levant gave it a natural command of the Mediterranean, and its people sought the profits of trade from every nation which had a seaboard on the three continents washed by this sea. Phœnicia was already a nation before the Jews entered the Promised Land, and when they did so they carried on inland traffic as middlemen to the Phœnicians. Many of the commercial centres on the shores of the Mediterranean were founded before Greece and Rome acquired importance in history. Homer refers to them as daring traders nearly a thousand years before the Christian era.

For many centuries the commerce of the world was limited to the Mediterranean, and when it extended in the direction of the East it was the merchants of the Adriatic, of Genoa, and of Pisa who brought the merchandise of India, at an enormous cost, to the Mediterranean by land, and who monopolized the carrying trade by sea. It was thus that the elephant trade of India, the caravan traffic through Babylon and Palmyra, as well as the Arab *kafilehs*, became united with the Occidental commerce of the Mediterranean.

As civilization and commerce extended westwards, mariners began to overcome their dread of the vast solitudes of the ocean beyond the Pillars of Hercules, and the discovery of America by Columbus, and the circumnavigation of Africa by the Portuguese, changed entirely the current of trade as well as increased its magnitude, and so relegated the Mediterranean, which had hitherto been the central sea of human intercourse, to a position of secondary importance.

Time will not permit me to enter into further details regarding the physical geography of this region, and its history is a subject so vast that a few episodes of it are all that I can possibly attempt. It is intimately connected with that of every other country in the world, and here were successively evolved all the great dramas of the past and some of the most important events of less distant date.

As I have already said, long before the rise of Greece and Rome its shores and islands were the seat of an advanced civilization. Phœnicia had sent out her pacific colonies to the remotest parts, and not insignificant vestiges of their handicraft still exist to excite our wonder and admiration. We have the megalithic temples of Malta sacred to the worship of Baal, the generative god, and Ashtoreth, the conceptive goddess, of the universe. The three thousand *nurhagi* of Sardinia, round towers of admirable masonry, intended probably for defence in case of sudden attack, and the so-called giant graves, were as great a mystery to classical authors as they are to us at the present day. Menorca has its *talayots*, tumuli somewhat analogous to, but of ruder construction than, the *nurhagi*, more than 200 groups of which exist in various parts of the island; with these are associated subordinate constructions intended for worship; altars composed of two immense monoliths, erected in the form of a T; sacred enclosures and megalithic habitations. One type of *talayot* is especially remarkable, of better masonry than the others, and exactly resembling inverted boats. One is tempted to believe that the Phœnicians had in view the grass habitations or *mapalia* of the Numidians described by Sallust, and had endeavoured to reproduce them in stone: *Oblonga, incurvis lateribus tecta, quasi navium carinæ sunt.*

For a long time the Phœnicians had no rivals in navigation, but subsequently the Greeks—especially the Phocians—established colonies in the Western Mediterranean, in Spain, Corsica, Sardinia, Malta, and the south of France, through the means of which they propagated not only their commerce but their arts, literature, and ideas. They introduced many valuable plants, such as the olive, thereby modifying profoundly the agriculture of the countries in which they settled. They have even left traces of their blood, and it is no doubt to this that the women of Provence owe the classical beauty of their features.

But they were eclipsed by their successors; the empire of Alexander opened out a road to India, in which, indeed, the Phœnicians had preceded him, and introduced the produce of the East into the Mediterranean, while the Tyrian colony of Carthage became the capital of another vast empire, which, from its situation, midway between the Levant and the Atlantic Ocean, enabled it to command the Mediterranean traffic.

The Carthaginians at one time ruled over territory extending along the coast from Cyrene to Numidia, besides having a considerable influence over the interior of the continent, so that the name of Africa, given to their own dominions, was gradually applied to a whole quarter of the globe. The ruling passion with the Carthaginians was love of gain, not patriotism, and their wars were largely fought with mercenaries. It was the excellence of her civil constitution which, according to Aristotle, kept in cohesion for centuries her straggling possessions. A country feebly patriotic, which entrusts her defence to foreigners, has the seeds of inevitable decay, which ripened in her struggle with Rome, despite the warlike genius of Hamilcar and the devotion of the magnanimous Hannibal. The gloomy and cruel religion of Carthage, with its human sacrifices to Moloch and its worship of Baal under the name of Melkarth, led to a criminal code of Draconic severity and alienated it from surrounding nations. When the struggle with Rome began, Carthage had no friends. The first Punic War was a contest for the possession of Sicily, whose prosperity is even now attested by the splendour of its Hellenic monuments. When Sicily was lost by the Carthaginians, so also was the dominion of the sea, which hitherto had been uncontested. The second Punic War resulted in the utter prostration of Carthage and the loss of all her possessions out of Africa; and in 201 B.C., when this war was ended, 552 years after the foundation of the city, Rome was mistress of the world.

The destruction of Carthage after the third Punic War was a heavy blow to Mediterranean commerce. It was easy for Cato to utter his stern *Delenda est Carthago*; destruction is easy, but construction is vastly more difficult. Although Augustus in his might built a new Carthage near the site of the old city, he could never attract again the trade of the Mediterranean which had been diverted into other channels. Roman supremacy was unfavourable to the growth of commerce, because, though she allowed unrestricted trade throughout her vast empire, and greatly improved internal communications in the subjugated countries, Rome itself absorbed the greater part of the wealth, and did not produce any commodities in return for its immense consumption, therefore Mediterranean commerce did not thrive under the Roman rule. The conquest of Carthage, Greece, Egypt, and the East poured in riches to Rome, and dispensed for a time with the needs of productive industry, but formed no enduring basis of prosperity.

