*THE BEGINNINGS OF LIFE**

II.

LEADING on to the newer and more important observations in the latter portion of the work, we have a sketch of the relation of crystals and organisms, in which a variety of curious and suggestive facts are adduced, tending to show that there is a striking analogy, if nothing more, in their mode of origin. The influence of changed conditions is shown to produce very similar results to both, and the views of Mr. G. H. Lewes—that organisms are not always united by the link of a common heritage, but that many may owe their similarity to having originated under the influence of uniform organic laws acting under uniform conditions—is quoted with approval. Just as similar crystals are produced in similar liquids under like conditions, so may low organisms of similar or identical structure be produced; and just as the fragments of a crystal will, under favourable conditions, form each an entire and perfect crystal, so do low

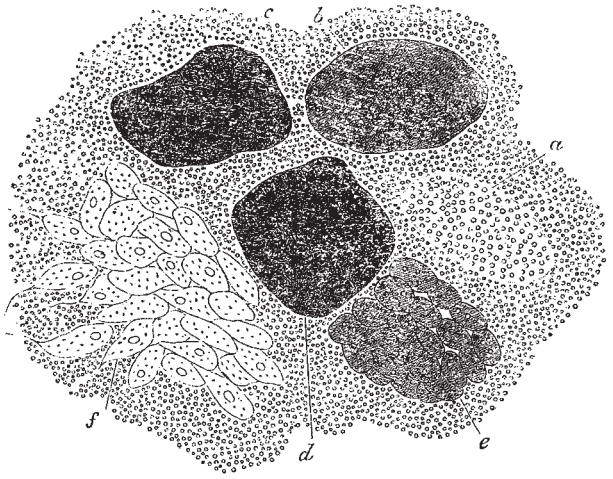

FIG. 1.—SEGMENTATION OF EMBRYONAL AREAS INTO MONADS—(× 1,670).

a. First stage of differentiation. *b*. Second stage; area almost homogeneous and refractive. *c*. First traces of segmentation. *d* Segmentation more complete; units highly refractive *e*. Units less refractive; forming tailless corpuscles. *f*. Fully developed Monads derived from such corpuscles.

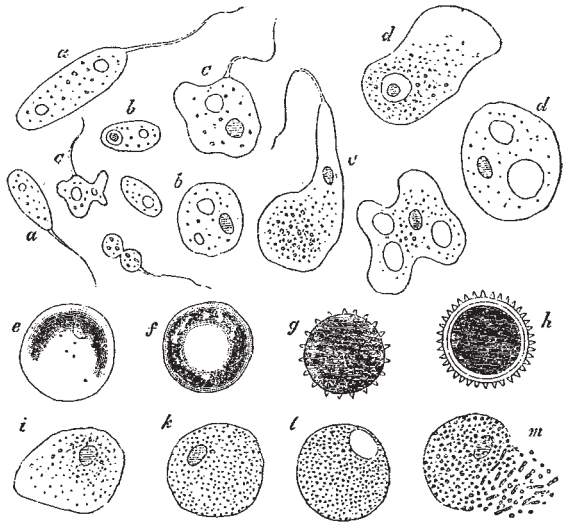

FIG. 2.—PHASES IN THE LIFE-HISTORY OF MONADS AND AMŒBÆ—(× 1,670).

a, a. Monads in different stages of growth. *b, b*. Similar Monads which have lost or retracted their flagella. *c, c*. Monads about to be transformed into Amœbæ. *d, d*. Resulting Amœbæ in active and motionless stages. *e, f, g, h*. Stages by which motionless Amœbæ become encysted. *i, k, l, m*. Stages by which other Amœbæ become resolved into Bacteria.

organisms multiply by fission, each part becoming a perfect whole. The difference between crystals and organisms is said to be less radical than has been supposed, and is mainly due to the much greater complexity and instability of the molecules which go to build up the latter. Crystals are statical; organisms, dynamical aggregations of molecules. Specks of new living matter soon aggregate into certain definite forms just as crystals do, but being much more complex and unstable, they are liable to much greater variations and successive modifications. The excessive variability and instability of low forms of life is dwelt upon as an anomaly on the ordinary theory, when viewed in connection with their supposed wonderful stability for immense periods of time. It is generally believed that every one of the lower animals is a descendant of other low forms which lived in ages far anterior to the Silurian epoch. Many of the foraminifera.

