A PLAIN ACCOUNT OF EVOLUTION

NEBULA OF ORION

Enlarged from a photograph taken direct by Mr. Common

THE STORY OF CREATION

A PLAIN ACCOUNT OF EVOLUTION

BY

EDWARD CLODD

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TO

GRANT ALLEN.

My dear Allen,

The inscription of this little book to you, whose interest in it has been constant since its framework was shown you, enables me not only to repeat the obligations which are set down in the Preface, but also to say, what is more gratifying to me, how deeply I value your friendship.

Yours ever sincerely,

EDWARD CLODD.

PREFACE.

THE scope and purpose of this book are explained in the Introductory chapter, but the justification for its publication in these days of over-production has to be given.

This lies in the fact that, so far as I know, no work of the kind exists in brief and handy compass; complete expositions of the theory of Evolution, foremost among which ranks Mr. Herbert Spencer's, being in bulky volumes with which few readers have the time or courage to grapple. In attempting to give a clear idea of the mechanism of the universe, I have felt the difficulty expressed years ago by such authorities as Sir W. R. Grove and Professor Tyndall, arising from the lack of precision in standard books on physics in the use of the terms 'force' and 'energy.' When talking over this matter with my friend Grant Allen, I was delighted to find that he had published (although privately) a pamphlet on the subject, in which rigid and definite meanings are given to 'force' and 'energy' as the two-fold and opposite forms of Power manifest through

Matter; and in that sense, as affording the reader a clearer conception of cosmic dynamics, those terms are used throughout this book. Mr. Allen has plunged me deeper in his debt by the labour of reading my proof-sheets, a service which, to their further gain, has also been kindly rendered by my friend Mr. H. W. Bates, F.R.S.

The chief authorities consulted in the preparation of this book are duly acknowledged in foot-notes. As for the work as a whole, there is probably not a new idea in it, but only an attempt to explain matters of abiding interest and deep significance in as simple and untechnical a style as possible.

E. C.

ROSEMONT, TUFNELL PARK, LONDON, N.:
December 1887.

P.S.—The publication of Darwin's *Life and Letters* while these sheets are under revision enables me to add a few foot-note references to that work. And it is gratifying to see that, in the chapter with which Professor Huxley has enriched the second volume, he substitutes (p. 201) the term 'powers' for 'forces' in quoting his definition of evolution given in *Critiques and Addresses*, p. 305.

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'First man appeared in the class of inorganic things,
Next he passed therefrom into that of plants.
For years he lived as one of the plants,
Remembering nought of his inorganic state so different;
And when he passed from the vegetive to the animal state,
He had no remembrance of his state as a plant,
Except the inclination he felt to the world of plants,
Especially at the time of spring and sweet flowers;
Like the inclination of infants towards their mothers,
Which know not the cause of their inclination to the breast
Again, the great Creator, as you know,
Drew man out of the animal into the human state.
Thus man passed from one order of nature to another,
Till he became wise and knowing and strong as he is now.
Of his first souls he has now no remembrance,
And he will be again changed from his present soul.'

Masnavi (Bk. IV.) of Jalâl ad Dîn (13th Century).

THE

STORY OF CREATION.

INTRODUCTORY

Happy the man whose lot it is to know
The secrets of the earth. He hastens not
To work his fellows' hurt by unjust deeds,
But with rapt admiration contemplates
Immortal Nature's ageless harmony,
And how and when her order came to be.
Such spirits have no place for thoughts of shame.

EURIPIDES, *Fragm.* 902.

ON the 27th of December 1831, Charles Darwin, then in his twenty-third year, embarked at Plymouth as volunteer naturalist on a five years' voyage in the *Beagle,* a ten-gun brig, which was commissioned to survey the shores of South America, and to circumnavigate the globe.

Few marked the departure of that ship; none could foretell what memorable results would follow from her voyage, or know that she carried the man whose theory was destined to revolutionise or profoundly modify every department of human thought and every motive to human action. But so it was. The true epoch-maker, never dreaming to what far-reaching and momentous issue his work would lead, retired, some time after his return, to a quiet home in Kent there to consider the significance of the materials gathered during his voyage. The distribution of living things in South America, and markedly in their relation to those in the Galapagos Islands, a group lying five hundred miles from that continent, was among the chief causes[1] which led Darwin to convictions regarding the mutability of species, and finally to a solution of the problem of their origin, which, after the lapse of nearly a quarter of a century spent in the testing of every fact and argument telling in favour of or against his theory, was published in the famous 'Origin of Species.' That book is the imperishable record of the most momentous advance in man's knowledge of the operations of nature since the publication of Newton's 'Principia.'

The pens of many experts, ready writers withal, have enriched our scientific literature with clear and charming expositions of Darwin's theory for the benefit of a public which runs so fast that it has little time to read. But that theory deals only with organic evolution, *i.e.* with the origin of the myriad species of plants and animals; and the prominence given to it in virtue of its more immediate interest makes us apt to overlook the fact that it is only a small part of an all-embracing cosmic philosophy. For whatever lies within the phenomenal—the seen or felt—and therefore within the sphere of observation, experiment, and comparison,

[1] 'In July opened first note-book on Transmutation of Species. Had been greatly struck from about the month of previous March on character of South American fossils, and species on Galapagos Archipelago. These facts (especially latter) origin of all my views.'—Extract from Pocket-book for 1837, *Darwin's Life and Letters*, i. p. 276. Referring to the same matter, Darwin says in a letter to Sir J. D. Hooker, dated January 11, 1844, 'Gleams of light have come, and I am almost convinced (quite contrary to the opinion I started with) that species are not (it is like confessing a murder) immutable.'—*Ibid.* vol. ii. p. 23.

whether galaxy which only the telescope makes known, or monad whose existence only the microscope reveals, is subject-matter of inquiry, both as to its becoming and as to its relation to the totality of things. It is this more general conspectus of evolution as a working hypothesis which, if it does not explain every fact, is inconsistent with none, that the following pages are designed to give in clear and, as far as possible, simple words.

Before attempting this it is desirable to outline the phenomena which that theory explains; and the first part of this book will therefore describe such matters as the stuff of which all things are made, its combinations, affinities, and distribution; the relation, likeness, and unlikeness between the stellar and solar systems, and between the earth and its fellow-planets; the varied forms and conditions of past and present life, and the relation between these and the inorganic or non-living—in brief, whatever makes up the visible universe. Many facts will, therefore, be set down which every schoolboy is supposed to know, but which most folks whose school days are long past have probably forgotten. But the repetition may make easier that which follows by way of explanation, and, moreover, may foster the growth of that feeling of an underlying and indivisible unity between the remote and near, the past and present, the living and non-living, which is apt to lie dormant when things in chemical or vital relation are treated as separate, or as differing in kind. Astronomer or chemist, geologist or palæontologist, psychologist or physiologist, botanist or zoologist, all are members one of another, and none can say to his fellow, 'I have no need of thee.' The astronomer captures the truant light from the stars, and the chemist, decomposing it, compels from it the secret of their structure, even the direction in which they travel. The geologist rives the strata asunder, and discloses their succession and contents; the palæontologist, disengaging the fossils embedded in them, or altogether composing them, finds the ancestral forms of living species and the missing links in the unbroken chain of life. The psychologist may analyse and catalogue the operations of the mind, but the key to understanding them lies in the study of brain structure and function, of which the physiologist is master; while the botanist and zoologist alike miss the significance of the phenomena of plant and animal life if these are treated as separate departments of biology. Truly, as Emerson says, 'the day of days, the great day of the feast of life, is that in which the inward eye opens to the unity in things.'

Yet must we exclaim with the chorus in the 'Antigone,' and in these days with a deeper meaning, 'Who can survey the whole field of knowledge? Who can grasp the clues, and then thread the labyrinth?' For the material is so wide-ranging and varied that only the barest outline is possible; and in dealing whether with star or species, the one must often represent the whole, the individual the class. 'For the purpose of getting a definite knowledge of what constitutes the leading modifications of animal and plant life it is not needful to examine more than a comparatively small number of animals and plants.'[1] Our knowledge will, however, thereby advance from the particular to the general, and be enlarged from a mere storage of facts to an all-inclusive philosophy of things; so that although we may not escape errors of detail, we shall be saved by true apprehension of the universal.

The limits of this book demand the exclusion of

[1] Huxley's *American Addresses*, p. 154.

reference to old cosmogonies, and to attempts to square them with facts. What this or that philosopher has guessed, what this or that ancient manuscript or tablet records, about the heaven and earth, 'and all that in them is,' has only an historical interest and value. To deal with such matters here would give them a false importance, and, moreover, confuse things proved with obsolete speculations. Still more does this apply when the mechanical explanation of the general and simple phenomena of the lifeless is extended to the special and complex phenomena of life in its ascending scale from moneron to man, without pause wherein caprice or chance could enter to disturb the sequence. But caprice and chance are not: the nebulous stuff of which the universe is the product held latent within its diffused vapours not only the elements of which the dry land and the waters are built, and from which the boundless varieties of plants and animals have been evolved, but aught else that, through work of man for good or ill, has composed the warp and woof of this world's strange, eventful story. Be it borne in mind, however, at the outset, that although much is explained by evolution, and although no limitations to its application can be admitted within the sphere of the phenomenal, there remains much more than is dreamt of in our philosophy unexplained, around the impenetrable marge of which imagination, and the sense of mystery that feeds it, can play. 'Positive knowledge does not and never can fill the whole region of possible thought. At the uttermost reach of discovery there arises, and must ever arise, the question, What lies beyond?'[1] The whence of the nebula and its potential life is an abiding mystery that overawes and baffles us. The beginnings of the crystal are no less unknown and

[1] *First Principles*, p. 16, 3rd ed.

undiscoverable than the beginnings of the cell: the ultimate causes which lock the atoms of the one in angular embrace, and which quicken with pulsating life the corpuscles of the other, lie beyond our ken. And if of the beginnings nothing can be known, so is it with the things themselves, which affect us by their colour, their weight, and movement. They remain the unknown cause of sensations which are themselves, as Helmholtz says, and as Descartes said two centuries before him, only *symbols* of the objects of the external world, corresponding to them in some such way as written characters or articulate words to the things which they denote. There is no greenness in the grass; there is no redness in the rose; there is no hardness in the diamond: that which our sensations report to consciousness as colour and hardness being the result of myriads of unlike motions, some of which are repeated as often every second as there are seconds in thirty millions of years.

Thought and emotion have their antecedents in molecular changes in the matter of the brain, and are as completely within the range of causation and as capable of mechanical explanation as material phenomena, but of them no material qualities, as weight and occupancy of space, can be predicated. Heat may be expressed in equivalent foot-pounds, light and sound and nervous transmission in measurable velocities, but these never. We cannot make the passage from chemistry to consciousness, or transform motions of nerve-tissue into love, reverence, and hate.

But let us, without further preamble, advance to the matter in hand, since, to quote the author of the Book of Maccabees, 'it is a foolish thing to make a long prologue and to be short in the story itself.'

PART I.—DESCRIPTIVE

CHAPTER I.

THE UNIVERSE: ITS CONTENTS.

THE Universe is made up of *Matter* and *Power*.

Power is manifest as Force and Energy.

1. *Matter.*—Under this term are comprised all substances that occupy space and affect the senses. Matter is manifest in three states—solid, liquid, and gaseous. It is probably also present throughout the universe in the highly tenuous form called ether.

Between the above three states there is no absolute break, matter assuming any one of them according to the relative strength of the forces which bind, and of the energies which loosen, the component parts of bodies; in other words, according to the temperature or pressure. *E.g.*, water becomes solid when its latent heat or contained motion is dissipated, and gaseous to invisibility when its particles are driven asunder by heat.[1]

Since the ultimate nature of matter remains unknown and unknowable, we can only infer what it *is* by learning what it *does*. The actions of bodies, whatever their states, are explicable only on the assumption that the bodies are made up of infinitely small particles which, in their com-

[1] In choosing water as an example, its peculiar action in expanding as it approaches the solid state should be noted. Perhaps this is due to the form in which, as in snow, its molecules crystallise.

bined state as mechanical units, are called molecules; and in their free state, as chemical units, are called atoms. The molecule is a compound body reduced to a limit that cannot be passed without altering its nature; the atom is a body which has not been yet divided.

The atoms, or so-called elementary substances, number, as far as is known at present, about seventy; but many of them are extremely rare, and exist in such minute quantities as to be familiar only to the chemist. Although his progress in analysis has not yet given us actual evidence of their compound nature, the evidence thus far gathered points to their common derivation.

Eighty years ago, Dalton, working in no luxurious laboratory, but with the meagre apparatus of a few cups, penny ink-bottles, and home-made thermometers and barometers, discovered that atoms combine in definite proportions of weight and volume with other atoms. For example, whether we take water in large or small quantities from the clouds, or from the ocean, or from the fluids of living things, and decompose or break up its molecules, they will always be found to contain sixteen parts by weight of oxygen to two parts by weight of hydrogen; whether we take salt from the sea or from the blood of animals, its molecules always consist of fixed proportions of chlorine and sodium, thirty-five and a half parts of the one and twenty-three of the other; in each and every case any excess of either element remains uncombined—left out in the cold for want of a partner.

Dalton's discovery changed chemistry from a qualitative to a quantitative science, giving an impetus to research which at last promises to bring us within sight of the fulfilment of Faraday's prophecy, that 'in the end there will be found one element with two polarities.' Many workers followed on the lines laid down by Dalton, notably Prout, who formulated the theory that the atomic weights are multiples of the atomic weight of hydrogen, the lightest of the so-called elements, which he argued might be regarded as the primordial element, the *materia prima*, from which the others are formed by successive condensations.

The researches of the past few years establish the fact that certain of the elements possess such strongly marked likenesses as to warrant their classification into groups, but these groups did not appear to be connected with one anothei, nor to have any relation to the far larger number of elements not falling into groups. Recently, however, a marked advance towards proof of the common origin of all the elements has been made by a Russian chemist, Mendelejeff,[1] who, following Newlands, has shown that if they are arranged 'in the order of their atomic weights, from hydrogen as 1, to uranium, the heaviest, as 240, the series does not exhibit continuous advance, but breaks up into a number of sections, in each of which the several terms present analogies with the corresponding terms of other series. Thus, the whole series does not run a, b, c, d, e, f, g, h, &c. &c., but a, b, c, d ; A, B, C, D ; *a*, *β*, *γ*, *δ*, and so on, in recurring similarities.' In this we have a *periodic law*, as it is called, which embraces all the elements according to the increasing value of their atomic weights, and which has restored to their rightful place in the succession certain elements for which no place in any of the series of groups could be found. More than this, and as evidencing the fruitful play of the imagination, Mendelejeff, finding certain gaps between neighbouring elements, pointed out that they could only be filled by elements possessing chemical and physical properties which he accurately

[1] Cf. Ad. Wurtz's *Atomic Theory*, pp. 154–163.

specified. And, sure enough, some of these vacancies have been filled by the discovery of elements with the properties which Mendelejeff predicted they must possess. This is as interesting a romance as the discovery of Neptune, the existence of which, it will be remembered, M. le Verrier and Professor Adams independently deduced from the anomalous movements of Uranus, which 'swam into the ken' of Dr. Galle at Berlin when he pointed his telescope to that part of the heavens where the mathematicians told him he would find the planet.

Commenting on this significant grouping of atoms, Professor Huxley, in his masterly survey of the progress of science in Mr. Humphry Ward's 'Reign of Queen Victoria,' says that 'this is a conception with which biologists are very familiar, animal and plant groups constantly appearing as series of parallel modifications of similar yet different primary forms. In the living world, facts of this kind are now understood to mean evolution from a common prototype. It is difficult to imagine that in the not-living world they are devoid of significance. Is it not possible, nay, probable, that they may mean the evolution of our "elements" from a primary form of matter? Fifty years ago such a suggestion would have been scouted as a revival of the dreams of the alchemists. At present it may be said to be the burning question of physico-chemical science.' Although no known energy that we can apply can separate any one atom into two, so that, as Dalton said, 'no man can split an atom,' we do not therefore any longer speak of it as indivisible or immutable: all that can be said is that it has not yet been divided, and that since the present universe had its beginning the elements have undergone no change.

For it matters not into how many myriad substances—animal, plant, or mineral—an atom of oxygen may have entered, nor what isolation it has undergone; bond or free, it retains its own qualities. It matters not how many millions of years have elapsed during these changes, age cannot wither or weaken it; amidst all the fierce play of the mighty agencies to which it has been subjected it remains unbroken and unworn; to it we may apply the ancient words, 'the things which are not seen are eternal.'

The elements seldom occur in a free state, nearly all bodies being compound, or formed by the union of two or more, rarely exceeding four, elements. Oxygen, which is the most abundant and important of all, and, when uncombined, a tasteless and invisible gas, enters into nearly one-half of the crust of the globe; while of such limited variety of stuff is the infinite complexity of things in earth and heaven produced, that the mass of matter in the universe, as the spectroscopic analysis of light radiated from the heavenly bodies shows, is made up of about fourteen elements. Living things are mainly composed of carbon, oxygen, hydrogen, and nitrogen.

Our knowledge of molecules, as of atoms, is yet in its infancy, and it would seem that particles which are beyond the range of our most powerful microscopes to reveal may be as astoundingly complex as the giant orbs of the heavens—nay, as the universe itself. Many ingenious experiments and calculations have been made to arrive at their size and structure, but they leave the problem where they found it. The seven-hundred-millionth part of an inch is considerably under the thickness to which, if it could be done, a plate of zinc or copper could be reduced without making it cease to be zinc or copper as we know and handle them. The film of a soap-bubble scarcely reaches the millionth of a millimètre (·03937 of an inch) in thickness. The size of a molecule of water is about $\frac{1}{500000000}$ of an inch in diameter; that is to say, if a drop of water the size of a pea were enlarged to the size of the globe, the molecules would be about as large as cricket balls. The number of molecules of albumen in a cube of $\frac{1}{1000}$ of an inch of horn is reckoned at seventy-one billions; while the egg of a mammal, which averages $\frac{1}{150}$ of an inch in diameter, may be estimated to contain 'so many molecules, that if one were lost or developed in every second, they might not all be exhausted until after five thousand six hundred years.'[1] But, as showing how only approximate such estimates are, the highest optical aid brings us no nearer a knowledge of the ultimate structure of organic bodies than we should be of the contents of a newspaper seen with the naked eye one-third of a mile off. It is, however, impossible for the mind to grasp the ideas which such figures and comparisons are intended to give.

We have now reached a point when the grounds for the assumptions made concerning the nature of matter throughout space, whether in masses, large or small; in molecules, atoms, or in the tenuous ether, must be stated.

If atoms are unchangeable under their present conditions, and changeable only in their relations through combination with other atoms, and in their distribution in space, it follows that all changes are due to motion.

2. *Power.*—Motion throughout the universe is produced or destroyed, quickened or retarded, increased

[1] Cf. Mr. Sorby's Presidential Address to the Royal Microscopic Society, *Microscopic Journal*, March 1876.

or lessened, by two indestructible powers of opposite nature to each other—(*a*) Force, and (*b*) Energy.

(*a*) *Force* is that which produces or quickens motions binding together two or more particles of ponderable matter, and which retards or resists motions tending to separate such particles.

When Force acts between visible masses of matter, large or small, distant or near, it is called *Gravitation*; when it acts between the molecules composing masses it is called Molecular Attraction, or *Cohesion*; when it acts between the atoms uniting them chemically into molecules it is called Chemical Attraction, or *Affinity*.

As Force inheres in, and can never be taken from, ponderable matter, every atom possesses the tendency to attract, and, in the absence of any opposing energy sufficient to overcome such tendency, the power to attract, every other atom, as well as to resist any separating power or counteracting energy. The sum-total of Force is constant, and its several qualities are grouped under one doctrine, called the Persistence of Force.