It is only in relation to the Mediterranean that I can refer to Roman history, but I must allude to the interesting episode in the life of Diocletian, who, after an anxious reign of twenty-one years in the eastern division of the empire, abdicated at Nicomedia and retired to his native province of Illyria. He spent the rest of his life in rural pleasures and horticulture at Salona, near which he built that splendid palace within the walls of which subsequently arose the modern city of Spalato. Nothing more interesting exists on the shores of the Mediterranean than this extraordinary edifice, perhaps the largest that ever arose at the bidding of a single man; not only vast and beautiful, but marking one of the most important epochs in the history of architecture.

Though now obstructed with a mass of narrow, tortuous streets, its salient features are distinctly visible. The great temple, probably the mausoleum of the founder, has become the cathedral, and after the Pantheon at Rome there is no finer specimen of a heathen temple turned into a Christian church. Strange it is that the tomb of him whose reign was marked by such unrelenting persecution of the Christians should have been accepted as the model of those baptisteries so commonly constructed in the following centuries.

Of Diocletian's Salona, one of the chief cities of the Roman world, but little now remains save traces of the long irregular wall; recent excavations have brought to light much that is interesting, but all of the Christian epoch, such as a large basilica which had been used as a necropolis, and a baptistery, one of those copied from the temple of Spalato, on the Mosaic pavement of which can still be read the text, *Sicut cervus desiderat fontem aquarum ita anima mea ad te Deus.*

The final partition of the Roman Empire took place in 365; forty years later the barbarians of the North began to invade Italy and the south of Europe; and in 429, Genseric, at the head of his Vandal hordes, crossed over into Africa from Andalusia, a province which still bears their name, devastating the country as far as the Cyrenaica. He subsequently annexed the Balearic Islands, Corsica and Sardinia, he ravaged the coasts of Italy and Sicily, and even of Greece and Illyria, but the most memorable of his exploits was the unresisted sack of Rome, whence he returned to Africa laden with treasure and bearing the Empress Eudoxia a captive in his train.

The degenerate emperors of the West were powerless to avenge this insult, but Byzantium, though at this time sinking to decay, did make a futile attempt to attack the Vandal monarch in his African stronghold. It was not, however, till 533, in the reign of Justinian, when the successors of Genseric had fallen into luxurious habits and had lost the rough valour of their ancestors, that Belisarius was able to break their power and take their last king a prisoner to Constantinople. The Vanda domination in Africa was destroyed, but that of the Byzantines was never thoroughly consolidated; it rested not on its own strength, but on the weakness of its enemies, and it was quite unable to cope with the next great wave of invasion which swept over the land, perhaps the most extraordinary event in the world's history, save only the introduction of Christianity.

In 647, twenty-seven years after the Hedjira of Mohammed, Abdulla ibn Saad started from Egypt for the conquest of Africa with an army of 40,000 men.

The expedition had two determining causes—the hope of plunder and the desire to promulgate the religion of El Islam. The sands and scorching heat of the desert, which had nearly proved fatal to the army of Cato, were no bar to the hardy Arabians and their enduring camels. The march to Tripoli was a fatiguing one, but it was successfully accomplished; the invaders did not exhaust their force in a vain effort to reduce its fortifications, but swept on over the Syrtic desert, and north to the province of Africa, where, near the splendid city of Suffetula, a great battle was fought between them and the army of the Exarch Gregorius, in which the Christians were signally defeated, their leader killed, and his daughter allotted to Ibn-ez-Zobair, who had slain her father.

Not only did the victorious Moslems overrun North Africa, but soon they had powerful fleets at sea which dominated the entire Mediterranean, and the emperors of the East had enough to do to protect their own capital.

Egypt, Syria, Spain, Provence, and the islands of the Mediterranean successively fell to their arms, and until they were checked at the Pyrenees by Charles Martel it seemed at one time as if the whole of Southern Europe would have been compelled to submit to the disciples of the new religion. Violent, implacable, and irresistible at the moment of conquest, the Arabs were not unjust or hard masters in countries which submitted to their conditions. Every endeavour was, of course, made to proselytize, but Christians were allowed to preserve their religion on payment of a tax, and even Popes were in the habit of entering into friendly relations with the invaders. The Church of St. Cyprian and St. Augustine, with its 500 Sees, was indeed expunged, but five centuries after the passage of the Mohammedan army from Egypt to the Atlantic a remnant of it still existed. It was not till the twelfth century that the religion and language of Rome became utterly extinguished.

The Arabs introduced a high state of civilization into the countries where they settled; their architecture is the wonder and admiration of the world at the present day; their irrigational works in Spain have never been improved upon; they fostered literature and the arts of peace, and introduced a system of agriculture far superior to what existed before their arrival.

Commerce, discouraged by the Romans, was highly honoured by the Arabs, and during their rule the Mediterranean recovered the trade which it possessed in the time of the Phœnicians and Carthaginians; it penetrated into the Indian Archipelago and China; it travelled westward to the Niger, and to the east as far as Madagascar, and the great trade route of the Mediterranean was once more developed.

The power and prosperity of the Arabs culminated in the ninth century, when Sicily fell to their arms; it was not, however, very long before their empire began to be undermined by dissensions; the temporal and spiritual authority of the Ommiade Khalifs, which extended from Sind to Spain, and from the Oxus to Yemen, was overthrown by the Abbasides in the year 132 of the Hedjira, A.D. 750. Seven years later Spain detached itself from the Abbasside empire; a new Caliphate was established at Cordova, and hereditary monarchies began to spring up in other Mohammedan countries.

The Carlovingian empire gave an impulse to the maritime power of the south of Europe, and in the Adriatic the fleets of Venice and Ragusa monopolized the traffic of the Levant. The merchants of the latter noble little republic penetrated even to our own shores, and Shakespeare has made the Argosy or Ragusie a household word in our language.