* "The Beginnings of Life: being some account of the Nature, Modes of Origin, and Transformations of Lower Organisms." By H. Charlton Bastian, M.A., M.D., F.R.S. (2 vols. London: Macmillan and Co. 1872.)

for example, have hardly undergone any essential change, the same forms and varieties recurring at very distant geological periods. If, however, living matter does continually come into existence, the lowest forms will probably have been very similar in all ages; and it is only as these forms developed into more complex organisms that the varying conditions of the different periods will have led to the development of specialised groups.

The nature and mode of development of the low organisms found in infusions is next elaborately discussed, with the following result:—"No other conclusion remains for us, but that the several organisms are products of the

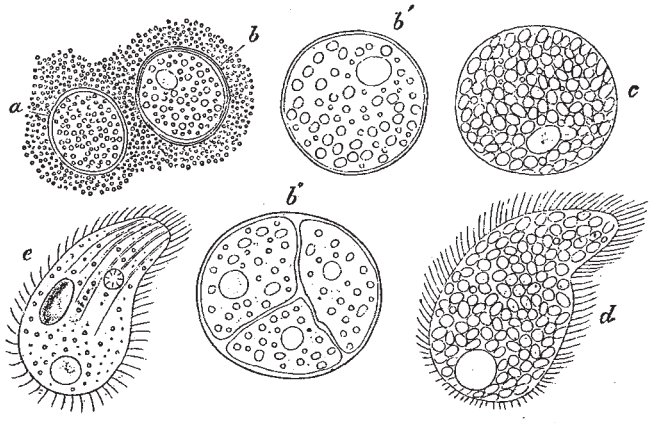

FIG. 3.—MODE OF ORIGIN OF PARAMECIA—(× 800).

a. First stage of differentiation. *b*. Later stage, in which vacuole has appeared. b^1. Similar stage of much larger embryo. b^2. Another embryo which has segmented into four (only three parts visible). *c*. Later stage; embryo filled with large particles, and revolving within its cyst. *d*. *Paramecium* after it emerges from its cyst. *e*. *Nassula*-like form into which many afterwards passed.

direct developmental unfolding of new-born specks of living matter. And yet among these forms we see Bacteria, Vibriones, Leptothrix, and Torulæ; Fungus filaments, with and without fructification; Protamœbæ and flagellated Monads; Pediastreæ and Algoid filaments. All these are therefore proved with the greatest certainty to be interchangeable forms, which may be assumed on different occasions by newly evolved specks of living matter." Evidence is also adduced of the changes in other low forms. Green corpuscles thrown off from a single Lichen have been seen by Dr. Hicks to assume the forms and mode of growth characteristic of no less than twenty-three supposed species of Algæ; while gonidia from an Alga or from a Moss were developed into Lichens, Algæ, or Mosses, according to the conditions under which they were placed, while they may sometimes give birth even to active Monads.

Having clearly proved that Bacteria and other low

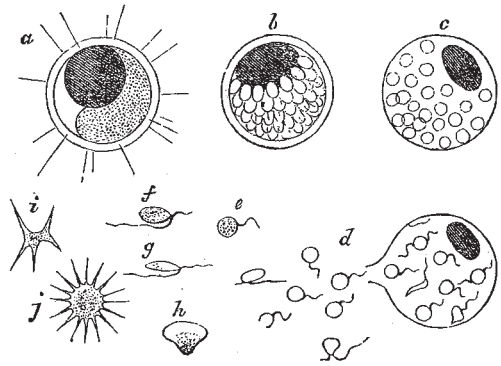

FIG. 4.—HETEROGENETIC ORIGIN OF MONADS FROM NITELLA (CARTER)—(× 350).

a. Contents of new-formed cyst separating into Protoplasm and dark brown refuse matter. *b*, *c*, *d*. Segmentation of the Protoplasm into Monads, which afterwards escape from the ruptured cyst. *e*, *f*, *g*. Different forms of the Monads. *h*, *i*, *j*. Forms of Amœbæ and Actinophrys which the Monads subsequently assume.