(*b*) *Energy* is that which produces or quickens motions separating, and which resists or retards motions binding together, two or more particles of matter or of the ethereal medium.

The sum-total of Energy in the universe is a fixed quantity, but it is not, like Force, bound up with matter so that it cannot be transferred. It exists whether it acts or not, and therefore it can be stored up.

Energy is of two kinds, active and passive, or, in the terms of science, kinetic and potential. *E.g.*, a stone lying on a roof or on a mountain; a clock wound up but not going; a bed of coal; a barrel of gunpowder, have potential energy. This becomes kinetic when the stone falls, the clock goes, the coal burns, or the powder explodes. Not only does the potential pass into the kinetic, and *vice versâ*, but the several forms of kinetic energy pass into one another—motion into heat, heat into electricity, electricity into heat, light, and chemical action; a definite amount of any one form of Energy passing into an equivalent amount of the other, the one disappearing as the other appears. And the tendency of all passive Energy is to be converted into active Energy until a dead or uniform level is reached, as in bodies of the same temperature, wherein no differences of separating power remain. The significance of this will be apparent when the ultimate destiny of the universe is considered.

These qualities of convertibility and indestructibility are grouped under one doctrine, called the Conservation of Energy.

The persistence of Force and the conservation of Energy may be grouped together under the doctrine of the Indestructibility of Power. Force is the attracting or pulling power; Energy is the repelling or pushing power; and by the antagonism of these the work of the universe is done. Every mass pulls every other mass by the force of gravitation; the earth the moon, the sun the earth, some other star the sun, and *vice versâ*. And the moon would fall to the earth, as also the earth to the sun, but that the energy of their orbital motion overcomes the force. When a loaded waggon is pulled, especially uphill, the muscular power which, in the form of kinetic energy, is expended by the horse overcomes the attractive power inherent in the earth to draw the waggon towards its centre and keep it there. When the energy of heat which drives asunder the particles of bodies, changing them from the solid to the liquid or gaseous form, is expended, then the particles resume the solid form in virtue of the force of cohesion.

If Force had unresisted play, all the atoms in the universe would gravitate to a common centre, and ultimately form a perfect sphere in which no life would exist, and in which no work would be done. If Energy had unresisted play, the atoms in the universe would be driven asunder and remain for ever separated, with the like result of changeless powerlessness. But with these two powers in conflict, like the Ahriman and Ormuzd of the old Persian religion, the universe is the theatre of ceaseless redistributions of its contents, whether in the sweep of the stars and their attendant systems through space, or in the pendulum-like vibrations of the invisible particles of every body, or in the throbs of the ethereal medium. So rapid are the motions, the rebounds between each molecule in hydrogen gas numbering seventeen thousand millions per second, that even if the molecules were within microscopic range we could not see them; and yet these collisions are few compared with the oscillations of light waves, which number hundreds of millions of millions in the same time.

Such action shows that just as there are spaces or distances between the stars measureless in their vastness, so there are pores or spaces between the molecules of bodies, and between the atoms which compose the molecules, measureless in their minuteness. And if added proofs of these intermolecular and interatomic spaces were needed, we find them in the contraction and expansion of bodies through the quickened or retarded vibrations due to the separating energy manifest as heat; in the compressibility, although slight, of liquids; in the actual solidification of the most refractory gases under extreme cold and pressure, oxygen resembling snow in appearance, and hydrogen falling on the floor with the rattling noise of hail. But more than this. These pores between invisible particles, these spaces between star and star, spaces so vast that the diameter of the earth's orbit, measuring one hundred and eighty-eight millions of miles, seen from the nearest star, is but a pin's point, are not vacant. Speaking of the force of gravitation, Newton said that to conceive of one body acting upon another through a vacuum is so great an absurdity, that no man who had 'in philosophical matters a competent faculty of thinking' could ever fall into it.

And the like applies to the transmission of light, heat, and other forms of energy between bodies far and near. Therefore for the explanation of these varied and yet related phenomena it is a necessary assumption that the minutest intervals between atoms, as well as the awful spaces of the universe, are filled with a highly rarefied, elastic medium called Ether, which, ever tremulous with unentangled vibrations, is the vehicle of Energy alike from the infinitely great and the infinitely small.

That matter should be unseen and unfelt is no new conception to us. Its existence in an ultra-gaseous state as proven by the action of molecules in tubes where as high a vacuum as seems possible is obtained; its invisibility in air—the vehicle of sound; in steam, and in substances vaporised by the voltaic arc—its extreme rarefaction in such bodies as comets, the stuff of whose tails, spreading across millions of miles, could be compressed into a small vessel; prepare us to conceive unseen realities. Thus, when the sensory organs are powerless to report the facts, Science, excluding no faculty from wholesome exercise, bids Imagination use her larger insight to make clear the significance of the things which eye hath not seen nor ear heard.

The value of the foregoing abstract of the relations between Matter and Power will be proved or disproved in the degree in which it squares with the phenomena to be hereafter described and explained. Meanwhile the subjoined tabular summary may set the subject in a clearer light.

MATTER.	POWER.		
	FORCE.	ENERGY.	
		POTENTIAL, OR PASSIVE.	KINETIC, OR ACTIVE.[1]
Masses	Attraction between Masses, or Gravitation	Separation of Masses (commonly called Visible Energy of Position) Ex. Stone on a roof A head of water	Motion of Masses Ex. Moon's motion round the earth Stone falling Water falling
Molecules	Attraction between Molecules, or Cohesion	Separation of Molecules Ex. Steam	Motion of Molecules Ex. Steam condensing into liquid Heat-vibrating particles of a poker
Atoms	Attraction between Atoms, or Chemical Affinity	Separation of Atoms Ex. Atoms in a free state	Motion of Atoms Ex. Atoms rushing to form molecules
Electrical Units[2]	Electrical Affinity	Separation of Positive and Negative Electrical Units Ex. A thunder-cloud and the earth	Motion of Electrical Units Ex. Electric current
Ether (?)	(No evidence of aggregating power inhering in it)		(All Kinetic Energy, except the small proportion intercepted by bodies in space, passes from matter to the ethereal medium. This is the doctrine of the Dissipation of Energy)

[1] Each kind of Kinetic Energy has separative, combining, and continuous or neutral motion. Example of Separative—a stone thrown upwards; example of Combining—a stone falling; example of Neutral—a top spinning in the same place.

[2] This concept of Electrical Units, which may be the equivalent of Polarity of the atom, is here added merely as a convenient mode of envisaging a certain order of phenomena.

CHAPTER II.

DISTRIBUTION OF MATTER IN SPACE.

MATTER is both visible and invisible, ponderable and imponderable. In its ponderable form it is distributed throughout space in bodies of varying densities ; in its imponderable form as ether it fills the intervals between the particles composing those bodies, as also the vast intervals between the bodies themselves. The most important of these—as the sand by the sea-shore, innumerable—are the 'fixed' stars, so called from having no apparent motion of their own, although in reality travelling at enormous velocities. Each of these, unless it be an extinct, burnt-out sun, shines by its own light, and is probably, like the sun, which is itself a star, the centre of a system of planets with their satellites or moons and other bodies. 'One star differeth from another star in glory.' Not, speaking broadly, in the stuff of which all are made, for the light thrown by the spectroscope on the chemistry of the heavenly bodies has revealed their general identity of structure. No matter how distant the star, so long as the light emitted is strong enough ; broken on prisms, it reveals through its spectrum not only what elements are present in the glowing vapour, but even the direction of the star's motion, *i.e.* whether it is receding from or approaching our system. The annual parallax (or the apparent change of position as seen from opposite points of the earth's orbit) of the nearest fixed star, Alpha Centauri, is nearly one second of arc, giving a distance of twenty millions of millions of miles. So vast is the interval, that our solar system would appear as only a point in space when viewed from this star, the light from which, travelling at the rate of one hundred and eighty-six thousand miles per second of time, takes nearly three years and a half to reach us, so that we see the star as it then shone.

The differences between the stars are in their sizes, their brilliancy or magnitude, and their colours, this last giving some clue to their stage of development. For there are stars young, middle-aged, old and decrepit ; and there are stars cold and dead, radiating no energy, and whose existence can be known only by their influence exerted through the force of gravitation upon the proper motion of other bodies, as, *e.g.*, of Sirius by its unseen companion.

Astronomers have not yet arrived at any certain conclusions regarding the general distribution of matter in space. But the combinations, as seen from our system, are as varied as they are complex. Besides double and multiple stars—their apparent nearness to one another often being due to their lying in nearly the same straight line from our system—there are the constellations, many of the names of which are relics of that animistic stage in man's belief when everything was personified. There are also star-clusters, light, cloudy-looking patches, made up of suns which, from our point of view, lie densely packed together in numberless galaxies.

Besides the fixed stars and their systems, straggling in scattered groups on either side of the milky way or composing its cloud-like arch, there are the vast masses of glowing matter called, in contradistinction to the stellar nebulæ, which the telescope has resolved into stars, gaseous nebulæ. These are of regular and irregular shape, circular, elliptical, and spiral; they are the raw stuff of which suns and systems are formed.

These nebulæ; the fixed stars, with whatever appertains to them, and the vagrant bodies known as comets, with their more or less associated myriad meteor streams, down to the fine cosmic dust that falls on polar snows or sinks into the deep ocean; comprise the ponderable matter of the universe. The sum-total of the radiant energy of all luminous bodies, save the small proportion intercepted by one from the other, is in course of continuous transfer to the imponderable ethereal medium.

The results of modern research into the structure of the universe, in which inquiry Mr. Proctor has taken a distinguished and important part, are thus summed up by him in the article on 'Astronomy' in the last edition of the 'Encyclopædia Britannica':

'The sidereal system is altogether more complicated and more varied in structure than has hitherto been supposed: in the same region of the stellar depths coexist stars of many orders of real magnitude; all the nebulæ, gaseous or stellar, planetary, ring-formed, elliptical, and spiral, exist within the limits of the sidereal system; and lastly, the whole system is *alive* with movements, the laws of which may one day be recognised, though at present they are too complex to be understood.'

CHAPTER III.

THE SUN AND PLANETS.

THE Solar System comprises—1, the Sun; 2, the Planets, large, small, and minor; 3, Moons or Satellites; 4, Comets, together with Meteors or Shooting Stars.

The *Sun* consists of a nucleus, surrounded by envelopes called the photosphere and the chromosphere, outside which lies the mysterious corona, whose delicate silver radiance forms the glorious nimbus of a total eclipse. The nucleus is a gaseous mass, burning at a temperature of which we have no conception, being probably millions of degrees; but the condensation which goes on under the radiation of energy may have already reduced the core to a liquid or putty-like state. The disc which we see includes the vaporous photosphere, with its puzzling grain-like face, here and there pitted with the cloud-patches or spots, from the movements of which we learn that the sun rotates on his axis in twenty-five days. The chief constituents of the chromosphere are hydrogen and an element unknown to us, called 'helium'; and it is from this atmosphere that the red prominences or tongues, which often reach a height of one hundred thousand miles, are expelled. Vast as is the sun's volume, exceeding several hundred times all the other members of his system, he is by no means the biggest of the stars, and, as compared with them in brightness, probably does not exceed the third or fourth magnitude. But he has the greatest interest and importance for us, seeing that to him are due those manifold energies by which the processes of nature, both chemical and vital,

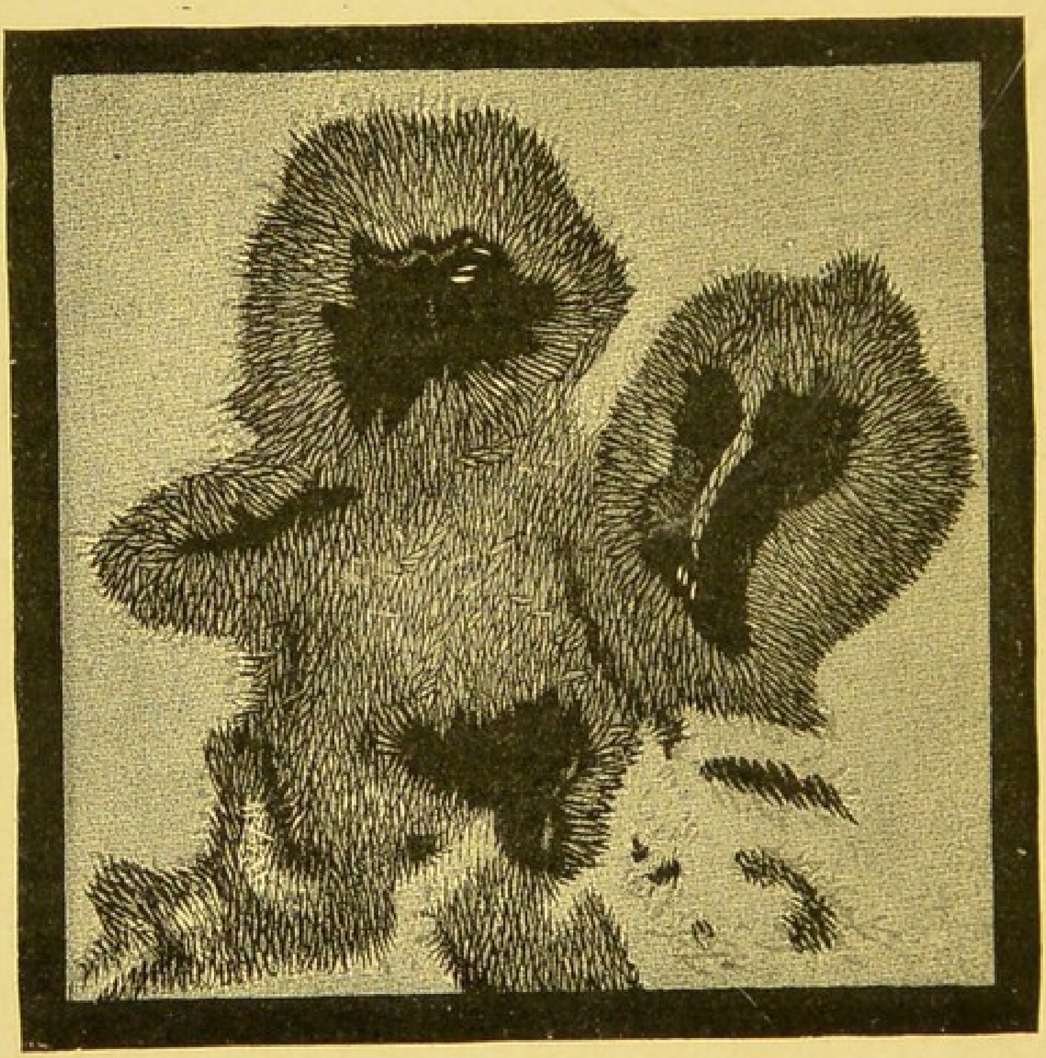

FIG. 1.—Sun-spots.

are carried on within the limits of his system. Further, with the knowledge which has been gained during late years concerning the sameness of the stuff of which nebulæ, stars, and planets are spun, the nature and arrangement of the contents of our solar system enables us to make lawful analogies concerning the contents of systems beyond it.

Of the solar radiant energy the *planets* receive or intercept only the two hundred and thirty millionth part, the earth receiving but the two thousand one hundred and seventy millionth part. Even a large proportion of this energy is immediately, and the whole of it finally, radiated into space.

The planets, one and all, revolve in nearly circular orbits, but on rather differently inclined planes, round the sun, in virtue of that energy of orbital motion with which each was endowed at birth, and which counteracts the opposing force of the sun's gravitation, which would otherwise pull them into him, absorbing them in his mass. Including the swarm of minor planets or asteroids, of which new ones are being frequently discovered, they are perhaps to be numbered by thousands. They are of various sizes and densities, and in different stages of progress and decay. The evidence for the primitive gaseous state of all bodies now possessing greater density will be given hereafter, but our system itself witnesses to the passage of planets and satellites to an ultimately solid form. Some, like our earth and Mars, have cooled down sufficiently to be covered by a hard crust, and to be fit abodes for living creatures ; others, like Jupiter and correspondingly huge bodies, are still in a more or less heated and partly self-luminous condition. The smaller bodies have long been cold and inert, like our airless, silent, and barren moon. In her pale reflected light, her scarred surface, and her vast ringed craters, illumined no longer by flame of central fires, we learn that what she is the planets and the sun himself will one day become.

The *moons* revolve round their several planets under similar restraint of force and freedom of energy as the planets themselves. The gaseous masses composing *comets* and *meteor streams* travel in very eccentric orbits.

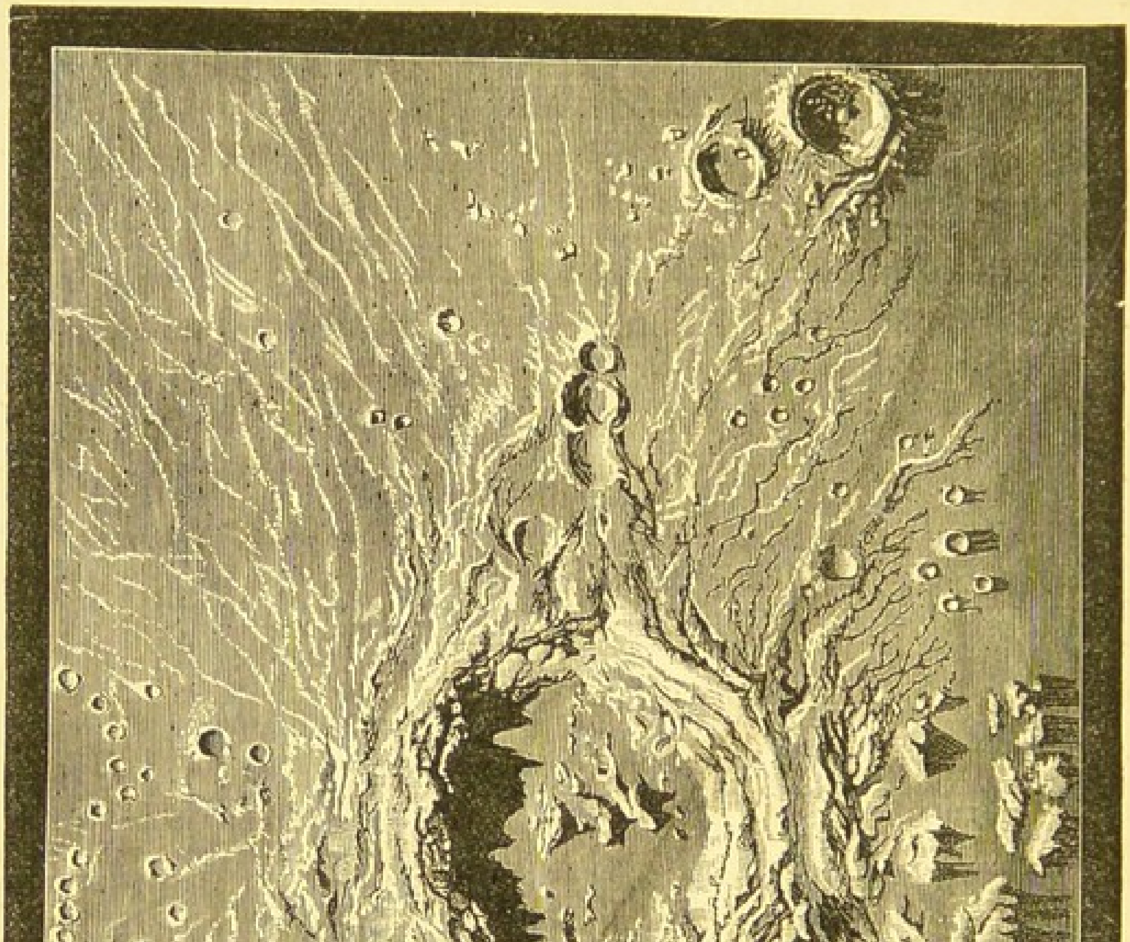

FIG. 2.—Lunar Crater : Copernicus.