During the eleventh century the Christian Powers were no longer content to resist the Mohammedans: they began to turn their arms against them. If the latter ravaged some of the fairest parts of Europe, the Christians began to take brilliant revenge.

The Mohammedans were driven out of Corsica, Sardinia, Sicily, and the Balearic Islands, but it was not till 1492 that they had finally to abandon Europe, after the conquest of Granada by Ferdinand and Isabella.

About the middle of the eleventh century an event took place which profoundly modified the condition of the Mohammedan world. The Caliph Mostansir let loose a horde of nomad Arabs, who, starting from Egypt, spread over the whole of North Africa, carrying destruction and blood wherever they passed, thus laying the foundation for the subsequent state of anarchy which rendered possible the interference of the Turks.

English commercial intercourse with the Mediterranean was not unknown even from the time of the Crusades, but it does not appear to have been carried on by means of our own vessels till the beginning of the sixteenth century. In 1522 it was so great that Henry VIII. appointed a Cretan merchant, Censio de Balthazari, to be "Master, governor, protector, and consul of all and singular the merchants and others his lieges and subjects within the port, island, and country of Crete or Candia." This is the very first English consul known to history, but the first of English birth was my own predecessor in office, Master John Tipton, who, after having acted at Algiers during several years in an unofficial character, probably elected by the merchants themselves to protect their interests, was duly appointed consul by Sir William Harebone, ambassador at Constantinople in 1585, and received just such an exequatur from the Porte as has been issued to every consul since by the Government of the country in which he resides.

Piracy has always been the scourge of the Mediterranean, but we are too apt to associate its horrors entirely with the Moors and Turks. The evil had existed from the earliest ages; even before the Roman conquest of Dalmatia the Illyrians were the general enemies of the Adriatic; Africa under the Vandal reign was a nest of the fiercest pirates; the Venetian chronicles are full of complaints of the ravages of the Corsairs of Ancona, and there is no other name but piracy for such acts of the Genoese as the unprovoked pillage of Tripoli by Andrea Doria in 1535. To form a just idea of the Corsairs of the past it is well to remember that commerce and piracy were often synonymous terms, even among the English, up to the reign of Elizabeth. Listen to the description given by the pious Cavendish of his commercial circumnavigation of the globe:—"It hath pleased Almighty God to suffer me to circumpass the whole globe of the world. . . . I navigated along the coast of Chili, Peru, and New Spain, where I made great spoils. All the villages and towns that ever I landed at I burned and spoiled, and had I not been discovered upon the coast I had taken a great quantity of treasure," and so he concludes, "The Lord be praised for all his mercies!"

Sir William Monson, when called upon by James I. to propose a scheme for an attack on Algiers, recommended that all the maritime Powers of Europe should contribute towards the expense, and participate in the gains by the sale of Moors and Turks as slaves.

After the discovery of America and the expulsion of the Moors from Spain, piracy developed to an extraordinary extent. The audacity of the Barbary corsairs seems incredible at the present day; they landed on the shores and islands of the Mediterranean, and even extended their ravages to Great Britain, carrying off all the inhabitants whom they could seize into the most wretched slavery. The most formidable of these piratical States was Algiers, a military oligarchy, consisting of a body of janissaries, recruited by adventurers from the Levant, the outcasts of the Mohammedan world, criminals and renegades from every nation in Europe. They elected their own ruler or Dey, who exercised despotic sway, tempered by frequent assassination; they oppressed without mercy the natives of the country, accumulated vast riches, had immense numbers of Christian slaves, and kept all Europe in a state bordering on subjection by the terror which they inspired. Nothing is sadder or more inexplicable than the shameful manner in which this state of things was accepted by civilized nations. Many futile attempts were made during successive centuries to humble their arrogance, but it only increased by every manifestation of the powerlessness of Europe to restrain it. It was reserved for our own countryman, Lord Exmouth, by his brilliant victory in 1816, for ever to put an end to piracy and Christian slavery in the Mediterranean. His work, however, was left incomplete, for though he destroyed the navy of the Algerines, and so rendered them powerless for evil on the seas, they were far from being humbled; they continued to slight their treaties and to subject even the agents of powerful nations to contumely and injustice. The French took the only means possible to destroy this nest of ruffians, by the almost unresisted occupation of Algiers and the deportation of its Turkish aristocracy.

They found the whole country in the possession of a hostile people, some of whom had never been subdued since the fall of the Roman Empire, and the world owes France no small debt of gratitude for having transformed what was a savage and almost uncultivated country into one of the richest as well as the most beautiful in the basin of the Mediterranean.

What has been accomplished in Algeria is being effected in Tunisia. The treaty of the Kasr-es-Saeed, which established a French Protectorate there, and the military occupation of the Regency, were about as high-handed and unjustifiable acts as are recorded in history; but there can be no possible doubt regarding the important work of civilization and improvement that has resulted from them. European courts of justice have been established all over the country; the exports and imports have increased from twenty-three to fifty-one millions of francs, the revenue from six to nineteen millions, without the imposition of a single new tax, and nearly half a million per annum is being spent on education.

Sooner or later the same thing must happen in the rest of North Africa, though at present international jealousies retard this desirable consummation. It seems hard to condemn such fair countries to continued barbarism, in the interest of tyrants who misgovern and oppress their people. The day cannot be far off when the whole southern shores of the Mediterranean will enjoy the same prosperity and civilization as the northern coast, and when the deserts, which are the result of misgovernment and neglect, will assume the fertility arising from security and industry, and will again blossom as the rose.