organisms, which form a pellicle on the surface of infusions and other liquids, are produced *de novo* in such infusions, the third part of the work, entitled "Heterogenesis," is devoted to a history of the microscopical examination of the changes which take place in this pellicle, and of all that is at present known of the transformations of the various classes of organisms to which it gives birth. To make this part of the subject clearly intelligible, it will be necessary to reproduce a considerable number of the woodcuts by which these changes are illustrated. One of the most simple series of changes—this transformation of motionless corpuscles into ordinary Amœbæ—was closely watched by Dr. Bastian, and seen with the most perfect distinctness in thousands of instances. Fig. 4 shows the stages by which the more highly organised Monads are developed. The first step was an increase of the amount of gelatinous matter between the corpuscles or Bacteria, which gradually became less defined, and at last scarcely visible in the protoplasmic mass, in which segmentation then began to take place, and continued till it separated into active Monads. After a time, however, these again began to change into Amœbæ, and these latter, passing through a motionless and encysted stage, became resolved into Bacteria (Fig. 5). The whole

series of these changes occupied about ten days. In other cases similar corpuscles developed into fungi; while in some instances in the same pellicle the change into Amœbæ on the one hand, and into Fungus germs on the other, went on simultaneously. It was soon discovered that the temperature at which the infusion was made was of great importance. If it had been heated to 212° F. no development beyond Bacteria occurred; if at 149°—158° F. Fungus germs arose; while an infusion in all other respects similar, but prepared at a temperature of 120°—130° F. gave rise to actively-moving Monads.

A step further takes us to the "spontaneous eggs" of Pouchet, which are seen to be formed in the pellicle, and afterwards give birth to Paramecia — highly organised ciliated Infusoria. These never appear except in infusions made with cold water, and Dr. Bastian assures us that he

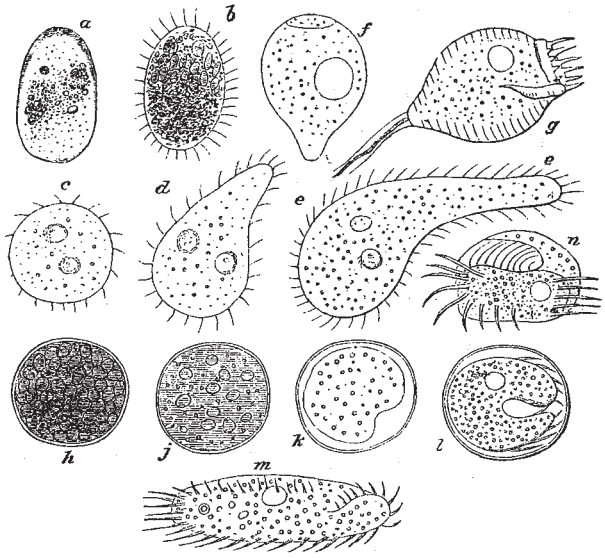

FIG. 5.—MODES OF ORIGIN AND DEVELOPMENT OF CILIATED INFUSORIA—(× 600).

a. A transforming Euglena with red "eye speck" still visible. *b* A similar body, having many of its chlorophyll corpuscles still green, fringed with almost motionless cilia. *c*. A completely decolourised sphere derived from a transformed Euglena, provided with a few partly motionless cilia. *d*, *e*. More advanced forms of a similar embryo developing into a Dileptus (?). *f*. Vorticella, soon after its emergence from a cyst of Euglena origin, which subsequently develops into a striated variety (*g*). *h*. A large Chlorococcus-vesicle whose contents gradually undergo decolourisation (*j*), and at last become converted into an animalised mass (*k*), which gradually shapes itself into the form of an Oxytricha (*l*); this after a time ruptures its cyst and soon takes on the characteristics shown at *m*. *n*. A form of Plæsconia derived from an embryo produced within other apparently similar Chlorococcus vesicles.

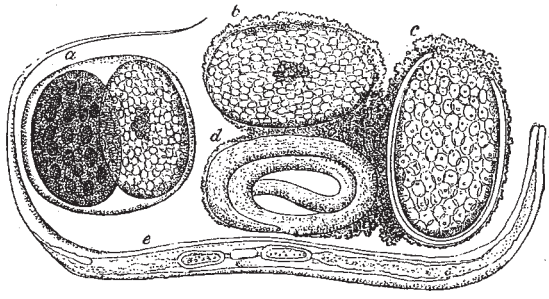

FIG. 6.—ORIGIN OF NEMATOIDS FROM EUGLENÆ (GROS).

a. A large Euglena which after encystment has undergone fission, whilst one of the halves has become decolourised. *b*. An Euglena which has become converted into a decolourised embryonic mass, leaving only a small coloured remainder. *c*. Another decolourised mass, which, after undergoing certain changes, becomes converted into a young Nematoid, as at (*d*). *e*. A female specimen of the developed Nematoid three weeks old, in whose ovaries two partially developed ova are seen.

has verified Pouchet's observations in all essential particulars, as represented in Fig. 6; and the still more complex Vorticellæ have been seen to arise in a similar manner. Now the germs of Ciliated Infusoria are comparatively very large and easily recognisable; they have never, or very rarely, been discovered in the atmosphere; and no competent observer could overlook them; so that it is almost impossible not to accept the fact of the origin of these organisms in the manner here described.