In fine, motion is everywhere, in ether, atom, molecule, and mass; the sun, like his fellow-stars, has his proper motion, carrying with him planets, satellites, and whatever other bodies are within the influence of his force of gravitation. This is itself obedient to the attractions of bodies perchance as much exceeding his own in power as he exceeds the mote dancing in his beams.

The mass of matter called the *earth* is of nearly spherical shape, being slightly flattened at the poles and bulged towards the equator.

It consists of a core within a rocky crust, three-fourths of which is covered by a layer of water, and the whole surrounded by an atmosphere.[1]

The entire mass, solid, liquid, and gaseous, spins on its axis at the rate of about one thousand miles every hour, and speeds through space in its orbit round the sun at the rate of one thousand miles every minute.

The atmosphere is composed, in the main, of the uncombined elements oxygen and nitrogen; the water is chiefly compounded of combined but mobile oxygen and hydrogen. Of every hundred parts of the crust, ninety-nine are made up of about sixteen out of the seventy elementary substances, and of these sixteen the larger number exist in small proportion. It is computed that fully one-half of the crust consists of oxygen which it has taken into itself from the atmosphere, and that already one-third of the water of the ocean has been absorbed by minerals.[2] The average density of the earth is about five times and a half that of a body of the same size made of pure water, but the large extent covered by the ocean in the southern hemisphere, whither the

[1] Taking the earth's surface as 1, the sea covers 0·734 parts, and the land 0·266 parts.

[2] Geikie's *Text-book of Geology*, pp. 30, 298.

tendency to collect was probably manifest at the outset when the steamy vapours condensed and filled the depressions in the crust, points to an excess of density in that direction.

What the inside of the earth is like no man can tell[1]; may be it is solid throughout, the denser materials being at the centre, and in a state of intense heat at no very great depth, as manifest in volcanic outbursts and allied phenomena.

These show that the unquiet earth has not yet lost the whole of the original store of energy which it acquired during the aggregation of the particles of which it is built up in their passage from a diffused nebulous state to one of increasing density under the action of the force of gravitation. But the escape of that energy through the crust to the ethereal medium is unintermittent, and its final dissipation into space is therefore only a question of time.

The crust was probably never uniformly smooth, because the contraction of the interior mass as it cooled would bring about a state of tension causing shrinkage of the surface, producing intense heat. Hence the beginnings of those wrinkled, cracked, and crumpled features which other agencies would score more deeply in the face of the globe, giving thereby beauty and variety in valley, mountain, table-land, and all else that makes the earth so fair a dwelling-place.

Our knowledge of the crust extends only to a relatively small depth, the aggregate thickness of the strata or layers of rock already measured being about twenty-five miles, or the one hundred and sixtieth part of the

[1] Cf. Geikie, *ibid.*, pp. 49-54, and Prestwich's *Geology*, ii. 537-540, for examination of various theories of the interior of the globe.

earth's semidiameter. The term 'rock' is applied alike to hard granite and loose sand, to ore veined with metal and to mud from country lanes, as including the materials composing the crust or shell. Rocks are divided into two classes—unstratified and stratified. The *unstratified*, which are also called igneous or Plutonic, embrace all rocks which, as they now exist, have been fused together by heat, or erupted from the earth's interior by volcanic agency. The *stratified*, which are also called aqueous or Neptunic, embrace all rocks which have been deposited as sediment by the action of water or of the atmosphere, or which are due to the growth and decay of plants and animals. With this class are grouped the *metamorphic*, for the most part stratified rocks which have been metamorphosed into a crystalline state by the action of heat and pressure, resulting in effacement of their original character, and in the destruction of traces of any organic remains in them. Throughout the entire series of rocks the newer have been, and are being, formed out of the older, which, unless upheaved, are always found at the bottom; but of the original crust perhaps no trace remains.

The depth to which the unstratified rocks extend is unknown, and as they contain no organic remains they tell us nothing concerning the origin and succession of life on the earth. The stratified rocks, which alone throw light on this question, have been divided for convenience, and not as implying any gaps between their several formations save where natural causes have operated, into four, or sometimes five, epochs. These, together with the typical remains of plant and animal associated with each, are as follows:—

Epoch	Thickness of Strata	Plant	Animal
Archæolithic or Eozoic (*dawn life*), chiefly metamorphic	70,000 feet	Algæ (Chiefly	Monera marine)
Primary or Palæozoic (*ancient life*) .	42,000 "	Ferns	Fishes
Secondary or Mesozoic (*middle life*)	15,000 "	Pine forests	Reptiles
Tertiary or Cainozoic (*recent life*) .	3,000 "	Leaf-bearing forests	Mammals
Quaternary or Post-Tertiary . .	600 "	Existing	species

CHAPTER IV.

THE PAST LIFE-HISTORY OF THE EARTH.

GEOLOGY deals with the stuff of which the earth is made, its origin, structure, and arrangement. But so interrelated is the material of which all things are formed, that inquiry into the structure of rocks has to be extended well nigh at the outset to their contents—that is, to the fossil remains of ancient life which are not only preserved within the larger number of strata, but entirely compose vast masses, as coal-beds, chalk hills, and coral islands. Therefore the interest which the study of the erupted, fire-fused, and water-laid rocks awakens, especially in their witness to ceaseless changes through an ever-receding past, becomes more immediate and human when the relics of ancient life-forms are examined; and when their appearance, persistence, or disappearance, their order and succession in an ever-varying, ever-ascending scale, are traced. For in them lies the record of life on the earth through measureless time; the life that was, parent of all life that is; from simple slime-speck to structure of subtlest complexity named man, with its passionate story of agonies and joys, of struggle towards a kingdom of heaven yet unentered.

True it is that the record is very imperfect, that the gaps remain wide and numerous, even when supplemented by fossils from different parts of the globe. But the wonder is that the blanks are not greater when the nature and extent of the changes to which all rocks have been, and are being, subjected, are considered. In addition to the havoc and effacement wrought by the earth's internal heat, the formation of every deposit involves the waste of an older deposit, which has in its turn been derived from more primitive stuff, the effect throughout being mutilation or destruction of the organic contents.

It is impossible that the vast number of lowest life-forms, whether plant or animal, should have been preserved. Traces of marine organisms survive in the trails and borings of sea-worms, or in the imprint of carcasses of jelly-fish stranded on the ripple-marked mud of ancient sea-shores ; but of the soft-bodied creatures themselves not a vestige remains. Only such hard parts as the shells or skeletons of animals, and the bark, wood, and seeds of plants, would reach the fossil state in more or less perfect form ; and even their preservation is contingent upon the nature of the beds in which they are interred. As it is, but a remnant of all that ever lived in the water, and a far less proportion of the smaller population of the land, are represented in actual fragments. Sometimes only an impression survives, as when a dissolved shell has left its witness in cast or mould, in clay or mud, or an extinct bird or reptile its footprints on the sands of a far-off time. Sometimes, in the compensating action of nature, chemical agents, in destroying the original structure, infiltrate the vacancy with minerals, replacing the form, occasionally in minutest detail.

Rich as are igneous rocks in wealth-yielding mineral veins and ores, they are, save where recent plants and animals have been accidentally enveloped in the flowing lava or dust of volcanic eruptions, destitute of fossils. There was a period in the earth's history when life was not, and its beginnings, which, as will be shown hereafter, were probably in polar regions, were certainly subsequent to the ejection of the molten or pasty masses which cooled into true volcanic or fire-formed rocks.

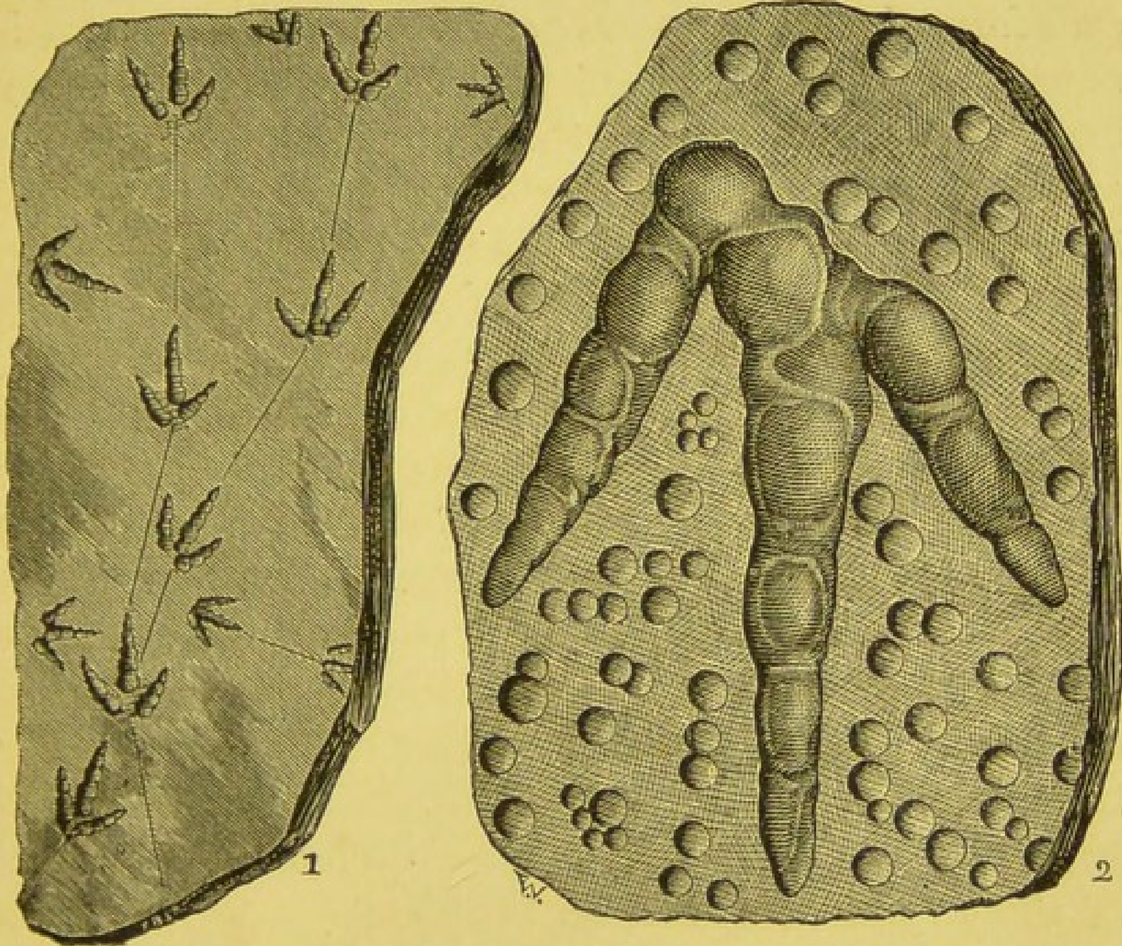

FIG. 3.—Footprints of Birds, with (2) marks of Raindrops.

Although fossils are found only in sedimentary rocks, they are not universally present in them. Varied and mixed as those rocks are in composition, it suffices here to group them under two heads—1, those derived from sediment, in its several states of gravel, sand, and mud; and 2, those formed of the remains of plants, as coal in its several stages from peat to the hard graphite or black-lead of the older formations; or of the remains of animals, composing chalk, limestone, and other organically derived rocks. But whatever their source, and however much the original order of strata has been deranged by hidden agencies which have tilted them at all angles, cleaved and contorted them, and superposed the older on the newer, there is a well-ascertained succession in them which their fossils alone have enabled us to determine, each formation having its own characteristic kinds or dominant types of plant and animal. Not that there are any hard and fast lines between the disappearance of an earlier species and the appearance of a later species, the forms being often commingled. Some of the low and simple types persist through almost all formations; some of the more complex are found in only one or two formations: but there is a merging of one into another; there are gradations and alliances of type, as of birds with reptilian characters, and *vice versâ*. And although seemingly isolated types occur, or the divergence between earlier and later types has blurred their relation, it will be seen that the modern are the ancient slowly and wondrously modified. In short, the life-history of the globe is one both of unbroken relation and progress; the gaps exist because the record is mutilated. Nature, like the Sibyl of Cumæ, has destroyed her books.

The stratified rocks are subdivided into the systems shown on fig. 4. There is no one section of the earth's crust where a complete series is to be found with layer superposed on layer like the skins of an onion; but whatever gaps exist locally do not affect the relative age and place of each stratum, which, as remarked above, are fixed by the fossils. No uniform principle has governed the choice of the system-names. Sometimes they indicate the place where a formation is markedly developed · sometimes as the Silurian (from the *Silures*,

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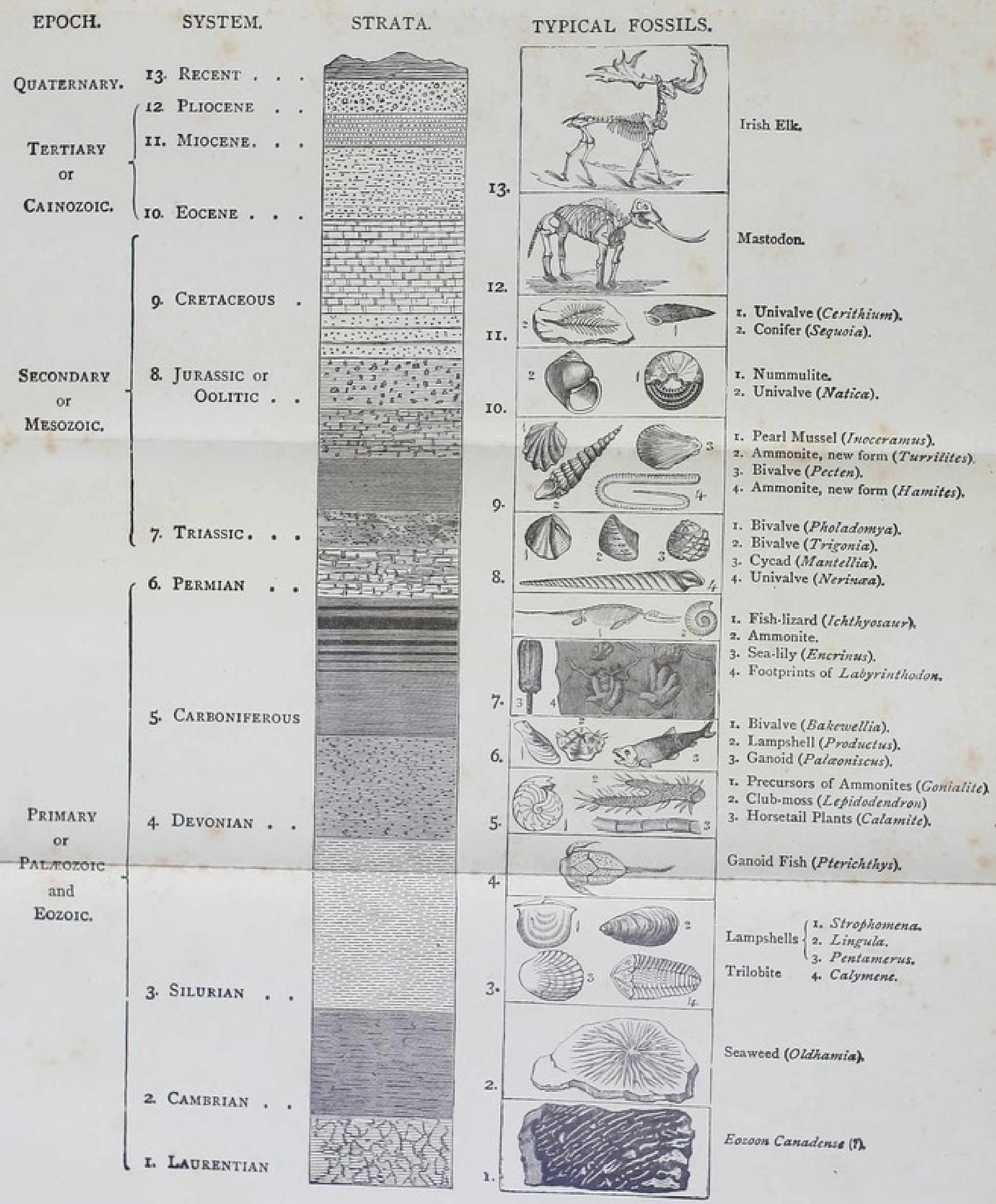
Fig. 4.—*TABLE OF STRATIFIED ROCKS.*



a tribe of ancient Britons), the people formerly inhabiting the district; sometimes they denote typical features of the formation: but they are the accepted nomenclature in treatises on geology, and are therefore adopted here.

1. PRIMARY.—The *Laurentian* rocks, vast and venerable sediments of primeval seas, are highly metamorphic. Heat, moisture, and enormous pressure have changed their sandstones into sparkling crystalline rocks, and their limestones into veined and variegated serpentines.

FIG. 5.—Fragment of *Eozoon Canadense*, natural size.

Formerly they were classed as 'Azoic'—*i.e.* without life; but of late years those which form the Laurentian Mountains in Canada, whence the general name of the series is derived, have acquired special interest from the discovery of certain veined structures in them, pronounced by some authorities [1] to be the remains of a large foraminiferal animal which has been named *Eozoon Canadense.* The foraminifera form perforated shell-

[1] Notably Professor Sir J. W. Dawson and the late Dr. W. B. Carpenter. The evidence against its organic character is given in Professors King and Rowney's *Old Chapter of the Geolog. Record* (Van Voorst, 1881). Cf. also Heilprin's *Distrib. of Animals*, pp. 134, 196, 236.

coverings of exquisite symmetry and beauty from the lime which they secrete from the water.

'The longevity of an organic type has, on the whole, been in inverse proportion to its perfection;'[1] and some of the lower types may smile at man's 'claims of long descent,' for they have survived through the long and change-bringing millions of years to this day, shedding their shells on the ocean floor, as their ancestors shed

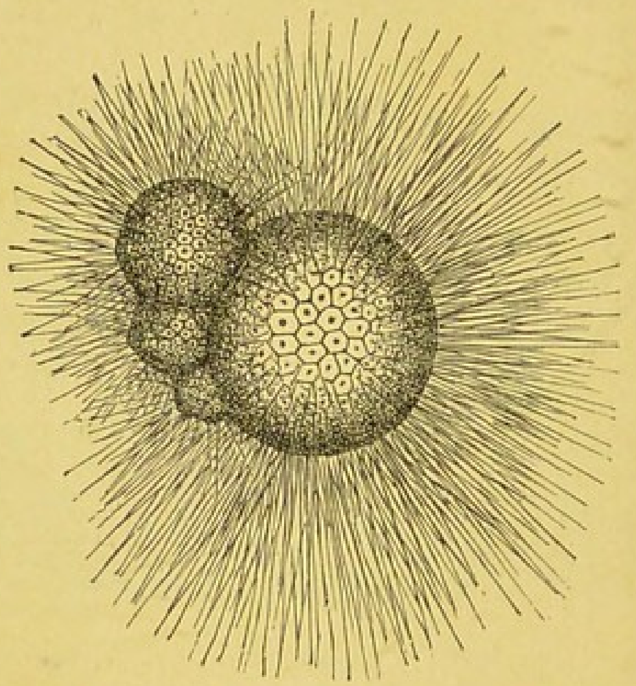


FIG. 6.—Foraminifer, *Globigerina bulloides*, magnified seventy diameters. This form is found floating in tropical and temperate seas.

theirs, forming vast chalk and limestone hills and mountain ranges in relatively shallow seas. Not in deep oceans, as was formerly held, since the fossils are shown to resemble present shoal water deposits rather than similar oozes found in water over a thousand fathoms deep, which further confirms the theory that the great ocean beds have never been upraised. While some secrete chalk, others secrete flint. Among the latter are the minute plants known as diatoms, whose remains

[1] Cf. Geikie, p. 612.

compose, among other deposits, the 'rotten-stone' used as polishing powder, of which no less than forty-one thousand million skeletons go to make up a cubic inch.