It cannot be said that any part of the Mediterranean basin is still unknown, if we except the empire of Morocco. But even that country has been traversed in almost every direction during the past twenty years, and its geography and natural history have been illustrated by men of the greatest eminence; such as Gerhard Rohlfs, Monsieur Tissot, Sir Joseph Hooker, the Vicomte de Foucauld, Joseph Thomson, and numerous other travellers. The least known portion, at least on the Mediterranean coast, is the Riff country, the inhospitality of whose inhabitants has given the word "ruffian" to the English language. Even that has been penetrated by De Foucauld disguised as a Jew, and the record of his exploration is one of the most brilliant contributions to the geography of the country which has hitherto been made.

Although, therefore, but little remains to be done in the way of actual exploration, there are many by-ways of travel comparatively little known to that class of the community with which I have so much sympathy, the ordinary British tourist. These flock every year in hundreds to Algeria and Tunis, but few of them visit the splendid Roman remains in the interior of those countries. The Cyrenaica is not so easily accessible, and I doubt whether any Englishmen have travelled in it since the exploration of Smith and Porcher in 1861.

Cyrene almost rivalled Carthage in commercial importance. The Hellenic ruins still existing bear witness to the splendour of its five great cities. It was the birthplace of many distinguished people, and amongst its hills and fountains were located some of the most interesting scenes in mythology, such as the Gardens of the Hesperides, and the "silent, dull, forgetful waters of Lethe."

This peninsula is only separated by a narrow strait from Greece, whence it was originally colonized. There, and indeed all over the eastern basin of the Mediterranean, are many little-trodden routes; but the subject is too extensive; I am reluctantly compelled to restrict my remarks to the western half.

The south of Italy is more frequently traversed and less travelled in than any part of that country. Of the thousands who yearly embark or disembark at Brindisi, few ever visit the Land of Manfred. Otranto is only known to them from the fanciful descriptions in Horace Walpole's romance. The general public in this country is quite ignorant of what is going on at Taranto, and of the great arsenal and dockyard which Italy is constructing in the Mare Piccolo, an inland sea containing more than 1000 acres of anchorage for the largest ironclads afloat, yet with an entrance so narrow that it is spanned by a revolving bridge. Even the Adriatic, though traversed daily by steamers of the Austrian Lloyd's Company, is not a highway of travel; yet where is it possible to find so many places of interest within the short space of a week's voyage, between Corfu and Trieste, as along the Dalmatian and Istrian shores, and among the islands that fringe the former, where it is difficult to realize that one is at sea at all, and not on some great inland lake?

There is the Bocche di Cattaro, a vast rent made by the Adriatic among the mountains, where the sea flows round their spurs in a series of canals, bays, and lakes of surpassing beauty. The city of Cattaro itself, the gateway of Montenegro, with its picturesque Venetian fortress, nestling at the foot of the black mountain, Ragusa, the Roman successor of the Hellenic Epidaurus, Queen of the Southern Adriatic, battling with the waves on her rock-bound peninsula, the one spot in all that sea which never submitted either to Venice or the Turk, and for centuries resisting the barbarians on every side, absolutely unique as a mediæval fortified town, and worthy to have given her name to the argosies she sent forth; Spalato, the grandest of Roman monuments; Lissa, colonized by Dionysius of Syracuse, and memorable to us as having been a British naval station from 1812 to 1814, while the French held Dalmatia; Zara, the capital, famous for its siege by the Crusaders, interesting from an ecclesiological point of view, and venerated as the last resting-place of St. Simeon, the prophet of the *Nunc dimittis*; Parenza, with its great basilica; Pola, with its noble harbour, whence Belisarius sailed forth, now the chief naval port of the Austrian Empire, with its Roman amphitheatre and graceful triumphal arches; besides many other places of almost equal interest. Still further west are Corsica, Sardinia, and the Balearic Islands, all easily accessible from the coasts of France, Italy, and Spain. Their ports are constantly visited by mail-steamers and private yachts, yet they are but little explored in the interior.

A physical and historical description of Corsica was then given. The address concluded as follows:—

I have endeavoured to sketch, necessarily in a very imperfect manner, the physical character and history of the Mediterranean, to show how the commerce of the world originated in a small maritime State at its eastern extremity; how it gradually advanced westward till it burst through the Straits of Gibraltar, and extended over seas and continents until then undreamt of, an event which deprived the Mediterranean of that commercial prosperity and greatness which for centuries had been limited to its narrow basin.

Once more this historic sea has become the highway of nations; the persistent energy and genius of two men have revolutionized navigation, opened out new and boundless fields for commerce; and it is hardly too much to say that if the Mediterranean is to be restored to its old position of importance; if the struggle for Africa is to result in its regeneration, as happened in the New World; if the dark places still remaining in the further East are to be civilized, it will be in a great measure due to Waghorn and Ferdinand de Lesseps, who developed the overland route and created the Suez Canal.

But the Mediterranean can only hope to retain its regenerated position in time of peace. Nothing is more certainly shown by past history than that war and conquest have changed the route of commerce in spite of favoured geographical positions. Babylon was conquered by Assyrians, Persians, Macedonians, and Romans, and though for a time her position on the Euphrates caused her to rise like a Phœnix from her ashes, successive conquests, combined with the luxury and effeminacy of her rulers, caused her to perish. Tyre, conquered by Nebuchadnezzar and Alexander, fell as completely as Babylon had done, and her trade passed to Alexandria. Ruined sites of commercial cities rarely again become emporia of commerce; Alexandria is an exception dependent on very exceptional circumstances.