The course of the argument is at this point interrupted by a chapter on the Atmospheric Germ Theory, which, though exceedingly interesting and well written, is quite out of place here; and we then come to some curious observations on the production of organisms within the closed cells of various plants. M. Trecul, a distinguished French botanist, has watched the formation of Amylobacters, low organism allied to Bacteria, and minute Fungi within the closed cells of living plants. In *Ficus carica* he discovered fungoid organisms within the completely closed cells of the medullary tissue, which, he believes, "negatives all ideas as to the introduction of germs from without." Minute crystalline tetrahedrons in cells of the bark of common elder and other plants were actually seen to be transformed into Amylobacters. The transformation of milk globules and a film of diluted cream-cheese into Fungus germs has also been closely watched by several

observers, and has convinced them that these organisms have not arisen from accidentally introduced spores, but by a true heterogenetic transformation of the substance examined. Dr. Lionel Beale has discovered lowly vegetable organisms "in the interior of the cells of animals, and in the very centre of cells with walls so thick and strong that it seems almost impossible that such soft bodies could have made their way through the surrounding medium." Many other observers have even watched the transformation of the contents of healthy epithelial cells into Bacteria and Vibriones; and well-developed Fungi have been found within the uninjured eggs of birds and serpents. Now, all these facts, and a vast number of others detailed by Dr. Bastian, are claimed to be in complete harmony with the facts he has already established by his experiments with hermetically closed flasks, and with the theory of Archebiosis, while they have always offered immense difficulties to the advocates of Homogenesis, and have never been explained but by means of pure assumptions of a most improbable character.

We next come to the consideration of true Heterogenesis among lower organisms. Dr. Braxton Hicks has observed the production of Amœbæ by the transformation of the chlorophyll and protoplasmic contents of the cells of Moss radicles. Mr. H. J. Carter has closely followed the changes occurring in the cells of Nitella, one of the Characeæ, resulting in the formation of Monads and Amœbæ, as represented in Fig. 1. A vast number of observations of a similar character by many different observers are detailed, showing that the chlorophyll vesicles of Algæ are sometimes metamorphosed even into Pediastreæ, Desmids, and Diatoms.

But we must pass on to still more remarkable facts. The cell contents of Confervæ give rise to Euglenæ and Astasiæ, beautiful green organisms which abound in stagnant water, and these undergo transformations into a variety of higher or lower organisms, such as Diatoms, Amœbæ, and Ciliated Infusoria, the latter process being represented in Fig. 2. But Ciliated Infusoria themselves undergo transformation into various forms of lower animals, among others into Rotifers. The low Euglenæ are also transformed into either Rotifers, Tardigrades, or Nematoids, and the latter even grew into well-developed males and females (Fig. 3). Still more extraordinary, if possible, is the transformation of the minute Algoid Chlorococcus into the large, complex, and well-known Rotifer, *Hydatina senta*. Concerning the reality of these transformations, astounding as they are, Dr. Bastian assures us he entertains not the slightest doubt, having traced them through all their stages. The extreme prevalence and almost universal distribution of certain common forms of Rotifers, Tardigrades, and Nematoids, whose germs or ova are unusually large, and have been proved not to be universally present in the atmosphere, is inexplicable to those who disbelieve in the occurrence of heterogenetic transformation. Not only is it said to be proved that such transformations occur among Algæ, Fungi, Lichens, and Mosses, in every group of animals belonging to the class Scolecida, and in some of the lowest Annelida, but also in some of the lowest Arthropoda. In concluding this part of his subject, our author remarks:—"The fact that animals with such distinct and specific organs should arise in this definite manner from the reproductive products of a plant, will doubtless seem to many to flavour more of fable than of fact. After the observations which have been detailed, however, we must accept the occurrence of such phenomena as established facts, just as we are compelled, and are now quite accustomed, unhesitatingly to believe in the reality of other equally inexplicable phenomena. When we are able really to explain the reason of the processes by which one minute vesicular mass of fatty and albuminoid particles develops into a man, another into a fish, and another into an insect, we may then, with a little more show of reason, think of rejecting other more or less similar facts because they are incomprehensible."