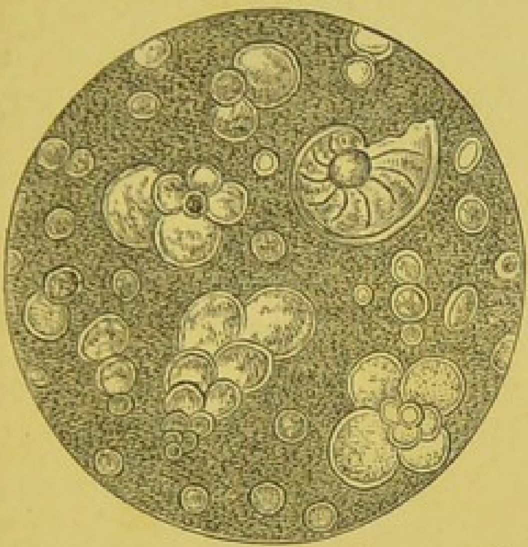


FIG. 7.—Section of Gravesend Chalk.

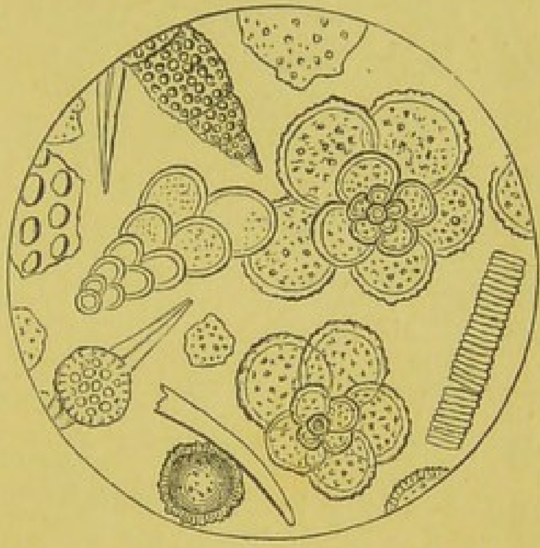


FIG. 8.—Organisms in Atlantic Ooze (highly magnified).

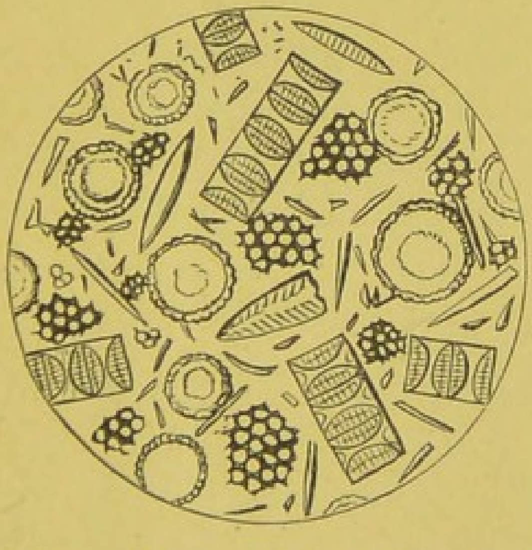


FIG. 9.—Diatoms from 'Infusorial Earth' of Richmond, Virginia (highly magnified).

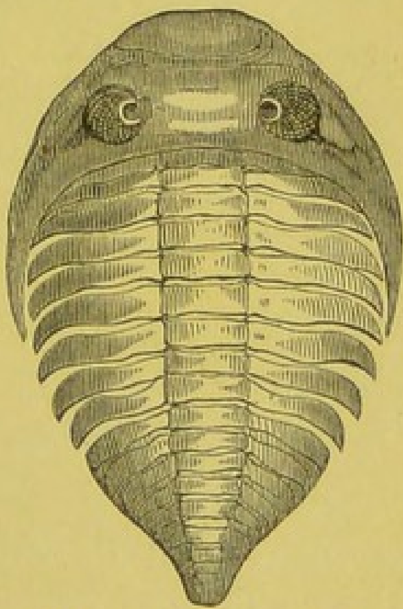


FIG. 10.—Trilobite.

It matters little if the organic character of *Eozoon Canadense* be finally disproved, for plentiful traces remain that the Laurentian waters swarmed with living things of low type but enormous size. The limestones, the abundant graphites, and the great beds of iron ore which occur in its rocks are due to the action of animal and plant life.

The *Cambrian* rocks, although less metamorphic, add little to our knowledge of primitive plant-forms, such as are preserved being probably algæ, or seaweed, corresponding to the tangles covering large areas of the Atlantic, especially the region called the Sargasso Sea. But the system is fairly rich in fossils of marine animals, themselves the descendants of a long line of perished ancestors. Sponges, sea-lilies, and low forms of mollusca, or true shell-fish, are found; but the typical and most perfect fossil is that of the three-lobed crustaceans called trilobites, which swarmed in those ancient seas, and survived till the Carboniferous period.

The *Silurian* rocks, although exhibiting in crumpled and rugged mountain chains the action of agents both above and below the earth, are much less metamorphosed than the preceding systems. They are in large measure the worn fragments of land areas which stretched across Northern Europe for above two hundred miles into the Atlantic, the sediment being deposited in a shallow sea which then covered Central and Southern Europe, and the floor of which was slowly raised as a primitive European continent at the close of the Silurian period by subterranean movements. The land plants, which are the earliest as yet met with, are allied to huge club-mosses, ancestors of the gigantic forest-kings of Devonian and Carboniferous times. The most ancient of all known land animals is a scorpion found in the upper Silurian beds of both Scotland and Sweden;[1] while the marine remains are varied and numerous, comprising seaweeds, foraminifera, corals, star-fish, shell-fish of every kind,

[1] *Smithsonian Report*, 1884, p. 604.

trilobites, and huger lobster-like crustaceans, sometimes measuring above six feet in length.

But the most important fossils are those of the earliest known vertebrates, in the form of armoured fishes,[1] allied to the sturgeon, and called ganoids (Gr. *ganos*, splendour ; and *eidos*, form), from the brilliancy of their enamelled scales.

In this seemingly sudden appearance of highly organised animals marking so great an advance in struc-

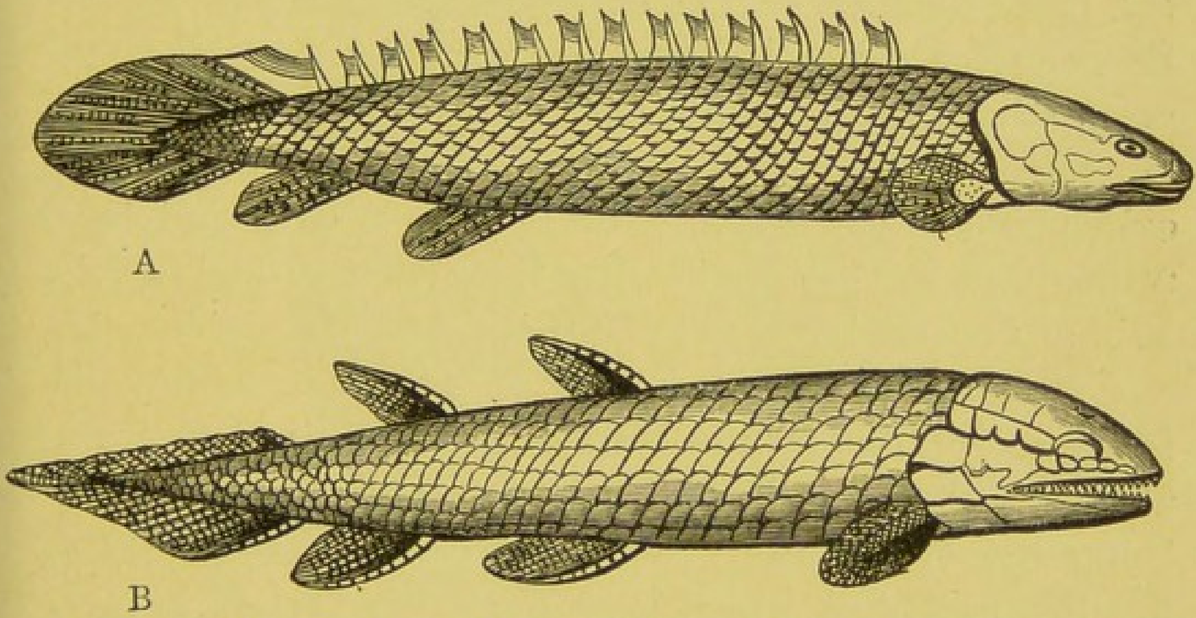


FIG. 11.—A, Recent Ganoid Fish ; B, Ganoid from Devonian strata.

ture on the higher invertebrates, the imperfection of the geological record is brought home to us. For if later forms are modified descendants of earlier, then not only are the transitional ancestral forms of the ganoids missing, but the species itself is enormously older than the fossils imply. The inquirer, however, need not despair, for only a limited portion of the dry land has as yet been explored with any completeness, and there are vast fossil-holding areas submerged and inaccessible ; yet one by

[1] Discovered by Professor Claypole near the base of the Upper Silurian in Pennsylvania; cf. *Smithsonian Report*, 1884, p. 622.

one missing links are being found. Probably the predecessors of the ganoids, the skeletons of which are cartilaginous, were of a structure too soft to permit of their preservation in a fossil state.

In this brief survey of the three earliest systems we have already traversed more than half the total thickness of the fossiliferous rocks, the deposit of which involved a lapse of time and series of changes of which no conception is possible. The base-line of our life is too short for measurement of the distance which separates the foraminifera from the ganoids; of time, as of space, we see neither beginning nor end.

The *Devonian* and *Old Red Sandstone* rocks, while evidencing frequent redistribution of sea and land, have undergone, as compared with the older systems of the Primary epoch, but slight disturbance from the upheaving and contorting agencies beneath. They are widely diffused, extending far north within the Arctic circle; and although their fossil contents are very incomplete, they bring less fragmentary witnesses to that continuity of life the record of which is so markedly broken in more ancient deposits. This is specially apparent in the relative abundance of vegetable remains, by which we may for the first time construct some picture of plant-life on the globe in Palæozoic times. Not only do we find huge tree-like plants of which our club-mosses and ferns are pigmy representatives, but true trees, as proven by the concentric rings of growth in their trunks. Of land animals, the preservation of which is so rare in all deposits, there are no traces; no reptiles wallow in the lagoons and marshy flats, neither are the verdant yet flowerless forests brightened by the plumage, nor their stillness broken by the song, of birds. But we find the earliest known insects; some happy chance, like that which envelops the insects of Tertiary forests in amber —the fossil resin of their conifers—has preserved a fragile wing, with the remains of a stridulating organ attached, as in the grasshopper and cricket, wherewith then, as now, mates were attracted or rivals challenged—perchance 'the first music of living things that geology as yet reveals.'

Fresh-water fossils abound, but the predominant types are marine—large sponges and corals; 'lamp-

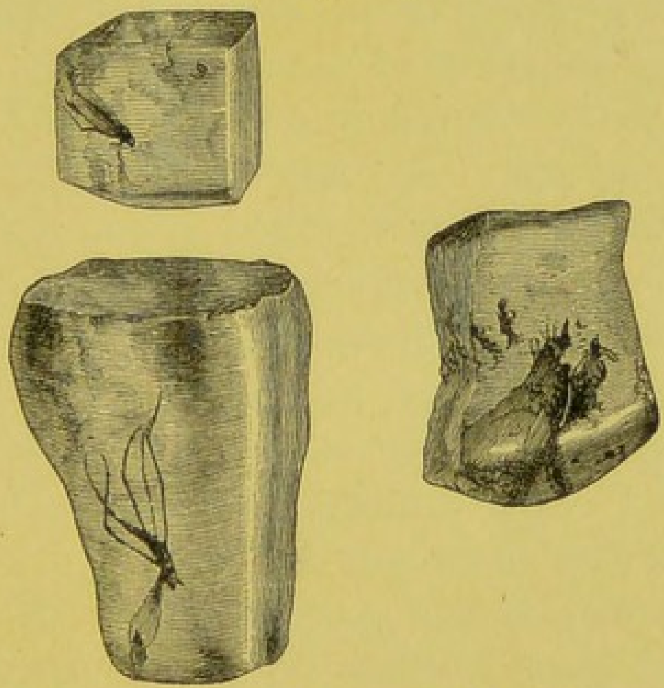


FIG. 12.—Insects in Amber.

shell' mollusca, which have persisted in varying forms from Cambrian times to the present; crustaceans huger than any that have lived since, and of which even the spawn masses are sometimes preserved. More or less special types appear and then vanish, through inability to adapt themselves to new surroundings and changed climates. But the Devonian is notably the 'age of fishes,' and its waters swarmed with the ganoid type.

Coal is formed of compressed and chemically altered plants, and occurs in all water-laid rocks, although in very different states and kinds. Sachs remarks that every experiment on nutrition with green-leaved plants confirms the theory that their carbon is derived solely from the atmosphere, and we get some idea how enormously large that derivation has been on 'reflecting that the deposits of coal, lignite, and turf spread over the whole earth, and the bituminous substances as great or even greater in quantity which permeate mountain formations, besides asphalte, petroleum, &c., are products of the decomposition of earlier vegetations, which in the course of millions of years have taken from the atmosphere the carbon contained in these substances, and transformed it into organic substance.'[1]

The climate and soil, during long eras of the *Carboniferous* system, specially favoured the growth of plants most fitted for coal formation. A large part of Europe (and the like conditions apply wherever the true coal measures abound) was then covered with shallow waters, both salt and fresh, divided by low ridges, bases of future mountain chains, and dotted with islands; while numerous rivers traversed the land, and silted up lagoons and lakes with the *débris* worn from older rocks. Vegetation flourished apace on these river banks and marshy flats, and, with intermittent subsidence of the soil occurring again and again, was buried under sand and mud, becoming changed into coal of varying seams of thickness. Hence the abundance of this mineral in the Carboniferous strata, which, as a whole, yield more of value and variety for the service of man than all the other systems put together. Sandstones for building; marbles for decoration; metals for machines; coals wherewith to drive them; purest oil from muddy shale; jet for the lapidary's art; loveliest colours, exquisite perfumes, and

[1] Sachs's *Lect. on the Physiol. of Plants*, p. 294.

curative drugs from gas-tar, even sugar therefrom, three hundred times sweeter than that from the cane—these are the rich gifts of the deep rocks, which, struck by a more magic rod than Moses wielded, have given up their treasures for man's needs and delight.

Of the plants forming the coal measures, the larger number are obliterated, but they all belong to the lower orders, as do the club-mosses, tree-ferns, and other forms which, in the warm, moist atmosphere of those times, reached a gigantic size, and had a world-wide range far into north polar regions, where coal seams have been found. Of the animal life that dwelt amongst them we know very little, nor do the extant fragments represent a tithe of the forms then flourishing. In the later deposits the lower sub-kingdoms are represented by spiders and large scorpions; by land-snails, beetles, cockroaches,[1] of which above eighty species occur, walking-stick insects a foot long, huge May-flies, and other insects; the honey-seeking, pollen-carrying species being still absent from the sombre forests. The first known land vertebrates appear in the salamander-like and long-extinct amphibians called labyrinthodonts, from the labyrinthine structure of their teeth. The marine remains are still dominant. The lower types persist; the trilobites are on the verge of extinction, but higher forms of the same group, allied more nearly to the lobster and the shrimp, succeed. The first known oysters appear, and, to the joy of the epicure, have survived all changes until now, spreading themselves over the whole northern

[1] The cockroach is historically one of the most ancient, and structurally one of the most primitive, of our surviving insects (cf. Miall and Denny's *Cockroach*, p. 22). It is amusing to find Gilbert White speaking of this househould pest, for which we have to thank the East, with curious interest, as 'an unusual insect in one of my dark chimney closets; and find since that in the night they swarm also in my kitchen.' (Selborne, *Obs. on Insects.*)

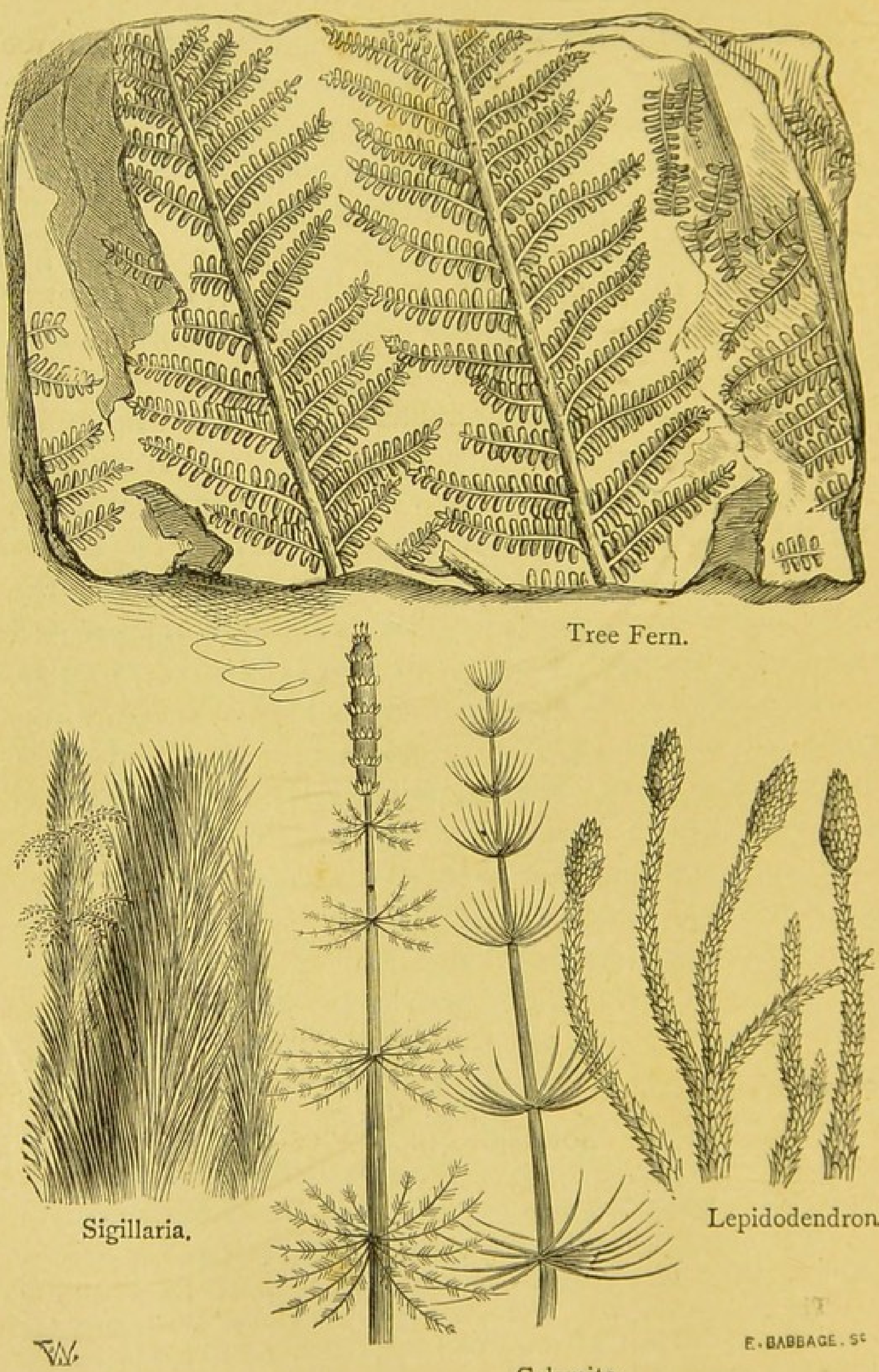


FIG. 13.—Fossil Plants from Coal-beds.

hemisphere. Forerunners of the beautiful ammonites are found; and the fish, while still of the armoured species, have a more reptilian character than their Devonian ancestors.