The old route to the East was principally used by sailing-vessels, and was abandoned for the shorter and more economical one by the Suez Canal, which now enables a round voyage to be made in sixty days, which formerly required from six to eight months. This, however, can only remain open in time of peace. It is quite possible that in the event of war the old route by the Cape may be again used, to the detriment of traffic by the Mediterranean. Modern invention has greatly economized the use of coal; and steamers, by the use of duplex and triplex engines, can run with a comparatively small consumption of fuel, thus leaving a larger space for cargo. England, the great carrying Power of the world, may find it more advantageous to trust to her own strength and the security of the open seas than to run the gauntlet of the numerous strategical positions in the Mediterranean, such as Port Mahon, Bizerta, and Taranto, each of which is capable of affording impregnable shelter to a hostile fleet, and though the ultimate key to the Indian Ocean is in our own hands, our passage to it may be beset with a thousand dangers. There is no act of my career on which I look back with so much satisfaction as on the share I had in the occupation of Perim, one of the most important links in that chain of coaling stations which extends through the Mediterranean to the further East, and which is so necessary for the maintenance of our naval supremacy. It is a mere islet, it is true, a barren rock, but one surrounding a noble harbour, and so eminently in its right place that we cannot contemplate with equanimity the possibility of its being in any other hands than our own.

It is by no means certain whether exaggerated armaments are best suited for preserving peace or hastening a destructive war; the golden age of disarmament and international arbitration may not be near at hand, but it is even now talked of as a possibility.

Should the poet's prophecy or the patriot's dream be realized, and a universal peace indeed bless the world, then this sea of so many victories may long remain the harvest field of a commerce nobler than conquest.

NOTES.

THE Kew Herbarium has just been enriched by a set of the dried plants from the extensive collections made by Regel, Przewalski, Potanin, and other recent Russian travellers in Central and Eastern Asia. This valuable set numbers about 2600 species, including very many novelties, and it was presented to the Royal Gardens, Kew, through the good offices of Dr. A. E. von Regel, Director of the Imperial Botanic Garden at St. Petersburg, and Mr. C. J. Maximowicz, the Curator of the Herbarium in the same establishment.

A LABORATORY for plant-biology has been recently opened at Fontainebleau. It is under the direction of M. Bonnier, Professor of Botany at the Sorbonne in Paris, to whom application should be made by any contemplating research there.

DR. WILLIAM WAAGEN, F.G.S., formerly Palæontologist to the Geological Survey of India, and of late years Professor of Geology at Prague, has been appointed Professor of Palæontology to the University of Vienna, in succession to the late Dr. Neumayr.

IN a "Supplement to the Catalogue of Diurnal Accipitres in the Australian Museum at Sydney, N.S.W.," Dr. E. P. Ramsay gives descriptions of many plumages of birds of prey not previously recorded. The nestlings described have been preserved for the Museum by Mr. K. H. Bennett, and include those of the rarest of the Australian accipitres. The colours of the soft parts have been most carefully noted, and are deemed in one instance (*Aquila morphnoides*, p. 7) to be worthy of a duplicate reproduction by Dr. Ramsay.

THE Rev. Dr. Norman has just returned from a dredging expedition in the Varanger Fiord and Sydvaranger. He has been absent nine weeks, and has brought home extensive collections in all branches of Marine Invertebrata. The fiords of Sydvaranger were found to possess a rich fauna, with depths descending to 120 fathoms. These fiords had never before been scientifically investigated, though Baron de Guerne took a few hauls of the dredge there in 1881 when on board the French vessel *Coligny* as a member of the Mission Scientifique en Laponie, and published a list of the Mollusca obtained.

DR. RAMSAY has also compiled a catalogue of the Striges in the Australian Museum, which appears to possess a good series of every species known to inhabit Australia and the adjacent islands, with the exception of *Ninox ocellata* and *Ninox rufa*, the latter being a good species in Dr. Ramsay's opinion, though Mr. Sharpe considered it to be the young of *N. connivens*. It is to be hoped that Dr. Ramsay will continue his useful catalogues of the specimens of birds in the Australian Museum.

DR. J. B. STEERE has just published his preliminary descriptions of new species discovered by the members of the expedition to the Philippine Islands. It is to be hoped that a complete memoir on this important exploration will be published later on, as the diagnoses set forth in the little *brochure* just issued are, in many cases, worse than useless.

IN the *Times* for September 9 we read the following note on "How to keep salt dry"—"The Dutch Indian Government offers a prize of 10,000 fl. for the best practical answer to the question in what manner the salt which is sold in Dutch India in small packets should be packed up so as to keep dry."

WE have received the general Guide to the Science and Art Museum, Dublin, under the directorship of V. Ball, LL.D., F.R.S. The Museum is divided into two parts. Part I., which is in the old museum buildings, deals with natural history, while Part II. treats of arts and industry, and is in the new buildings. In this Museum there are short printed labels attached to the specimens, and for the more important objects, descriptive tables containing "greater detail than even an ordinary hand-book could conveniently contain" are added. In some cases small maps are attached, indicating the localities where the objects were found. In this edition, which by the way is the first issued, the several branches of the collections are dealt with generally, and we are told that "hand-books will be prepared later on for some of them," which will add greatly to the interest of the objects concerned.

THE Observatory of Zi-ka-Wei, near Shanghai, has published vol. xv. of its *Bulletin Mensuel*, for the year 1889. This Observatory is equipped with the best self-recording and other instruments, and the volume in question contains, in addition to the usual tables of hourly observations, diagrams of the mean diurnal variations, and of the tracks of typhoons, as well as comparisons of the monthly means of magnetical and meteorological observations for the year 1889, and those of the previous 17 years. An appeal was made to the missionaries of the province of Kiang-nan to record thunderstorm observations, and some interesting results are published for each month. These storms occur most frequently between noon and midnight, and generally proceed from west to east; they mostly occur in July and August; there is also a second maximum in April; they most frequently occur with a falling barometer, and are generally accompanied with rain, but very rarely with hail. The work also contains interesting general remarks upon the depressions and cyclones of the coast of China.