Passing now from facts and observations of which we have only been able to indicate the character and extent by a few examples, Dr. Bastian proceeds to discuss the nature of "individuals" and "species" by the aid of the new light these researches have thrown upon them. He adopts the definition of an "individual" given by Herbert Spencer as being any organised mass "having a structure which enables it continually to adjust its internal relations to external relations, so as to maintain the equilibrium of its functions," and would define species to be any assemblage of individuals which are enabled for many generations to reproduce their like. But between these two he believes we must now establish a third category, for which he proposes the term "Ephemeromorphs," to include all those various forms which, although they sometimes produce their like, are shown to be interchangeable, and which, occasionally or regularly, arise from, or give birth to, forms quite distinct from themselves. All groups in which there is no differentiation of sexes are probably Ephemeromorphs, and the phenomenon of "alternate generations" in sexual animals is thought to be a recurrence to a partially Heterogenetic mode of reproduction.

The facts of Heterogenesis, if established, will undoubtedly largely modify our views as to the universality of the action of "Natural Selection." They seem to show that among the lower organisms, unknown laws of "polarity" akin to those which influence the production of crystals, but of infinitely greater complexity, directly cause the development of a vast variety of forms; while conditions of existence to a great extent determine the special forms that shall arise in each individual case. For such creatures "laws of heredity" hardly exist, and if so, Natural Selection can have little or no power. If we consider the enormous variety of forms that have been here shown to arise by Heterogenesis, it becomes evident that the field of action for Natural Selection becomes thereby considerably reduced. Again, the experiments detailed by Dr. Bastian prove the overwhelming importance of external conditions in determining the form that shall be assumed by many of the lower organisms, just the reverse of what has been found to obtain among the higher animals. And, what is still more important, the varying conditions do not act by producing changes in the adult organism which may be transmitted to their offspring, but actually so modify the developing germs as from a similar starting point to produce organisms which would rank as of distinct species, genera, or even families. The change produced seems to be quite incommensurate with the modified conditions which lead to it, and we are thus forced to accept some form of belief in innate tendencies or laws of progressive development, dependent on the polarities, forms of equilibrium, and attractive or repulsive properties of the complex physiological units of which organisms are built up. Such views are generally repudiated by modern thinkers; but Dr. Bastian believes they are necessitated by the facts now brought forward, and that they are really not only in harmony with, but almost necessary deductions from, the principles of the philosophy of evolution.

The phenomena of Heterogenesis also lead us to conclusions as to the rate of change in time of lower organisms exactly the reverse of those generally held. From having mainly studied the higher forms of life, and from having ascertained that the complex actions and reactions of such organisms on each other have been more efficient in producing specific changes than mere variability or the influence of changed conditions, Mr. Darwin has been led to the conclusion that the rate of change of the early forms of life, which had far less complex actions and reactions among themselves, must have been exceedingly slow

This has almost the appearance of a paradox, in view of the admitted fact of the extreme variability and instability of these lower forms; yet it has been generally accepted as a sound inference from the law of natural selection, and has greatly increased the difficulty that has been felt as to the enormous time required for the development of all forms of life from the supposed primordial germs. But if the facts of Archebiosis and Heterogenesis are true, and all the lower forms of life are continually being produced *de novo*, under the influence of unknown laws of development, then we may fairly conclude that, when once the earth had arrived at conditions favourable to the production of living organic matter, the process of development would be rapid, and an immense variety of low forms of animals and vegetables would soon people it. It is a fair inference, too, that if such complex organisms as Ciliated Infusoria, Rotifers, Nematoids, and even simple Acari, can be developed independently of the slowly modifying influence of natural selection, the same laws of development will continue to act a subordinate part much higher in the scale, and, by assisting natural selection in its work, may have enabled a much more rapid progress to be made.