The life-features of the *Permian* system, the last division of the Primary epoch, differ but little from those of the Carboniferous; the only, although important, distinction is in the remains of true reptiles with crocodile-like characters.

2. SECONDARY.—We now leave the Primary epoch and enter the Secondary epoch, with its widely different features and contents, explicable only by a great break in the succession of strata, and by an enormous lapse of time for the modification of the life-forms. Although, as in every period, volcanic action is manifest, the igneous rocks being pushed through the strata, or now and again alternating with them, we meet with few traces of the metamorphism which so baffles examination of the earlier rocks; we can mark more definitely the boundaries of land and water, measure more accurately the changes, and trace more clearly the relations between the successive life-forms, of which the marine are still the preponderating, and the reptilian the most marvellous.

In the earliest division of this epoch, the *Triassic*, many of the leading Palæozoic types are extinct. Several plants of the Coal and Permian systems have disappeared, and the flora consists mainly of ferns, of cycads or palm-ferns, and of conifers, or pines and firs, to which the cycads are allied. Among the invertebrate animals certain molluscs are no longer found, but there is an intermingling of old and new types. Oysters and whelks and members of the cuttle-fish group are abundant. As yet fishes exhibit no marked advance in structure, and the labyrinthodonts, the time-range of which is thus shown to have been enormous, are changed only in size, as their footprints evidence. Reptiles allied to the crocodile group, and sea-lizards, which attained gigantic size in later periods, are now the dominant types. Whether certain bipedal footprints in the Triassic sandstones are those of birds is doubtful; perhaps they are tracks of reptiles with bird-like movements. But in the absence of proof that they are due to birds, assuming that these preceded mammals in the succession of species,[1] a great link is missing in the Trias, since that system has yielded teeth of the earliest known mammal.[2] It was probably of the marsupial or pouched order, a form now represented most nearly by the Australian phalangers and the American opossums.

The *Jurassic* or *Oolitic* system occupies extensive areas in both hemispheres, and ranges from the Arctic circle to Australia. Its strata, largely composed of coral growths and other organic remains, are rich in special life-forms which are limited to the Secondary epoch.

Its seas, which overspread the greater part of Europe, covering the large salt lakes of the Trias, swarmed with exquisite spiral ammonites, large and small; with conical bolt-like belemnites, allied to the cuttle-fish group; with lobsters, prawns, and crabs, which succeeded the trilobites and other crustaceans; with ganoid fishes, sharks, and rays. And 'there were giants in those

[1] Cf. Heilprin, p. 161.

[2] 'I entertain no sort of doubt that the reptiles, birds, and mammals of the Trias are the direct descendants of reptiles, birds, and mammals which existed in the latter part of the Palæozoic epoch, but not in any area of the present dry land which has yet been explored by the geologist.'—Huxley's *Critiques and Addresses*, p. 213.

days'—monsters of the deep—in the ferocious sea-lizards, with their fish-like bodies and flipper-like limbs; monsters of the land, too, of dread aspect and size seen neither before nor since, one found in North American beds being, it is computed, nearly one hundred feet in length and above thirty feet in height Very interesting and unique remains of the marine lizard plesiosaurus have recently been found in the shape of minute mummies under five inches long, in which the substance of the flesh is perfectly preserved, even the circle of the eyes and the constituent bones being clearly distinguished. There were flying lizards, winged like bats, hollow-boned like birds, and with claws, skin, and teeth like reptiles; and it is in a Jurassic limestone stratum that the oldest known true bird, a creature about the size of a rook, called archæopteryx, is found. It does not correspond to any known past or present birds, but represents a transitional type, having both bird- and reptile-like characters. In addition to free claws to each wing, the tail is long, and made up of separate bones or prolonged vertebræ, a feature noted in the embryos of birds. The remains of a bird about the size of a crane, but with uncertain affinities, have also been found in the Jurassic beds of Wyoming.

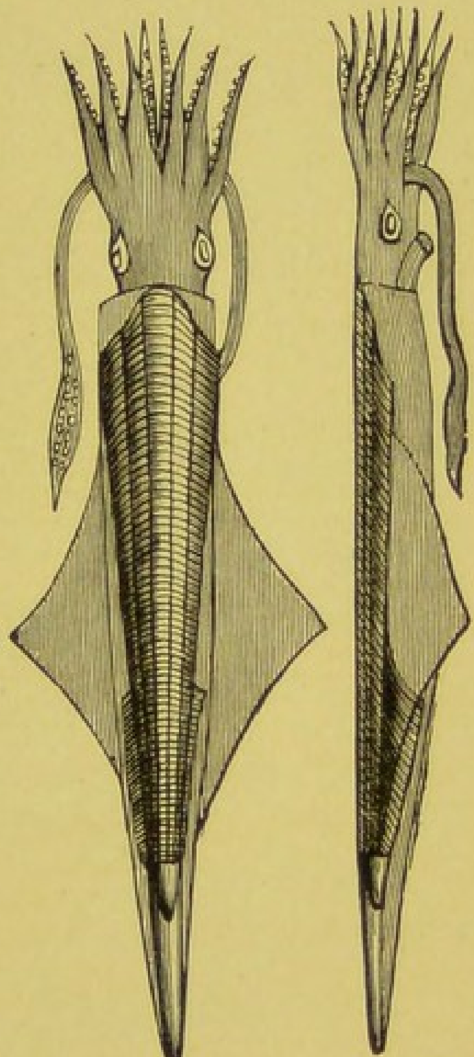


FIG. 14.—Belemnites.

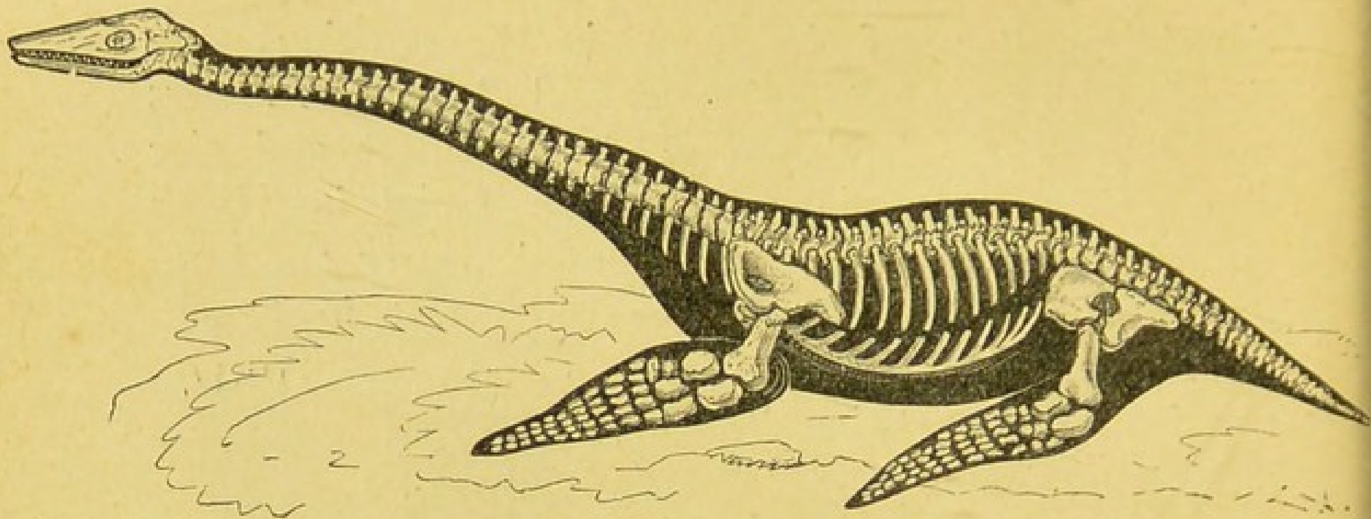


FIG. 15.—Piesiosaurus.

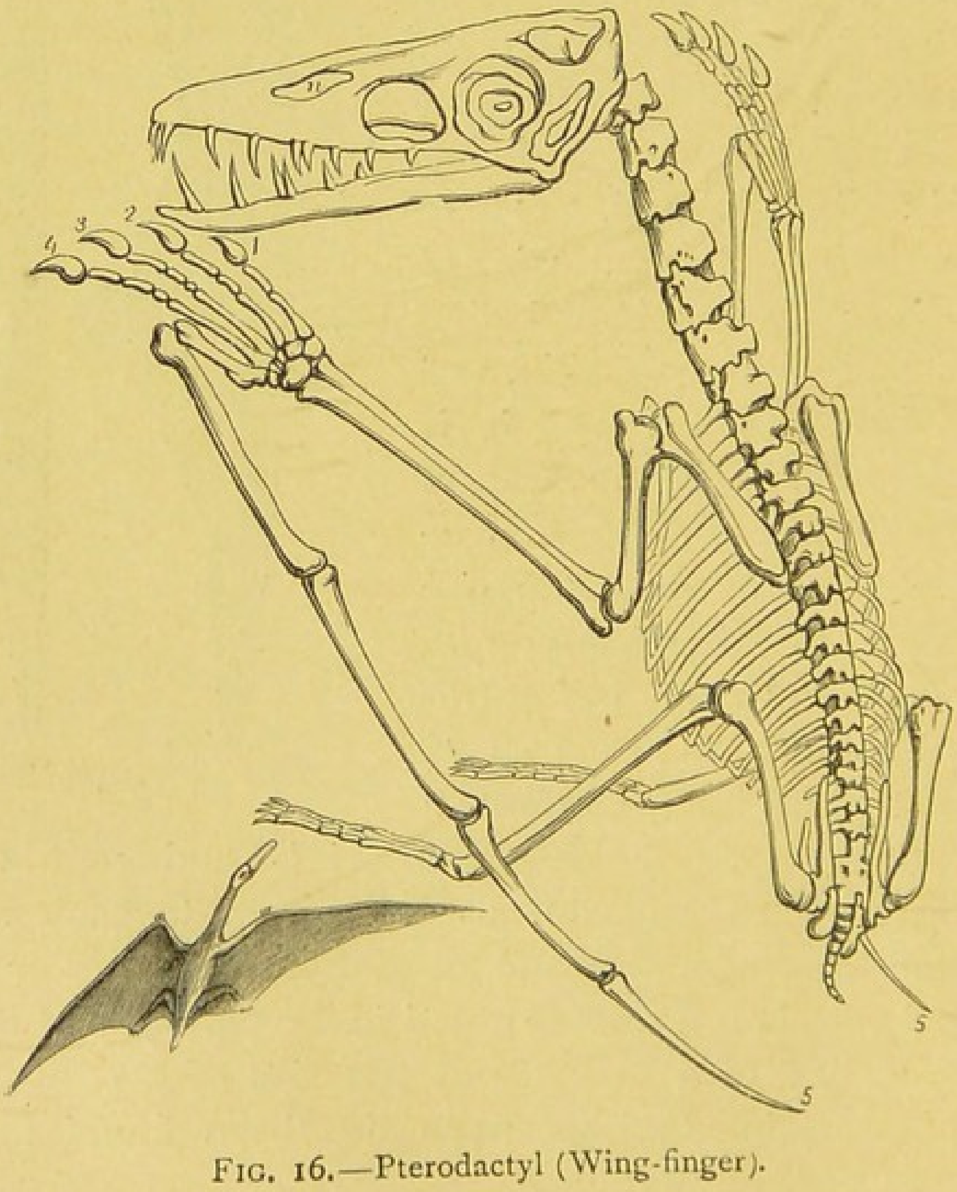


FIG. 16.—Pterodactyl (Wing-finger).

While the sea, then, as ever, was the more thickly peopled, the land had a far more important air-breathing population, both of small things and great. The hum

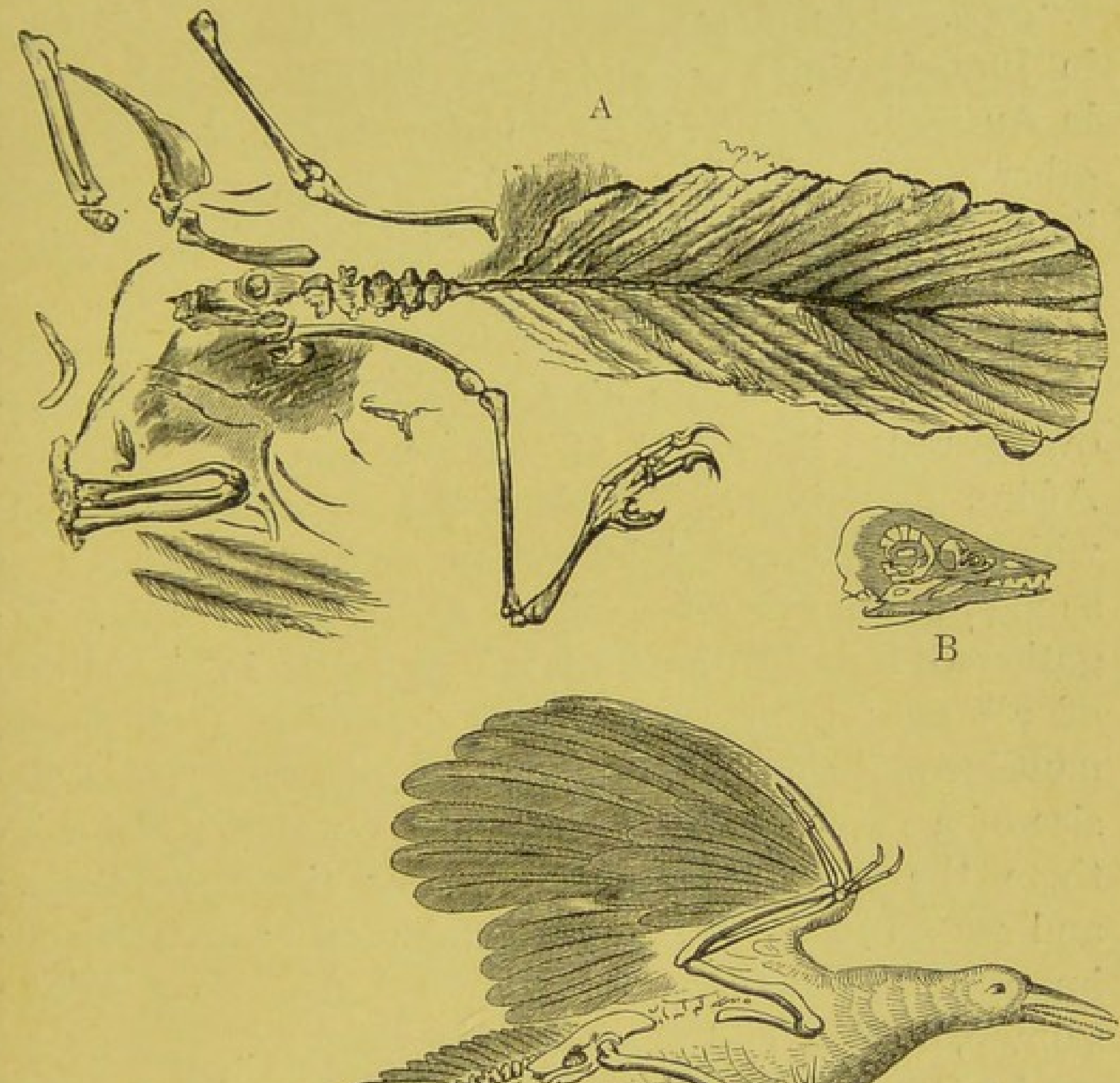


FIG. 17.—Archæopteryx. A, Fossil, showing tail and leg, from specimen in the British Museum (South Kensington). B, Head from Berlin Museum. (Both reduced.) C, Archæopteryx restored.

of insect life filled the cycadaceous forests, butterflies[1] sported in the sunshine, spiders spread their webs for prey, and the remains of marsupials point to the range of these small but highly organised creatures over Western Europe. The plants and animals of the British Isles in Jurassic times probably resembled those still found in Australia, which, by reason of its long isolation from other continents, has preserved in its pouched mammals, its mud-fish, and its cycads more ancient life-forms than any other country, perhaps New Zealand excepted.

The vast chalk formations of the globe are the typical features of the *Cretaceous* period, when the sea overspread a large part of Europe, Asia, and Northern Africa, receiving on its floor the foraminiferal shells which were converted into chalk, and the skeletons of sponges and other organisms round which silica has gathered, forming the flints which occur in limestones of all ages from the Silurian downwards. Molluscs, nautiluses, belemnites, ammonites, some of them the size of a cart-wheel, swarmed in its waters; and with them the huge reptiles of Jurassic times, sea-lizards and sea-serpents, also ganoids and sharks; and, what is important to note, bony-skeletoned fish allied to the salmon, herring, and perch families.

In the North American formations, which have so largely added to our knowledge of ancient life-forms,

[1] Mr. Bates remarks that butterflies, owing to the registry of all changes of the organisation on the wings, are 'better adapted than almost any other group of animals or plants to furnish facts in illustration of the modifications which all species undergo in nature under changed local conditions. As the laws of nature must be the same for all beings, the conclusions furnished by this group of insects must be applicable to the whole organic world; therefore the study of butterflies—creatures selected as the types of airiness and frivolity—will some day be valued as one of the most important branches of biological science.'—*Naturalist on the Amazons*, pp. 347-48.

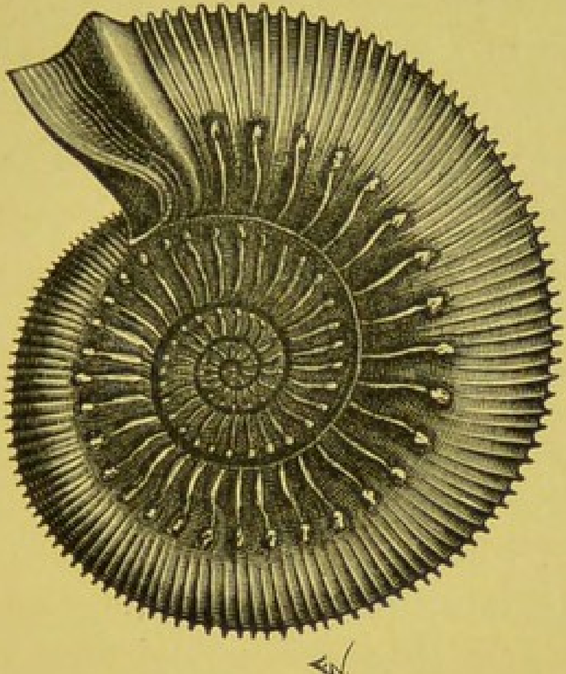


FIG. 18.—Ammonite.