THE Journal of the Asiatic Society of Bengal, three numbers of which we have received, contains some interesting papers on various subjects. In No. 1, Part 2 of vol. lix. there is a paper by John Eliot on the occasional inversion of the temperature relations between the hills and plains of Northern India. Alfred Alcock, Surgeon-Naturalist to the Marine Survey, contributes a paper on observations on the gestation of some sharks and rays, made on board H.M. Indian Marine Survey steamer *Investigator*, Commander Alfred Carpenter, R.N., while from the same ship we have descriptions of seven additional new Indian Amphipods by G. M. Giles, late Surgeon-Naturalist to the Survey. Asutosh Mukhopadhyay contributes three papers, as follows:—Note on Stokes's theorem and hydrokinetic circulation; on Clebsch's transformation of the hydrokinetic equation; and on a curve of aberrancy. The supplement to No. 1 of this part consists of a catalogue of the Insecta of the Oriental region and the order of Coleoptera, family Carabidæ, by E. T. Atkinson. The third pamphlet contains the title-page, index, &c., to vol. lvii. Part 2, 1888.

THE *American Meteorological Journal* for August contains the conclusion of M. Faye's articles on Trombes and Tornadoes. The author considers that the facts adduced show (1) that there are no centripetal movements, either at the foot of trombes or tornadoes, or toward the base of cyclones; (2) that these are descending whirls with vertical axes, originated in the upper currents of the atmosphere, and follow the direction of these currents. The same journal contains the tornado prize essays. The first prize has been awarded to Lieutenant J. P. Finley. The following are some of the general results arrived at:—Tornadoes generally accompany an area of low barometer. Their progressive motion to the north-east arises from the fact that as they always form in the south-east quadrant of an area of low barometer, they must come within the influence of the general drift of the atmosphere on that side of the low barometer which is always to the north-east. A hailstorm is an incipient tornado in the cloud-region of an area of low barometer. As the area of low barometer progresses eastward, the region lying on an average about 350 miles to the south and east of the centre of the general storm, is the region within which tornadoes may be expected. Tornadoes, with hardly an exception, occur in the afternoon, just after the hottest part of the day; the destructive power of the wind increases rapidly from the circumference of the storm to its centre. The months of greatest frequency, as determined from a period of over 200 years, are April to July; the average frequency of the storms does not appear to have changed within that time. The shortest time occupied by the tornado-cloud in passing a given point varies from an instant to about twenty minutes, the average time being 74 seconds. The second prize was awarded to Mr. A. McAdie.

A NEW method of measuring the inductive power and conductivity of dielectrics has been recently described by M. Curie in the *Annales de Chimie et de Physique*; it is based on the use of an apparatus he calls the piezo-electric quartz. He has studied with it those qualities in various crystalline dielectrics; and he enunciates a *law of superposition*, which shows the independence of the effects produced by different variations of electromotive force. Quartz shows a difference of conductivity in the direction of the optic axis (where it is strong), and at right angles (where it is insensible); and this gives rise to striking phenomena. Plates parallel to the axis, and with the extremities of the axis communicating with the earth, behave, beyond 120°, as dielectrics of zero inductive power. With prolonged heating, the conductivity along the axis quite disappears. Water plays a capital *rôle* in the conductivity of a great many dielectrics (possibly in all). With plates of baked porcelain kept moist the various types of conductivity could be reproduced. The electromotive forces of polarization of moist porous bodies may attain several hundred volts.

PRAIRIE dogs, it appears from a recent letter by Dr. Wilder to *Science*, lack the sense of distance. At Cornell University, several individuals walked off chairs, tables, and window-sills unhesitatingly. This is thought to be due to the nature of their usual habitat, a plain, with no sharper inequalities than burrows and mounds. One adult female seemed to have wonderful immunity from the ill-effects of falls: it once fell from the top of an elevator 21 feet high, and another time from a window-sill, about as high, on a granite pavement, but soon recovered. These animals respond to sudden sound by erecting the body and barking, and the nervous mechanism involved seems to be largely reflex, rapidly exhausted, but nearly or quite uncontrollable; indeed, one of those falls seems to have been due to an unguarded erection of the body on hearing a large clock strike.

THE additions to the Zoological Society's Gardens during the past week include a Rhesus Monkey (*Macacus rhesus* ♂) from India, presented by Mr. Jesser Coope, F.Z.S.; a Nightingale (*Daulias luscinia*), British, presented by Mr. J. Young, F.Z.S.; two Green Doves (*Chalcophaps indica*) from Ceylon, presented by Mrs. Thompson; a Common Chameleon (*Chamæleon vulgaris*) from North Africa, presented by Master E. S. Forwood; two Short-tailed Wallabys (*Halmaturus brachyurus*) from Australia, received in exchange; a Brown Capuchin (*Cebus fatuellus* ♂) from Brazil, a Squirrel Monkey (*Chrysothrix sciurea*) from Guiana, a Banksian Cockatoo (*Calyptorhynchus banksii*) from New South Wales, deposited; two Red-vented Bulbuls (*Pycnonotus hæmorrhous*), bred in the Gardens.

OUR ASTRONOMICAL COLUMN.

OBJECTS FOR THE SPECTROSCOPE.

Sidereal Time at Greenwich at 10 p.m. on September 11 = 21h. 24m. 28s.