It is very strongly argued by Dr. Bastian that the conception of an origin of living organisms at a single remote epoch in past time, and the lineal descent of all existing organisms from those primal forms, is one quite opposed to the uniformitarian and the evolutional philosophy, and in the highest degree difficult to accept. It is almost inconceivable that Bacteria, Moulds, Monads, Amœbæ, and a thousand other minute and simple organisms, should still exist so universally over the earth, and under such an infinite variety of simple forms, if all were descended from ancestors which could hardly have been more simple in the almost infinitely remote past, and which throughout all that time had been subject to those same causes of change and advance in complexity of organisation which have resulted in the varied forms of all the higher animals. Whatever laws and conditions led to the production of the earliest organisms, they are hardly likely to have been of so exceptional a nature as never to have occurred since. It does not seem probable that the very existence of life upon the earth depended on so rare and improbable a set of conditions that, having once occurred, they should never occur again in the whole period between some remote pre-Laurentian epoch and the present day. If, therefore, there is good evidence of the continued *de novo* production of lower forms of life, and of the direct transformation of these into various higher and more complex organisms, such a view will have many *a priori* considerations in its favour, and will tend to bring the whole series of life-phenomena into greater harmony with those of inorganic nature, without in any way diminishing the mysterious grandeur that surrounds them.

But if these views should be established, we shall have to form an entirely new conception of the genealogical history of the various existing organisms. We shall no longer have one "tree of life," but a vast number of such trees, all having their roots in a similar substratum of the lowest organisms, evolved at various periods of the earth's history, but differing greatly in their subsequent development. It is probable that by far the greater number of these "trees of life" have become extinct at various periods of their growth, and that all existing living things belong to portions of but a few "trees," some of which may be comparatively recent, while others may have their roots far back in the past, anterior to the earliest epochs of which geology affords us a record. But notwithstanding this diversity and separateness of origin, through the whole life-history of our globe the progress of organisation seems to have been essentially similar; which is readily explicable on the ground that living things, both as regards their origin and subsequent differentiation or development, are the immediate products of natural laws or material properties, which are probably the same now as they have ever been. Similar types of form may, therefore, again and again have arisen; and Dr. Bastian remarks, that even "the vertebrate grade of organisation *may* have been attained by ultimate branches of different trees of life." It remains to be seen how far this conception will throw light on obscure and difficult questions of biological classification, and on those facts of geological succession which are most difficult to reconcile with the usual view of all organisms whatever having originated from a single almost infinitely remote source.

It will now be seen, even from the very imperfect sketch of its subject-matter, how many questions of the highest scientific importance rise out of the facts adduced in Dr. Bastian's work. It is not too much to say that, if its main conclusions are established, it will create a revolution in organic philosophy of equal importance with that which was effected by Mr. Darwin, whose observations and most important theories will, however, remain unaffected by it. That gentleman has himself remarked that "analogy is a deceitful guide," and it is only by analogy that he extends the laws he has established for the higher animals and plants to those lower forms with which Dr. Bastian deals; and the establishment of facts proving that they come under a different category will even relieve the theory of natural selection from some of its greatest difficulties, and neutralise some of the most serious objections that have been brought against it. The whole question, however, is primarily one of facts, and, however it may be ultimately decided, every lover of science must admire the courage and energy with which Dr. Bastian has taken up an unpopular subject, the skill and patience with which he has experimented, the labour which he has bestowed in collecting the records of widely scattered and almost forgotten observations, and the logical force as well as the philosophical spirit with which he has worked out his conclusions. It is a book that cannot be ignored, and must inevitably lead to renewed discussions and repeated observations, and through these to the establishment of truth.

ALFRED R. WALLACE

NOTES

THE Lords of the Committee of Council on Education having decided to transfer the instruction in Physics, Chemistry, and Natural History from the Royal School of Mines in Jermyn Street, and the College of Chemistry in Oxford Street, to the new buildings in Exhibition Road, South Kensington, notice has been given that in future the following courses of lectures and practical laboratory instruction will be given at South Kensington at the date specified:—Chemistry by Prof. Frankland, D.C.L., F.R.S. A course of forty lectures on Inorganic Chemistry commencing 21st of October, 1872. A course of thirty lectures on Organic Chemistry commencing 13th of January, 1873. Laboratory instruction consisting of an elementary and an advanced course commencing on 1st of October. Biology by Prof. Huxley, LL.D., F.R.S., a course of eighty lectures on Biology (or Natural History, including Palæontology) with laboratory instruction, commencing the 7th of October, 1872. Physics by Prof. Frederick Guthrie. The course will consist of lectures, with laboratory work on the subject of the lectures, divided as follows:—Twelve lectures on Molecular Physics, Sound, &c., commencing 24th of February, 1873; fifteen lectures on Heat, commencing on 24th of March; fifteen lectures on Light, commencing on 12th of April; twenty lectures on Electricity and Magnetism, commencing on 19th of May. Each course will be complete in itself, and may be taken separately.