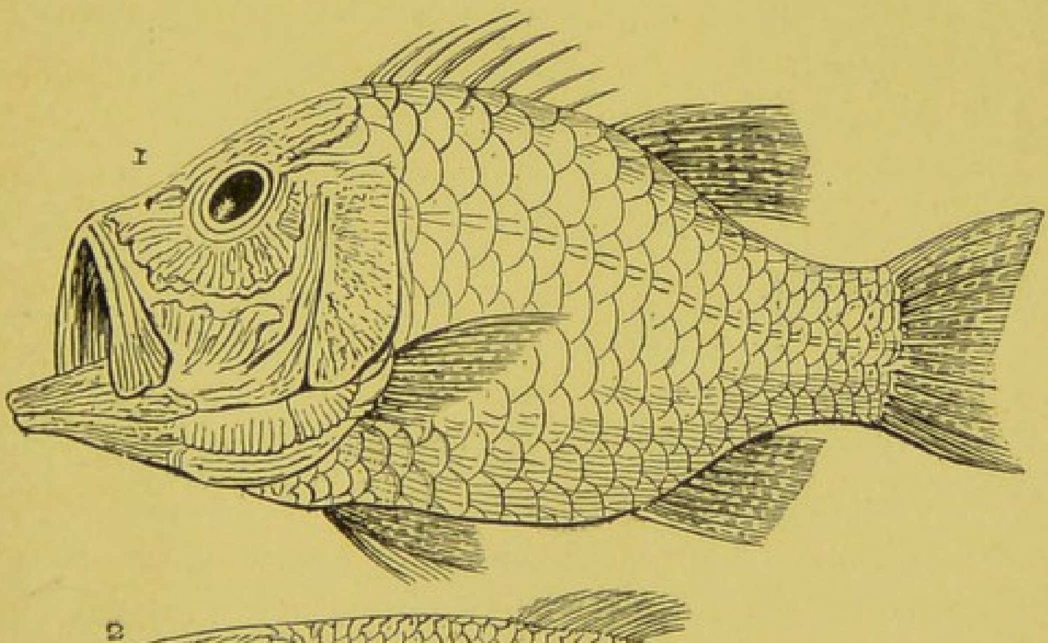


FIG. 19.—1, Fossil Perch; 2, Fossil Salmon.

'dragons of the prime,' crocodile-like, bird-like, and bat-like, are found ; also toothed birds, with reptile-like brains, and the remains of true birds, these last being rare in the Old World. Little trace of the Cretaceous land-areas remains, but the plants of the upper strata resemble existing vegetation, as angiospermous exogens, or leaf-bearing trees having a true bark, and growing from the outside, with their seeds enclosed in a vessel. They are called 'exogens' in contrast to 'endogens,' or palms, grasses, and lilies, which have no true bark, and grow by additions from the inside.

Of the total thickness of the stratified rocks, estimated at one hundred and thirty thousand feet, the Secondary systems occupy only fifteen thousand, or less than one-ninth of the whole. But their importance, like that of later and thinner formations, is not to be measured by the space which they fill, since it is during their deposition, when, as the coal seams and coral deposits of extreme northern zones show, warm climates prevailed, that the marked advance in specialisation of plant and animal forms is manifest.

3. TERTIARY.—Those warm climates continued far into the Tertiary epoch, but they were followed by declining temperatures, which at last resulted in the long and intermittent period of intense cold known as the Glacial epoch. Large areas of Europe and North America were then swathed in ice, which gouged and moulded the subsiding land, choking the sea with *débris*, and destroying numberless species of plants and animals, to the lasting biological impoverishment of after times. In the end the temperature gradually rose to its present level.

The Tertiary epoch marks the beginning of the present order of things, and of the existing distribution of land and sea, as also the uprising of most of the great mountain chains.

Although much of the existing land-area was then submerged under shallow seas, the sites of the great continents of both hemispheres had well-nigh the same outlines as now. Varied as are the life-forms of that epoch, unrelated and, save in the nummulitic limestones, detached as are the strata, those life-forms manifest a gradual approach to existing species and a marked divergence from the species of older epochs. The colossal reptiles of Jurassic and Cretaceous times, the coiled ammonites and other mollusca of their seas, are extinct. The age of huge reptiles has given place to the age of mammals, with their intermediate forms, but with no one group dominant, and with no important group unrepresented. Larger animals have always been less able to resist changes than smaller animals. When the particular conditions which enabled them to attain to a great size have altered, they have been the first to perish. It is the smaller, nimbler, and larger-brained animals that adapt themselves to changed conditions; hence their long time-range compared with that of animals of unwieldy structure and small brains. And while the big reptiles of the Secondary epoch, like the big plants of the Carboniferous system, have left only dwarfed representatives, it is from the persistent smaller types that the higher mammals are descended.

The links between the Secondary and the Tertiary epochs are, except meagrely in the United States, unrepresented by any known strata, denudation having swept away the intermediate deposits with their contents. And so confused are the Tertiary strata that their order in time is determined solely by the proportion of their shell-fish to existing species, ranging from as low as three per cent. in the oldest beds to ninety-five per cent. in the newest. Mollusca have been called the alphabet of palæontology, because their extensive distribution through the several epochs renders them the most valuable and trustworthy of all organic remains in assigning the order in time and the conditions of life, not only of their own species, but of other species whose life-history is briefer, and whose range is more limited.

The rocks of the Tertiary epoch witness to widespread aqueous and volcanic action. This is specially

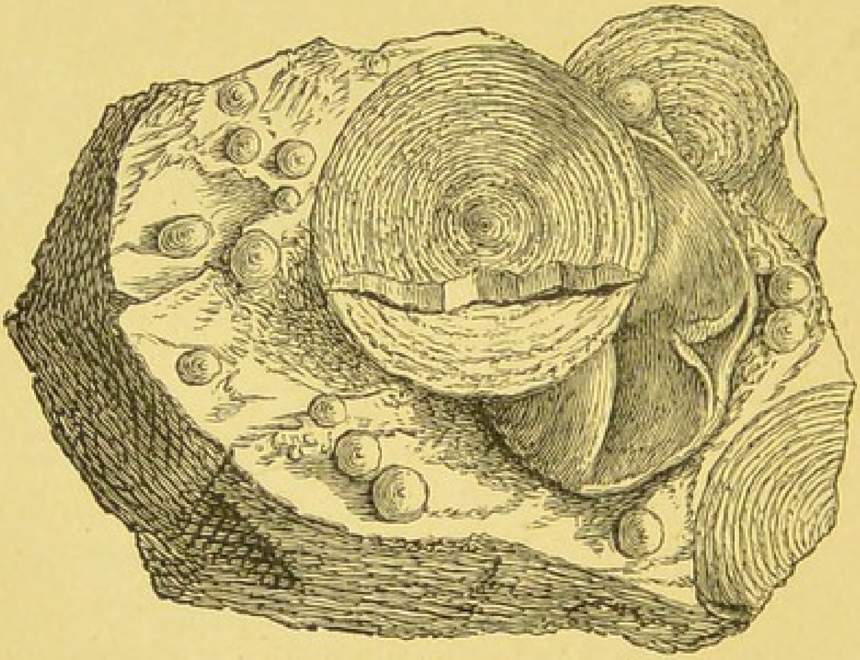


FIG. 20.—Fragment of Nummulitic Limestone from the Great Pyramid.

noticeable in the *Eocene* strata, prominent among which are the vast beds of limestone laid down when Europe, its north-west corner excepted, and Central Asia were covered by the sea, Hindostan being then an island, and Northern and Southern Africa separated by the sea which then covered the Sahara. These beds extend from the Pyrenees to China and Japan, and also largely compose the Alps, Carpathians, Himalayas, Atlas, and lesser mountain chains. Not many noble nor mighty are called to the enduring tasks of nature. It is the minute agents, unresting and widespread, that have been the efficient causes of much that is grandest in earth-structure; and it is of shells of the coin-like nummulites that these stupendous formations are mainly composed. Their foundations were laid in archæan times in the fissures opened in the crust by volcanic action. Into these fell the sediment and organic deposits of ancient seas, which ultimately, as the cooling crust caved-in by its own weight upon the shrinking hot nucleus, were squeezed and puckered and overturned by lateral pressure into numberless folds; or, according to a later theory, plicated and bulged through the heat generated by the accumulation of sediment.[1] Then, when the twisted and crumpled strata were upheaved above sea level, water and the powers of the air sculptured them into pinnacle and peak, into ravine and valley. So the big mountains, as we know them, are relatively modern; the lesser ones are the older, as longest subject to the wear and tear of eroding agents. Mont Blanc and the Matterhorn are not older than the Eocene marine clay on which London stands; and the Righi, a fresh-water shingle bed, is younger still.

Broadly grouping the life of Eocene seas, we find large whales, teleost or bony-skeletoned fish in abundance, and the persistent ganoids. Birds and bats are

[1] Mr. Mellard Reade s recently published *Origin of Mountain Ranges* is an important contribution to a difficult subject. The author contends that the earth's cooling has not extended to such a depth as to make internal contraction a cause of mountain ranges. He regards them as due to sedimentation, whether organic or inorganic, accompanied by local change of temperature in the crust. The heaping up of the sediment produces a rise in temperature, which causes expansion in all directions. This is illustrated by the effect in the course of time on the lead lining of a sink, which, through alternate heating and cooling, gets bulged up in ridges.

in the air ; crocodiles and turtles swarm in the shallows ;[1] snakes and serpents make their appearance ; the mammals are no longer restricted to pouch-bearers, for the placentals—huge quadrupeds, carnivora, hornless deer, and hog-like forms of a type between the tapir and the horse—appear in large numbers. Among the most remarkable fossils from North American beds are those of the ancestor of the horse, a creature about the size of a fox, with four hoofed toes on each foot, and in one form

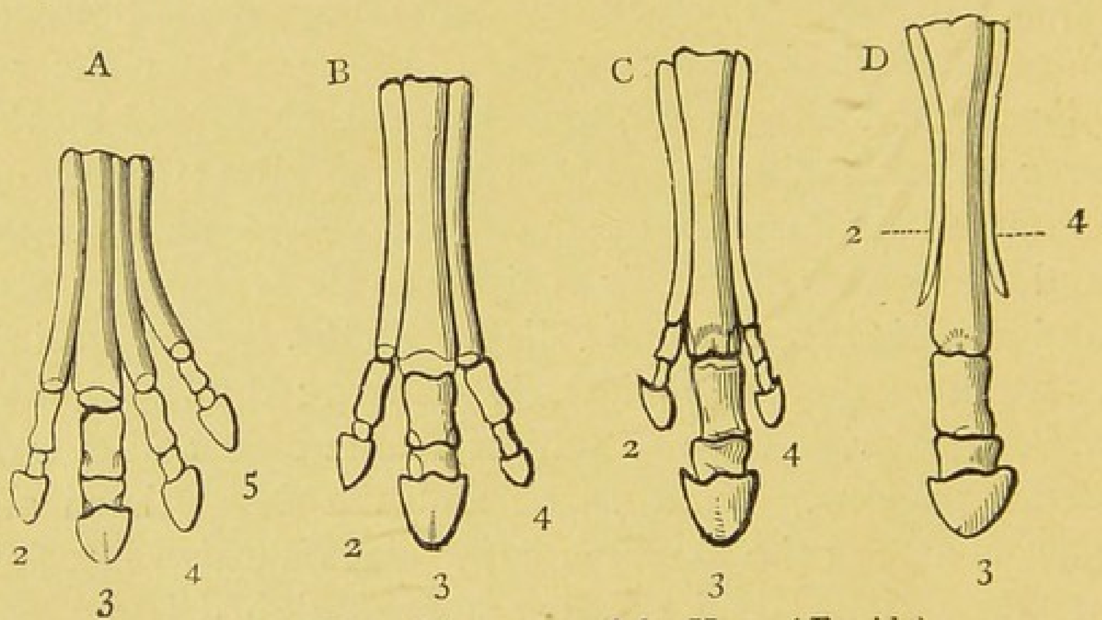


FIG. 21.—Feet of Ancestors of the Horse (*Equidæ*).

A, Orohippus, Eocene ; B, Anchitherium, Upper Eocene ; C, Hipparion, Upper Miocene ; D, horse of Pliocene and Quaternary. The figures indicate the numbers of the digits in the five-fingered hand of mammals.

(*Eohippus*) with the rudiments of a fifth toe. A still more significant biological link is found in the lemuroids of the Upper Eocene (which belong to the Primates, or order of mammals including man and ape), possessing characters allying them to one or other of the hoofed quadrupeds then living. The plants, which were slowly dispersed over the northern hemisphere from polar

[1] ' More true turtles have left their remains in the London clay at the mouth of the Thames than are known to exist in the whole world.'—Sir R. Owen, *Palæontology*, p. 281.

regions, were tropical in character, as shown by remains in the Thames delta and corresponding deposits.

The like character applies to the flora of early *Miocene* (in which is included *Oligocene*) times, which are represented by only a patch or two of deposit in Britain. Timber trees, evergreens, and water-lilies flourished within eight degrees of the north pole, with which Europe and America were connected by way of the Faroe Islands, Iceland, and Greenland, or of Behring Straits. The animals approximated more nearly to those of the present, save in the huge size of some of the mammals, as of the mastodon and other creatures allied to the elephant.

Small rhinoceroses, hornless deer, anthropoid apes, as large as man, and, probably, the ape-like ancestors of man himself, appeared ; the horse corresponded more nearly to his modern descendant, the variation being that each foot had three toes, of which only one touched the ground. Birds and insects were abundant: of the latter, thirteen hundred species have been found in Switzerland alone.

The *Pliocene* period ushered-in great local changes in land and water distribution. The lofty ridge, clothed with oaks and vines, that had stretched from France to Greenland, and the remnants of whose volcanic chain, of which Hecla is the sole active relic, are extant in the Hebrides and the Highlands of Scotland and Wales, was submerged. Europe was thus severed from America, but Britain was left as a peninsula, the newly invading waters of the North Sea dividing Scotland from Norway. On the other hand, the Eurasian continent was upraised in parts, leaving the deeper basins of the Black, the Aral, and the Caspian Seas as remnants of the shallow waters that had linked together the Baltic and the Persian Gulf, and also the Arctic and the Indian Oceans.

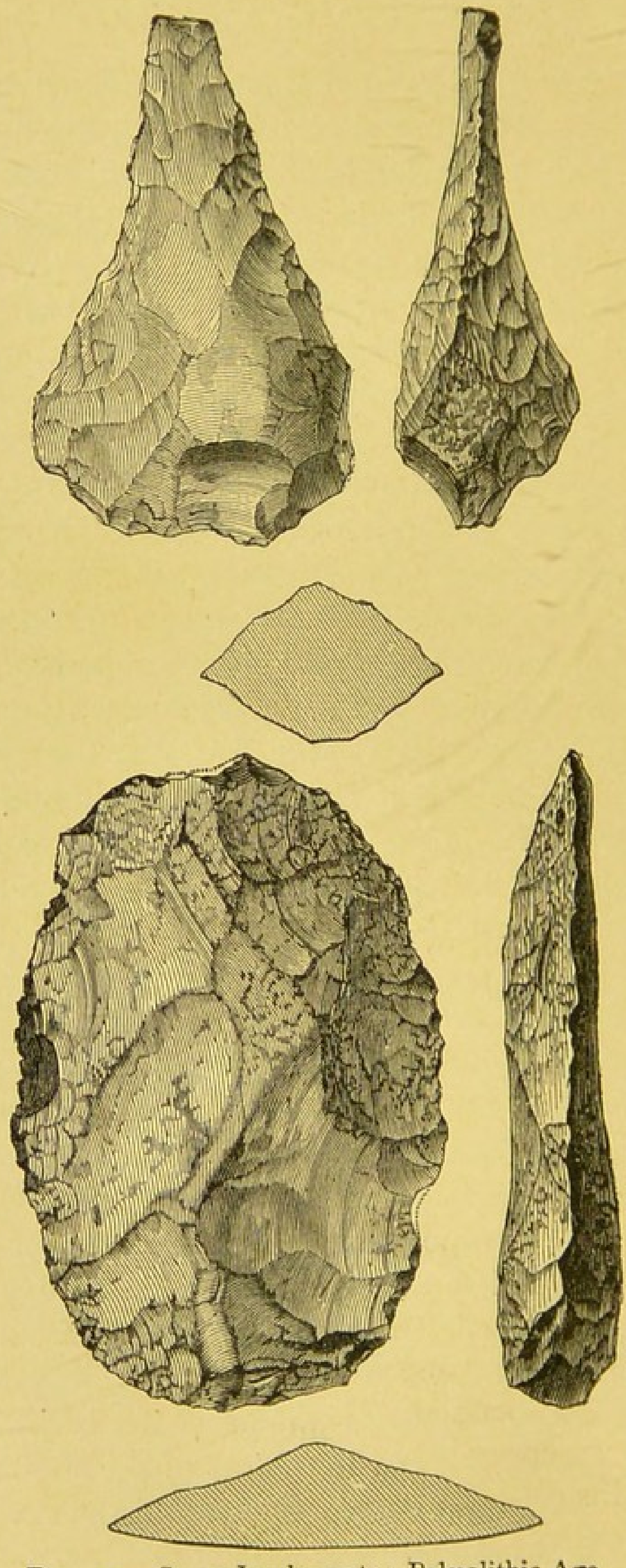


FIG. 22.—Stone Implements: Palæolithic Age.

Except in the larger species, which gradually died out, the hippopotamus alone among them surviving to this day, the quadrupeds varied little from those of the *Miocene*, the most remarkable among the carnivora being fierce sabre-toothed felines.

But for us the most interesting Pliocene relics are the scanty fragments of the skeleton of man, and the flints bearing marks of artificial chipping, which have been found not only in France, Italy, and Portugal,[1] but, what is far more important, in the Pliocene gravels of California.[2] For as it is agreed that the birthplace of man was in the Old World, probably, in the judgment of some authorities, in the far north of Asia, the time-range of the genus from which he is descended has to be extended to allow for his development and dispersion.

Pliocene fauna and flora alike witness to a cooling climate. The life-destroying agencies are at work; the cold fingers of the ice-giant are being spread over the northern hemisphere to the fiftieth parallel of latitude, dinting and rounding its surface, and leaving to this day the traces of their impress in the snow-fields and glaciers of Scandinavia and Switzerland. Glacial action swept away the northern flora, never to return, the existing vegetation being almost entirely post-glacial and of eastern origin.

4. QUATERNARY.—Upon the glacial deposits or boulder clays, only the most recent of which contain fossils, and these poor and scanty, rest the strata of the present geological epoch, the *Quaternary*, or *Post-Tertiary*, or *Pleistocene*, as it is variously called. This is subdivided into the Post-Pliocene and the Recent, the former containing the remains of many extinct animals, as huge

[1] Cf. M. de Quatrefages' *Introduction à l'Etude des Races Humaines*, p. 91 (Paris, 1887); and, for opposite views, Prof. Boyd Dawkins's *Early Man in Britain*, pp. 90–92.

[2] On the authority of Prof. J. D. Whitney, U.S. Geol. Survey.