Name.	Mag.	Colour.	R.A. 1890.	Decl. 1890.
			h. m. s.	° ′
(1) G.C. 4600	—	—	20 41 7	+30 19
(2) D.M. + 44° 3877 ...	6·7	Reddish-yellow.	21 31 51	+44 53
(3) 2 Pegasi	4·5	Yellowish-red.	21 24 58	+23 10
(4) δ Equulei	4·5	Whitish-yellow.	21 9 6	+ 9 34
(5) α Equulei	4·0	White.	21 10 18	+ 4 45
(6) 238 Schj.	7·4	Yellowish-red.	20 10 40	−21 35
(7) S Vulpeculæ	Var.	Yellow-red.	19 43 53	+27 1

Remarks.

(1) In the General Catalogue this nebula is described as "a very remarkable object; pretty bright; considerably large; extremely irregular figure; *k* Cygni involved." The spectrum, as observed by Dr. Huggins, is a continuous one with a suspicion of an unusual brightness in the region beyond F. The excess of blue light is probably due to the radiation of some substance, most likely carbon, added to a dim and short continuous spectrum. The green flutings would in that case be masked by continuous spectrum, and the result would be a spectrum apparently continuous in the green and discontinuous in the blue. This discontinuity should be looked for in the nebula spectrum, and comparisons made with the carbon flutings.

(2) This star has a spectrum of Group II. "of extraordinary beauty," all the bands 1–9 being very wide and very dark (Dunér). It is probably a star of mean condensation, and the bright carbon flutings should therefore be well seen.

(3) The spectrum of this star may advantageously be studied in connection with the observations of stars which have a spectrum hitherto described as of the solar type. It is one of a very late stage of Group II., the distinctive dark bands being very narrow, so that the spectrum approaches one of Group III. The *lines* which are seen at this stage will in all probability be continued to Group III. stars, and will therefore serve as criteria for distinguishing between stars of Group III. and stars of Group V.

(4) Vogel writes the spectrum of this star as II.*a* (I.*a*), which means that the star is either at a late stage of Group III., or an early one of Group V. Its precise position on the "temperature-curve" may be determined by reference to the criteria mentioned in the note on (3).

(5) The spectrum of this star is one of Group IV.

(6) Although this star is far from being a faint one compared with many other stars of Group VI., very few details have been observed in its spectrum, either by Secchi or Dunér. Dunér simply states that the spectrum consists of three zones, the blue being very weak. The intensity of band 6 (λ 564) relatively to band 9 (λ 517), and other details, should be noted.

(7) This is a variable of Group II. of very small range and short period. The mean magnitude at maximum is about 8·85, and that at minimum 9·95. The mean period is about 67·8 days, and the increase to maximum is much more rapid than the decrease to minimum, the former occupying 20·6 days, and the latter 47·2. According to Dunér, the spectrum is only feebly developed, and this is exactly what it should be if Mr. Lockyer's view as to the constitution of this class of bodies be correct. The central swarm being well advanced in condensation, only revolving swarms of short period will be effective in producing changes of light, because long period swarms will pass clear of the central swarm at periastron. It is only to be expected, therefore, that a well advanced, or "feebly-developed" spectrum should be associated with a short period in variables of Group II. Under these circumstances it is not likely that bright hydrogen lines will appear at maximum, but an observation of their absence will be of value, and other variations may occur. There will be a maximum about September 15.

A. FOWLER.

OBSERVATIONS OF THE COMPANIONS TO BROOK'S COMET (V. 1889).—Mr. E. E. Barnard, in *Astronomische Nachrichten*, No. 2988, gives the physical and micrometrical observations of the companions to this comet made with the 12-inch and 36-inch refractors of the Lick Observatory, and those made elsewhere. It will be remembered that Mr. Barnard discovered two companions to Brook's comet on August 2, 1889, and two others on August 5. His remarks on the appearance of the companions, and the physical changes which they underwent from the date of discovery, until they disappeared from sight, are very important. Two of the companions seemed to undergo the same process of disintegration. Beginning with a nucleus and a tail, each became enlarged, diffused, and fainter, until it had dissipated into space. In some concluding remarks Mr. Barnard writes: "I have no doubt but that the great telescope would readily reveal more unknown nebulæ than the entire number now contained in the latest catalogue of Dreyes," and the number of unknown nebulæ incidentally found by him during these observations supports this assertion.

PARALLAX OF β ORIONIS.—In the *Observatory* for September, Dr. Gill has a note on the parallax of β Orionis. The star is situated near one corner of the nebulous area encircled by α Orionis, Lalande 11382, Lalande 11329, ω Orionis, ψ Orionis, and β Eridani, and the observations show that it has a negative parallax of about 0″·17 relative to the near parallax of the stars D.M. − 7° 997 and − 8° 1078, and therefore belongs to a more distant system. It also results from the calculations that the former star and θ Orionis are members of an immensely more remote system than the latter one. The reductions were suggested by an examination of a photograph of the region about the Orion nebula taken under the direction of Prof. E. C. Pickering.

CARL FREDERIK FEARNLEY.—The death of this eminent Norwegian astronomer occurred on the 23rd ult. at Christiania. He was born at Frederikshald on December 19, 1818. In 1844 he became attached to the Observatory of Christiania University as an assistant, and since 1861 has been the Director. He was made a Professor of Astronomy in 1857.

The deceased astronomer published many observations of planets, comets, and the sun, and directed some attention to the determination of the height of the aurora borealis. He also published a memoir on atmospheric refraction, and participated in many geodetical observations.

Fearnley's death is severely felt by those with whom he came in contact.

UNITED STATES NAVAL OBSERVATORY, WASHINGTON.—The report of the superintendent of the U.S. Naval Observatory for the year ending June 30, 1889, has just been issued, and contains an account of the work done in each department.

The large equatorial has been employed in observing double stars and the satellites of Saturn; attention also being paid to the division on the ring and to the shadows.

Seventeen hundred observations have been made with the transit circle since October 9, 1888; of this number 68 were of the sun, 60 of the moon, 93 of the major planets, 18 of the minor planets, and 5 of Comet *e* 1888.

The 9·6-inch equatorial has been used for the identification of stars whenever necessary, and for the observations of small planets, comets, and occultation of stars by the moon. During the past year 3 comets were seen and observed whenever possible. Two nights a week this instrument is set apart for the accommodation of visitors, and permits for 1665 visitors were issued.

Assistant-Astronomer H. M. Paul, who has for the last year and a half been here observing suspected variables, has just discovered a new variable in the constellation Antlia, with a period of less than 12 hours, the shortest period yet known.

The chronometer and time service, under the charge of Lieutenant Taylor, have been doing good work. Fifty-six chronometers received from the makers, cleaned, and repaired, were tested in the temperature-room for a period of about two months. Chronometers were issued to eleven ships and one shore station, and the same number were received back.

No alteration has been made in the routine of sending out time signals, which are telegraphed every day, Sundays and holidays excepted.

In the magnetic department under the charge of Ensign Marsh, observations have been made on Tuesdays each week for the determination of the absolute horizontal intensity, and on each month they were made with the inertia cylinder attached to the magnet. Observations on the magnetic inclination, using three needles in rotation, were made every Monday and Friday. Two seismoscopes and a seismograph have been added to the stock of instruments, and they have been set up and are in good working order.

The library, which has lately been placed under the charge of Assistant-Astronomer Paul, in addition to his other duties, contains, up to June 30, 12,226 volumes and 2696 pamphlets, of which the accessions, since the last Report, have been 308 in number, 235 volumes and 73 pamphlets.

The appendix contains a report of the work done during the past year, by Prof. William Harkness, who was attached for special duty as a member of the Transit of Venus Commission, and had charge of the reductions and computations of the observations of 1874 and 1882. The result of his work is the determination of the sun's distance to be 92,455,000 miles, with a probable error of 123,400 miles.

SOCIETIES AND ACADEMIES.

LONDON.

Entomological Society, September 3.—Mr. Henry T. Stainton, F.R.S., in the chair.—Mr. C. Fenn exhibited and remarked on specimens of *Eupithecia satyrata*, *Eudorea ambigualis*, and *Tortrix viburnana* from Darlington.—Mr. H. Goss exhibited, on behalf of Mr. Martin S. Higgs, a remarkable variety of *Melitæa aurinia* (*artemis*), taken a few years ago, in Gloucestershire, by Mr. Joseph Merrin.—The Rev. Dr. Walker communicated some observations on the entomology of Iceland, and gave an account of his recent travels in that island. He stated that he had taken *Bombus terrestris* this year, for the first time, in the north-west of Iceland, from which quarter of the island it had not been recorded by Dr. Staudinger; he also referred to the enormous numbers of Ichneumonidæ and Diptera which he had noticed in the island. He further stated that in 1889, in the months of June and July, *Noctua conflua* was the most abundant species of Lepidoptera in Iceland; but that this year, in July and August, *Crymodes exulis* was the prevailing species, and that *Charæas graminis* and *Coremia munitata* also occurred in great numbers. In reply to a question by Mr. Stainton, Dr. Walker said that the flowers chiefly frequented by the humble-bees were those of a small species of white Galium (probably *Galium saxatile*) and *Viola tricolor*. Dr. Walker also read notes on *Calathus melanocephalus* collected in Iceland and the Faroe Isles in June and July 1890. Messrs. M'Lachlan, Stainton, Jenner Weir, Stevens, Jacoby, Lewis, and others took part in the discussion which ensued.—Mr. Arthur G. Butler communicated a paper entitled "Further Notes on the Synonymy of the Genera of Noctuites."

PARIS.

Academy of Sciences, September 1.—M. Duchartre in the chair.—MM. G. Seguy and Verschaffel gave a description of a photometer founded upon the principle of Crooke's radiometer.—M. Faye announced the publication of the *Connaissance des Temps* for 1892.—Influence of altitude on the development of plants, by M. Gaston Bonnier. The author has observed that the amount of carbon dioxide decomposed by plants increases with the altitude. Plants cultivated in an Alpine climate undergo a modification of their functions such that the chlorophyllian assimilation and transpiration are augmented, whilst respiration and transpiration in the dark appear little modified or slightly diminished.—On the chlorophyllian assimilation of trees with red leaves, by M. Henri Jumelle. The author has investigated the difference of physiological functions in the leaves of the green and red type of such trees as the beech, sycamore, elm, &c. He finds: (1) in trees with red or coppery-coloured leaves the chlorophyllian assimilation is always more feeble than in trees of the same kind having green leaves; (2) the intensity in the copper beech and purple sycamore is only about one-sixth that of the ordinary types of the same trees.—On the oospores formed by the fusion of multi-nuclei sexual elements, by M. P. A. Dangeard. The author has studied the sexual reproduction of plants of a lower order.—First observations on the cyclone of August 19 in Jura, by M. Bourgeat. A circumstantial account of the St. Claud cyclone is given. It is noted that the lower parts of the region visited by the storm suffered the most, that the direction of the gyratory movement was opposite to that of the hands of a watch, that the velocity of translation was about 1 kilometre a minute, and that the zone ravaged had a breadth from 500 to 1000 metres.—On the signification of the word "cyclone," by M. H. Faye. It was remarked by M. Faye that although all the papers and the author of the preceding note had named the St. Claud storm a cyclone, yet really it was a tornado. The difference between the two phenomena was pointed out, it being noted that the base of a cyclone is considerably larger than that of the St. Claud storm, and has a well-defined region of calm at its centre.

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