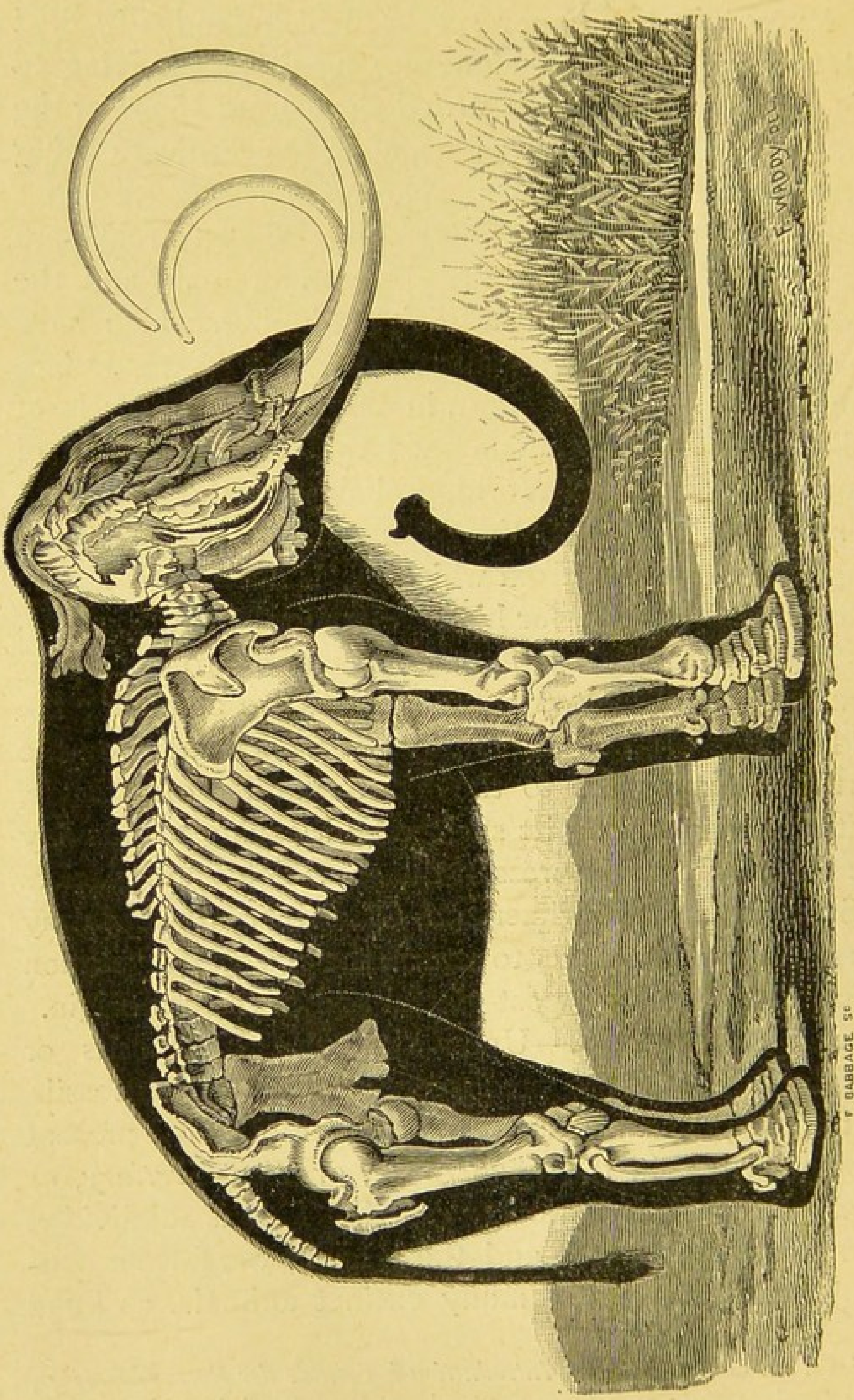


FIG. 23.—Mammoth, or Woolly-haired Elephant.

wingless birds and sloth-like mammals, and the latter the remains of none but existing species. The Post-Pliocene beds furnish plentiful evidence of man's presence

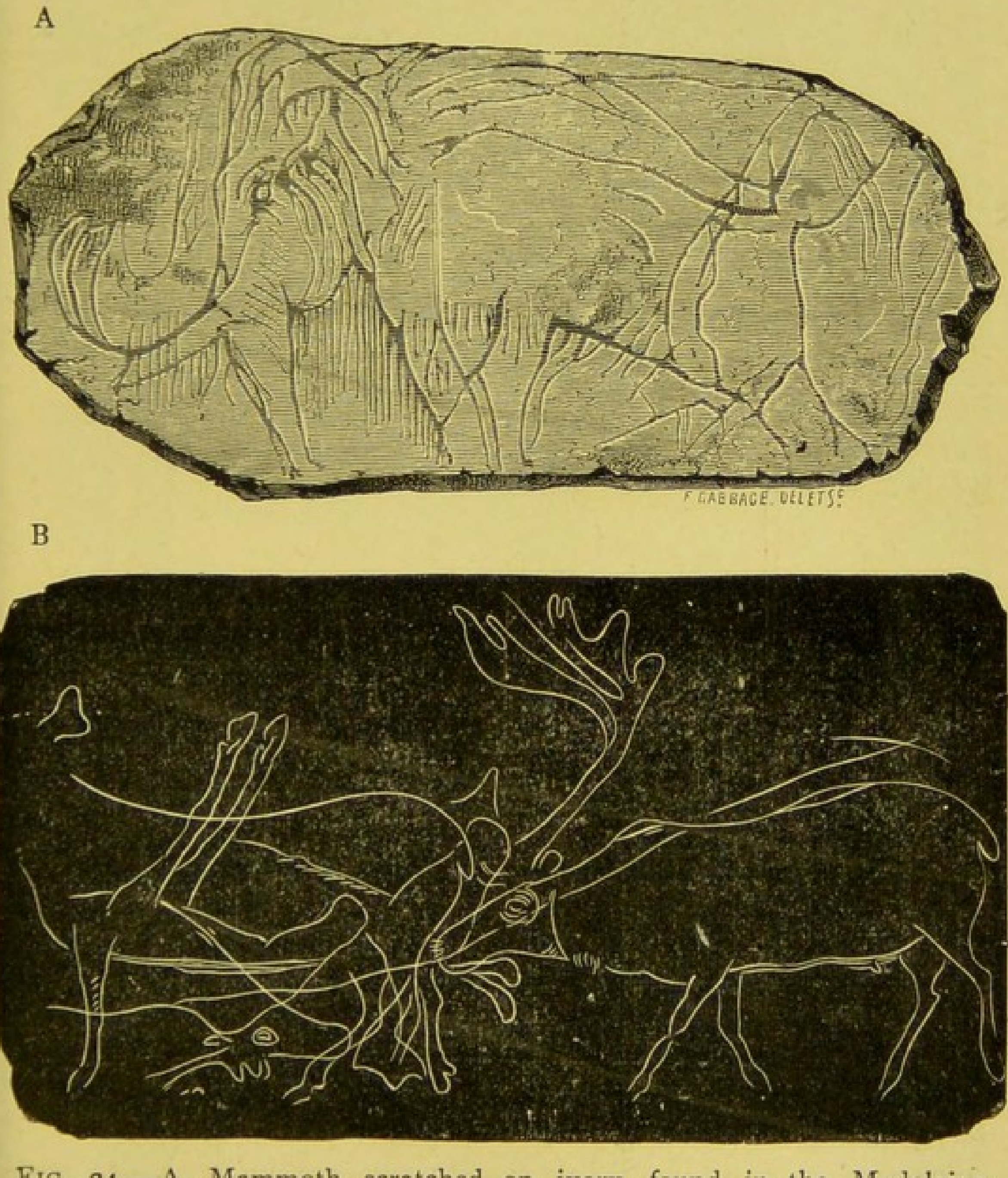


FIG. 24.—A, Mammoth scratched on ivory, found in the Madelaine cavern in the Dordogne. B, Fight between Reindeer: scratched on slate.

in Western Europe, although more in his works than in himself, since only the scantiest remains of his fragile skeleton have been preserved. The roughly chipped

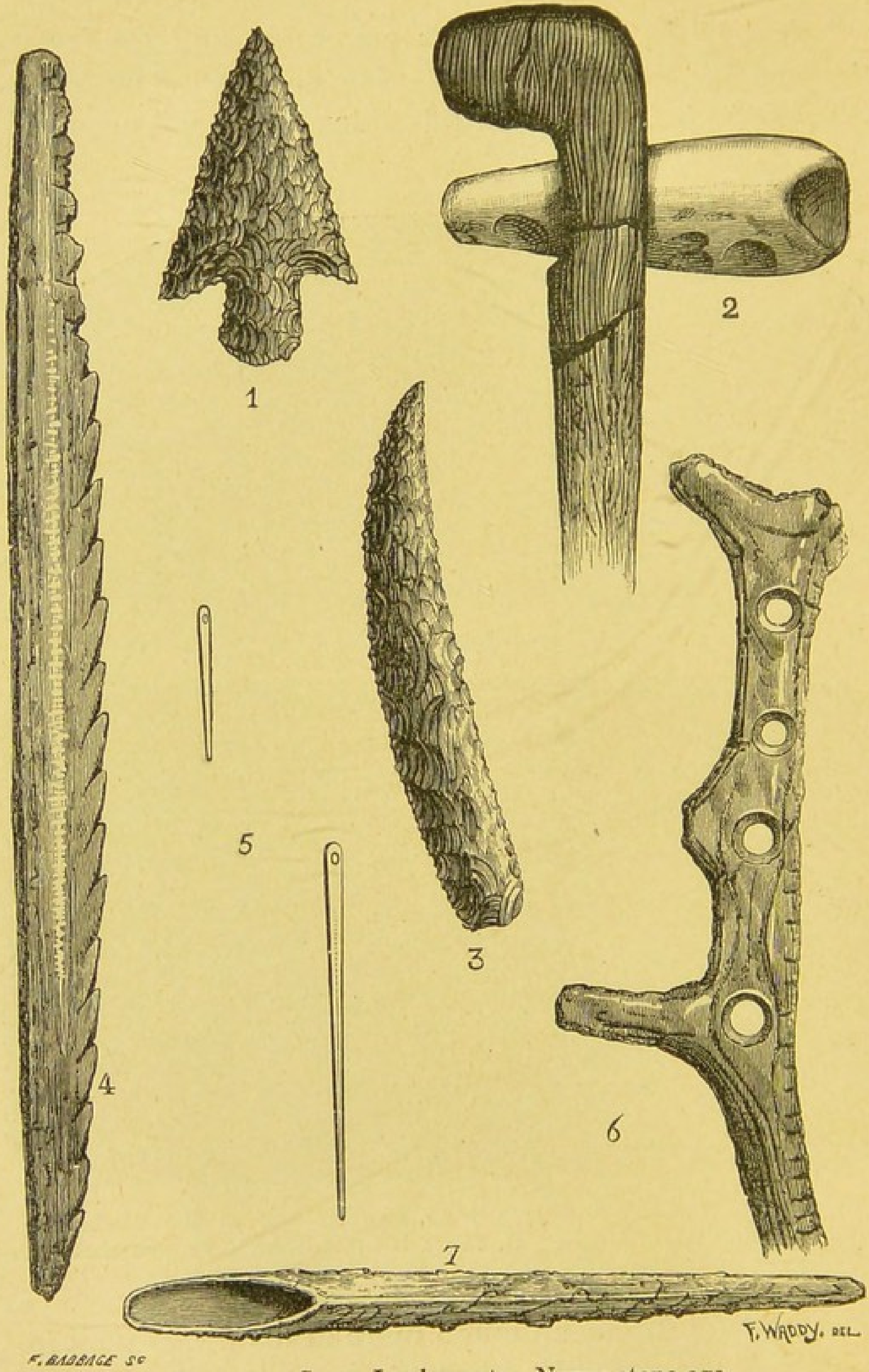


FIG. 25.—Stone Implements: Newer stone age.

1, flint arrow-head; 2, stone axe-handle; 3, flint knife; 4, bone harpoon; 5, bone needle; 6, perforated horn; 7, spoon for scooping marrow from bones.

stone tools and weapons with which he made shift have been found buried in ancient river gravels with bones of the mammoth or woolly-haired elephant, and other arctic animals, as well as with bones of temperate and tropical animals, probably witnessing to sharp alternations of climate. When the foundations were being dug for Drummond's new bank at Charing Cross the following fossils were found in the Pleistocene gravels :—Cave lion ; tusks and bones of the mammoth ; extinct Irish deer ; rhinoceros ; extinct oxen ; red deer and the remains of a species allied to the fallow deer. Stone implements and rude works of art of a somewhat more advanced race, possibly ancestors of the Eskimo, have also been found associated with remains of sub-arctic animals in limestone caverns.

A vast range of time and wide gap of altogether different conditions separate the rude savages of the Palæolithic or old stone age from the progressive races of the succeeding periods into which prehistoric time is divided—namely, the Neolithic or newer stone age, the age of Bronze, and, lastly, the age of Iron, which merges into the brief and modern period embraced by the historian.

In the foregoing rapid summary of the earth's past zoology and botany much of detail has been left out for clearer presentment of the typical features of each epoch, and of the scale of life as an ascending scale. The older the rock the simpler the life-forms.

The seaweed and the lichen, stemless and leafless, are lower than the club-moss and the tree-fern ; these are lower than the true timber tree, with its complex arrangement of trunk, branches, leaves, flowers, and fruit. The sponge, rooted plant-like to the rock, is lower than the coral or the star-fish ; these, again, than crabs or shell-fish, the most highly organised of which are lower than the vertebrates, between the several groups of which the ascents are manifest in fish, reptile, bird, and mammal. And among these last there are the lesser and the greater: the pouch-bearers, bringing forth their young immature, are less specialised than the placentals, bringing forth their young fully developed; while here, also, the ascending grades are seen in whales, ungulates, carnivora, monkeys, men.

To all which the fossil-yielding rocks bring their witness. Imperfect as is their record, obscure as in certain cases are the causes of modification resulting in the appearance of new types, the evidence as to ascent of life from the simple to the complex, and as to its succession, is overwhelming. There was a time when the earth was devoid of life, and we are very far from its 'protoplast' beginnings in the earliest known organic remains, just as all species probably came into being long before we have any trace of them. But no evidence as to their first appearance that may be gathered from parts still unexplored is likely to alter the relative order assigned to the several types as compared with one another.

The history of the earth is written by fire and water; its life-history by water alone.

The volcanic and other modes of igneous disturbance that have upheaved, depressed, contorted, and fissured its cooling crust are due to the internal energy manifest in the escape of pent-up heat and in chemical action. The more potent agents of change in the visible crust, however, have not been from within, but from without. As the internal energy, derived from contraction of the hot nucleus, decreased, the energy derived from the sun became more effective, giving rise to changes wherein

TABLE OF THE SUCCESSIVE APPEARANCE OF TYPICAL LIFE-FORMS.

Epoch	System	Animal	Plant
PRIMARY or PALÆOZOIC (Earliest known Life-forms)	Laurentian	*Eozoon Canadense* (?); Foraminifera	Seaweeds; club-mosses
	Cambrian	Sponges; corals; crustacea; shell-fish	
	Silurian	Huge crustacea; the lowest known vertebrates (ganoids or armoured *fish*)	
(Age of Ferns and Fishes)	Devonian	Insects; swarms of ganoids	Ferns; calamites; cycads
	Carboniferous	Land vertebrates (labyrinthodonts)	
	Permian	*Reptiles*	
SECONDARY or MESOZOIC (Age of Pines and Reptiles)	Triassic	Immense reptiles; sea-lizards; *marsupial mammals*	Conifers; palms
	Jurassic	Immense bird-reptiles; true *birds*[1]	
	Cretaceous	Bony-skeletoned fish; large ammonites	
TERTIARY or CAINOZOIC (Age of Leaf-forests and Mammals)	Eocene	Huge *placental mammals*; serpents; nummulites	Trees, shrubs, herbs allied to existing sub-tropical species
	Miocene and Pliocene	True whales; man-like apes	
(Glacial epoch intervening, and continuing into the—)			
QUATERNARY	Post-Pliocene	Mammoth and other woolly quadrupeds; man	Arctic and temperate
	Recent or Historic	Existing species	Existing species

variations of temperature and the circulation of air and water over the surface of the earth would come into play. It is to these—to the solvents of the atmosphere and rain, to the driving wind, to water in its several states and movements, whether of disrupting frost, grinding glacier, eroding river, or waves and currents of the sea—that the five-and-twenty miles and more of stratified rocks (for the same stuff has been used over and over again), with all the varied contour of the earth's surface, are mainly due.

[1] The discovery of the lowest mammalian forms in earlier strata than those containing birds seems opposed to the accepted order of succession, but there is considerable uncertainty as to the exact period of the first appearance of birds.

Vast, slow, and continuous as are the changes, they occur within defined limits. The deep ocean basins, the lines or seams of the great mountain chains, have probably been permanent from the remotest geological epochs, and the variations in land and water distribution, although enormous and unceasing, have been confined to certain areas. All the evidence furnished by the aqueous rocks, from the earliest primary to the alluvial formations of to-day, point to their tranquil deposition on the floors of relatively shallow seas, where they have been converted by pressure and other means into solid beds, entombing organic remains which give the key to their relative place. Then, on their upheaval above the sea, the eroding agents have begun their slowly levelling work, and the *débris* of lands, where life-forms have flourished and perished, have returned to the waters whence they uprose, to become once more 'the dust of continents to be.' And so 'the thing that hath been, it is that which shall be; and that which is done is that which shall be done: and there is no new thing under the sun.' Between the opposing agents of waste and repair, of upheaval and subsidence, with interplay of the organic in growth and decay, as in limestone ranges, coral isles, and coal-beds, and the action of man himself on nature, the ancient earth is maintained from age to age mother of all living.

CHAPTER V.

PRESENT LIFE-FORMS.

I. PLANTS.

Sea and other water-weeds (*Algæ*) . Fungi . . . . . . Lichens	Gymnospores, *i.e.* naked spores.
Mosses . . . . . . Ferns and Horsetails . . . Club-mosses	Angiospores, *i.e.* enclosed spores.
Pines and Palm Ferns . . . (Many seed-lobes.)	Gymnosperms, *i.e.* naked seeds.
Grasses, Sedges, Palms . . . (One seed-lobe.) Trees, Shrubs, Herbs . . . (Two seed-lobes.)	Angiosperms, *i.e.* enclosed seeds.

II. ANIMALS.

1. INVERTEBRATES, *i.e.* without backbone:

Monera[1] (Gr. *monos*, single) .	Structureless, sticky, alike all over.
Amœbæ[1] (Gr. *amoibe*, change)	Slight unlikeness of parts; always changing shape.
Foraminifera (Lat. *foramen*, an opening . . .	Secrete shell or skeleton of lime from water. Show passage to further unlikeness in parts.
Polycystina (Gr. *polus*, many; and *kustis*, a cyst) . .	Secrete shell or skeleton of flint from water.
Sponges.	
Coral animals, anemones,[1] jelly-fish.[2]	

[1] No fossils of these soft-bodied lowest forms exist.

[2] Impressions of bodies only.

Sea-lilies, star-fish.
Worms of all kinds . . . } Annulosa.
Crabs, spiders, centipedes, insects . }
Oysters, snails, cuttle-fish . . } Mollusca.
Sea-squirts (Ascidia) . . . }

2. VERTEBRATES:

A. *Pisces.*
Lancelet (Amphioxus).[1]
Fish of all kinds.

B. *Amphibia.*
Toad, frog.

C. *Reptilia.*
Serpent, lizard, crocodile, turtle.

D. *Aves.*
Birds of all kinds.

E. *Mammalia.*

1. Aplacental (bringing forth immature young):—*Monotremes*, or one-vented: duckbill, spiny ant-eater. *Marsupials*, or pouched: kangaroo, opossum.

2. Placental (bringing forth mature young):—Ant-eater, sloth, manatee; whales and porpoises; horse and all other hoofed animals; elephant; seal, dog, lion, tiger, and all other flesh-feeders; hare and all other gnawing animals; bats; moles and all other insect-feeders; apes; man.

If the life-forms of the past somewhat baffle us by their scantiness and imperfectness, those of the present embarrass us by their abundance. But although the existing species of plants and animals are numbered by hundreds of thousands, and the tale is not yet complete, they are classified into a few primary divisions or sub-kingdoms representing certain allied types, of which the several species included in each sub-kingdom are modified forms. For example, olives and daisies are grouped as angiosperms because their seeds are enclosed within a seed-vessel; flies and lobsters, beetles and crabs, are grouped in the sub-kingdom of the Annulosa, because they are alike composed of distinct segments; boys and frogs, pigs and herrings, are grouped in the sub-kingdom of the Vertebrata, because they alike

[1] No fossils.

possess an internal bony skeleton, the most important feature of which is the spine or vertebral column. And this classification is applicable alike to past and present organisms, there being throughout the whole series of fossil remains no form, however unlike any existing living thing, that is not to be placed in one or other of the sub-kingdoms.

> All things the world which fill
> Of but one stuff are spun ;

and this stuff, the basis of all life, the formative power, 'universally known and yet essentially unknown,'[1] to which the name protoplasm (Gr. *protos*, first ; *plasma*, moulded) has been given, is a semi-fluid, sticky material, full of numberless minute granules in ceaseless and rapid motion. 'It is not a compound, but a structure[2] built up of compounds, consisting of the elementary substances carbon, hydrogen, oxygen, and nitrogen, in very complex union.' They are the *essential* elements, but a few others enter into the chemistry of life, with resulting slight differences in the *incidental* elements in animals and plants. Moreover, a fundamental unity of form and of function underlies and pervades living matter, from the slime of a stagnant ditch to the most complex animal ; the differences between living things being in degree, and not in kind. Therefore, although each genus, nay, in most cases, each species, needs for its complete study the labour of a lifetime, it suffices for the majority of us, grateful for the results which the zeal of specialists has achieved, to acquaint ourselves with the essential characteristics which mark the main divisions of the twin sciences of botany

[1] Sachs, p. 294.

[2] Sir Henry Roscoe's *Presidential Address to the British Association*, 1887.

and zoology. If this is the only possible thing for us, it is the one thing needful for all, whether specialists or non-specialists; otherwise the significance of facts, in their relation and dependence, is missed, and the larger generalisations are swamped in a sea of detail, so that we cannot, as the phrase goes, see the wood for the trees.

In the old division of the three kingdoms of nature into the mineral, the vegetable, and the animal, we were taught that stones grow; that plants grow and live; while animals grow, live, and move. But this no longer holds good, at least in respect of the lower life-forms. There are locomotive plants and stationary animals. The swarm-cells or zoospores which are expelled from some of the lower plants, as algæ and certain fungi, behave like animals, darting through the water by the aid of hair-like filaments called vibratile cilia, finally settling down and growing into new plants. Other plants, as diatoms and desmids, are locomotive throughout life; certain marine animals, as sponges and corals, are rooted to the spot where they grow; while there are organisms which appear to be plants at one stage of their growth and animals at another stage.

Other marks of supposed unlikeness have vanished. It was formerly held that among the distinctive features of animals are—(1) a sac or cavity in which to receive and digest food; (2) the power to absorb oxygen and exhale carbonic acid; and (3) a nervous system. But although nearly all animals, in virtue of their food being solid, have a mouth and an alimentary cavity, the lowest forms are without these organs; and although plants, in virtue of their food being liquid or gaseous, need not that cavity, there are some that have it. Not only is the process of digestion apparent in the leaves of carnivorous plants, the hair-like glands on which contain pepsin, but embryonic forms have been found to secrete a ferment similar to the ferment in the pancreatic secretion of animals, by which they dissolve and utilise the food-stores in their seed-lobes as completely as food is digested in our stomachs. And although green plants, under the action of light, break up carbonic acid and release the oxygen, they do the reverse in the dark, as also in respiration; while the quasi-animal fungi which are independent of light absorb oxygen and give off carbonic acid.

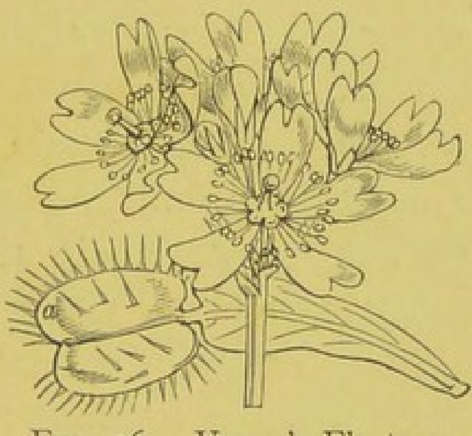


FIG. 26.—Venus's Fly-trap.

a, bristles in triplets, which when touched cause the sides of the leaf to collapse and enclose the intruder.

In the 'irritability' of the sundew, Venus's fly-trap, and other sensitive plants, still more so in subtile and hidden movements in plant-cells, we have actions corresponding to those called 'reflex' in animals, as the contraction of the shapeless amœba when touched, or the involuntary closing of one's eyelid when the eye is threatened, or the drawing back of one's feet when tickled. The filament in the amœba which transmits the impulse causing it to contract differs only in degree from the sensory nerves in ourselves which transmit the impression to the motor nerves, causing the muscles to act; and since there is every reason for referring the contractile action of plants, *i.e.* their movements in obedience to stimulus, to like causes, the germs of a nervous system must be conceded to them. The minute observations of Darwin and his son into the large class of quasi-animal movements common to well-nigh all vegetable life go far to confirm this. The highly sensitive tip of the slowly revolving root, in directing the movements of the adjoining parts, transmitting sensation from cell to cell, seems to 'act like the brain of one of the lower animals; the brain being seated within the anterior end of the body, receiving impressions from the sense-organs and directing the several movements.'[1]

In these and kindred vital processes, in the so-called sleep-movements of leaves and flowers, both regulated by the amount of light, apparently acting on them as it acts on our nervous system; in the detection of subtile differences in light which escape the human eye, by plants; in the higher range of sensation which they manifest, as compared to some animals; in their choice of food, and of the material of the covering which some of them secrete; in their general sensitiveness to external influences; even in the diseases which attack them, and the study of which Sir James Paget has commended to pathologists, we have the rudiments of attributes and powers which reach their full development in the higher animals, and therefore a series of fundamental correspondences between plant and animal which point to the merging of their apparent differences in one community of origin.

In fine, that which was once thought special to one is now found to be common to both, and to this there is no exception. Not only is there correspondence in external form in the lower life-groups, but, fundamentally

[1] Darwin's *Movements of Plants*, p. 572.

plants and animals are alike in internal structure, and in the discharge of the mysterious processes of reproduction and of nutrition, although, as will be shown presently, this last forms a convenient line of separation. Notwithstanding agreement in essential points of comparison, there is this difference to be noted, that while animals, the lower forms excepted, reach a given development, the vast majority of plants do not, but continually put forth growing points, so that life goes on indefinitely, and is multiplied and distributed over large areas. The life of the higher animals is indivisible and, as compared with the plant, brief, while cuttings or tubers from a single plant are taken without detriment to the vigour and duration of the parent life.

Of course the difficulty of classifying vanishes in the higher forms; the lowest plants are allied to the lowest animals, but the higher the plant the more it diverges from the animal, which is evidence that in the succession of life the highest plants do not pass into the lower animals. Descent is not lineal, but lateral; the relations between the two kingdoms are represented by two lines starting from a common point and spreading in different directions (see diagram, fig. 62). Even 'lower' and 'higher' are relative terms; the organisation of the amœba is as complete for its purpose as is that of man for his purpose, the modification in the complex forms being due to the division of functions which are performed in every part by the simple forms. The like does everything; the unlike does some things.

Although the foregoing and numberless other facts, together with the evidence from continuity, alike forbid the drawing of any hard and fast lines, and involve the conclusion, to borrow Professor Huxley's words, 'that the problem whether in a given case an organism is an animal or a plant may be essentially insoluble,' there exists, as noted already, a broad distinction in the mode of nutrition.

The plant possesses the mysterious power of weaving the visible out of the invisible, of converting the lifeless into the living. This it does by virtue of the green colouring matter called chlorophyll, which is found united with definite portions of the protoplasm mass, of which it is a modification, the exact nature being unknown. The water supplied by the root and the carbonic acid which the plant absorbs through the numberless stomata or mouth-pores in its leaves or integuments are, when the sunlight falls upon them, broken up by the chlorophyll,[1] which sets free the oxygen, and locks together the hydrogen and carbon, converting this hydrocarbon into the simple and complex cells and tissues of the plant, with their store of energy for service to itself and to other organisms. Animals cannot do this ; they are powerless to convert water, salts, gases, or any other inorganic substances into organic : they are able only to assimilate the matter thus supplied by the plant, nourishing themselves therewith, either directly, by eating the plant ; or indirectly, by eating some plant-feeding animal. In other words, the plant manufactures protein from the mineral world, and the animal obtains the protein ready made ; the plant converts the simple into the complex, and this the animal, by combining it with oxygen, consumes, using up the energy which it thereby obtains in doing work. So the plant is the origin of all the energy possessed by living things ; but how it can convert the stable inorganic into the

[1] The formation of chlorophyll in complete darkness, but under sufficiently high temperature, has been observed in a few instances, as in the seed-leaf of some conifers and in the leaves of ferns.

unstable organic, while the animal cannot, we do not know.

Structurally, the lowest animal is below the lowest plant, since it is a speck of relatively formless, colourless protoplasm, whereas the protoplasm of the lowest plant is visibly organised to the extent that it has formed for itself an outer layer or membranous coat called the cell-wall. For example, the vegetable character of yeast-granules is determined, apart from their mode of nutrition, by the protoplasm being enclosed within a cellulose coat; and the animal character of the amœba is determined, not because of contractile or locomotive power, or of inability to manufacture protein from inorganic matter, but by the absence of any such covering. The vegetable cells sealed their fate when enclosed within a hard thick shell, because they became thereby less accessible to external influences, less able to combine for the construction of nervous and muscular tissues, than animals, and condemned to an automatic life. For while the animal remained free to wander, and developed organs of digestion and motion, the plant, being fixed, perforce struck its tentacles into the soil for foothold, and developed a large surface of green leaf to take in the food which the wind and the water brought it. In changing the substance of its cell-wall into woody tissue it prevented the evaporation of the food-carrying fluids, and gained that solidity and form of which man has availed himself in the use of timber for the needs and arts of life.

Since the function creates the organ, and where function is not localised there is no variation of parts, life probably began in combinations having no visible distinction of parts. And as the cell is the first step in visible organisation, it is the fundamental structure of living things; 'it marks only where the vital tides have been, and how they have acted.'[1] The lowest organisms consist of one *cell* only, and the higher consist of many cells, which, increasing in complexity or diversity of form adapted to their different functions at later stages,

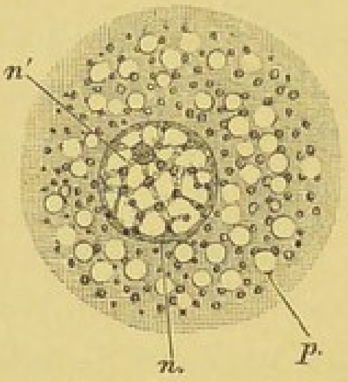


FIG. 27.—Diagram of a Cell.

p, protoplasm; *n*, nucleus; *n'*, nucleolus.

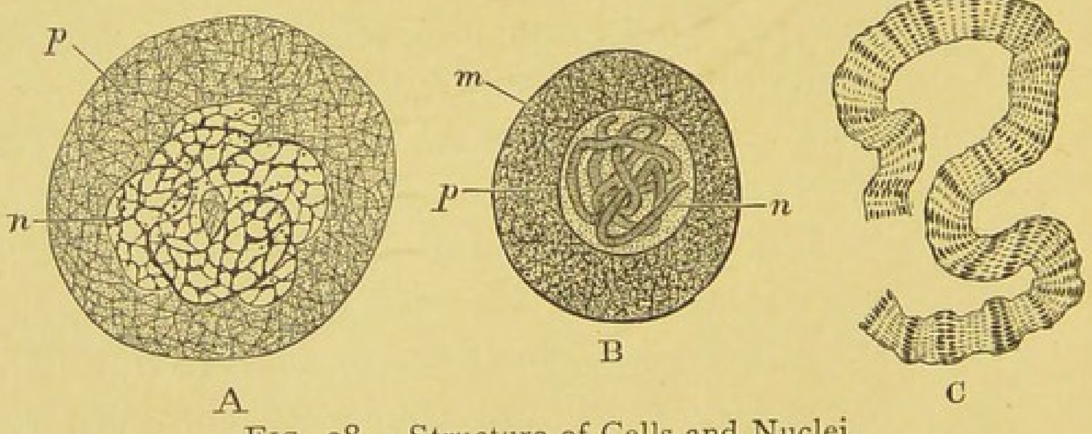


FIG. 28.—Structure of Cells and Nuclei.

A, cell from the marrow: *p*, protoplasm; *n*, irregular nucleus. B, gland-cell: *m*, cell membrane; *p*, protoplasm; *n*, nucleus with convoluted filament. C, part of the filament greatly magnified.

are modified into the special *tissues*, with resulting unlikeness in parts or *organs*, of which all higher plants and animals are composed. Every variation in structure is therefore due to cellular changes, and every living thing is propagated in one way or another by cells: by their

[1] Huxley, in *Brit. and For. Medico-Chirurgical Rev.*, 1853, xii. p. 14.

self-division or fission; or by gemmation, *i.e.* throwing off buds; or by the union of like cells; or in more complex mode, by the spontaneous or aided union of unlike cells, as the sperm-cell of the male with the germ-cell of the female, giving rise to a seed or egg from which grows offspring more or less like its parents.

In both plant and animal the cell contents, although here again exceptions occur in some of the lowest

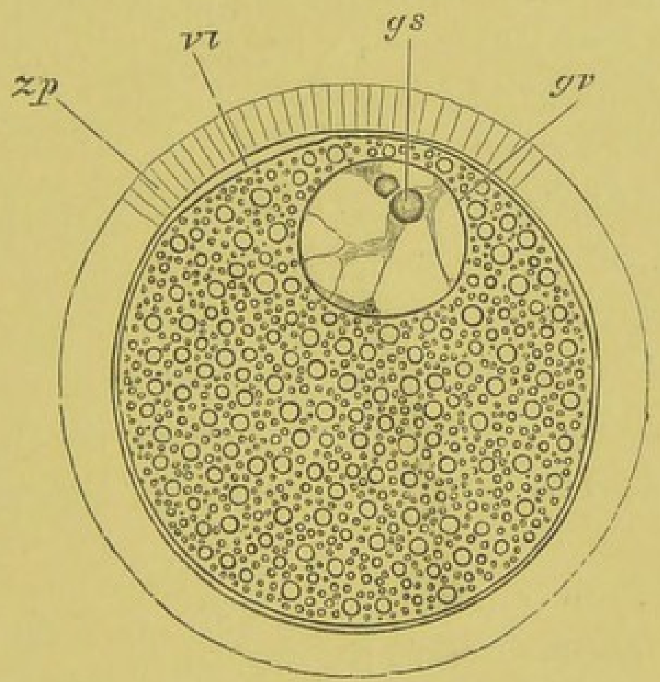


FIG. 29.—Semi-Diagram of Ovum of Mammal.

zp, membrane; *vi*, protoplasm filled with fatty granules; *gv*, nucleus or germinal vesicle; *gs*, nucleolus or germinal spot.

organisms, exhibit a rounded body called the *nucleus*,[1] which itself often encloses another body called the *nucleolus*, but the functions performed by both in cell development are obscure. That even this much is known of cell structure may awaken wonder when it is remembered that we are dealing with bodies for the most part beyond the range of our unaided vision. Bacon

[1] When the cells are very large or long, nuclei are present in large numbers. (Sachs, p. 86.)

truly says that 'the complexity of nature exceeds the subtilty of man;' the infinite divisibility of matter is apparent in the organic as in the inorganic. And size counts for little: the oak and pine, the acacia and the rose, are lower in the scale of life than the thistle and the daisy;[1] the elephant is one hundred and fifty thousand times heavier than the mouse, but the egg of the one is nearly as large as that of the other; and it has been calculated that if one molecule in the *nucleus* of the ovum of a mammal were to be lost in every second of time, the whole would not be exhausted in seventeen years.

These molecules are the sufficing material media of transmission of resemblances, both striking and subtile, between parent and offspring; and of the vast sum-total of inherited tendencies, good or bad, which are the product of no one generation, but which reach us charged with the gathered force of countless ancestral experiences.

Born into life, man grows
Forth from his parents' stem,
And blends their bloods, as those
Of theirs are blent in them;
So each new man strikes root into a far foretime.[2]

A. *Plants.*

Plants are divided into two main groups or sub-kingdoms: I. Cryptogams (Gr. *kruptos*, hidden; *gamos*, marriage), or flowerless. II. Phanerogams (Gr. *phaneros*, open; *gamos*, marriage), or flowering.

[1] See Grant Allen's *Flowers and their Pedigrees*, p. 42.
[2] Matthew Arnold, *Empedocles on Etna.*

I. The *Cryptogams* are subdivided into—

1. Thallophytes (Gr. *thallos*, a shoot; *phyton*, a plant), comprising algæ, fungi, and lichens. These have no leaves, stems, or roots; many of them are one-celled.

2. Bryophytes (Gr. *bryon*, moss), comprising mosses and liverworts. These have leaves and stems, but no true roots.

3. Pteridophytes (Gr. *pteris*, a fern), comprising ferns, horsetails, and club-mosses. These have stems, leaves, and roots.

The feature common to the cryptogams is the absence of any conspicuous organs, *i e.* true flowers, with stamens and pistils for the production of seeds or fruits. The simplest or single-celled plants increase by subdivision, each cell carrying on an independent life and repeating the process of division. But sexuality is manifest in plants very low down in the scale, the mode of reproduction varying a good deal in different species. In some cryptogams it is almost as complex as in the flowering plants; but notwithstanding the different kinds of sexual organs, there is this fundamental resemblance between them, that the union of the contents of two cells, a male or sperm cell, and a female or germ cell, each of which is by itself incapable of further development, is essential to the production of the embryo or seed.

The lowest cryptogams are congregations of simple fibreless cells united in rows, or gathered round one another, and spreading on all sides. At the bottom of the scale are the *Algæ*, comprising some ten thousand species, from the microscopic fresh-water desmids, one-millionth of an inch in length, with their whip-like cilia the two hundred millionth of an inch long, to the giant sea-weeds or tangles, hundreds of feet in length, that cover thousands of square miles of ocean. The green scum of stagnant ponds, the waving filaments in streams, the shell-coated microscopic diatoms that people the ocean, tingeing its depths with olive-green, and whose skeletons form deposits hundreds of miles in length ; the rose and purple weeds that flourish in shallow seas, and are cast upon their shores, are all members of a group which is perhaps the most venerable of living things. For although their generally fragile forms have been fatal to their preservation as fossils, there is little doubt that the algæ flourished in dense masses in primeval oceans, and were the chief, if not the sole, representatives of plant life on the earth during millions of years. Like the foraminifera and other low animal organisms, they illustrate the persistency of the earlier forms, in virtue of their simplicity of structure, despite changing conditions ; whereas the more complex structures, by reason of the greater delicacy of their parts, can less readily adapt themselves to altered surroundings, and therefore have a much narrower distribution both in time and space.

Next to the algæ in ascending order are those fantastic products of decay, the quick-growing, short-lived *Fungi*, animal-like in their mode of nutrition, plant-like in their fixity, and through untold epochs the agents by which dead plants and animals are resolved into the inorganic, and made available to enter into new combinations. Next in order are the *Lichens*, which, it is now generally agreed, are composite plants, being a special kind of parasitic fungi growing on algæ. These are widely spread, living, after the adaptive manner of simple forms, where nothing else can live ; unwithered by the heat, unsmitten by the frost ; redeeming the earth's desolate places, from treeless desert flats far as the lines of enduring snow, where, like the mosses, they shine in hues of gold and purple ; spreading their flowerless patches of richest colours in metallic-like stains over rock and ruin; incrusting the trees with tint of freshness or touch of age, with hoary fringe or mock hieroglyph; and in their decay yielding rich soil wherein fern and flowering tree may strike root.

In *Mosses*, whose glossy, many-coloured masses weave softest carpet over the earth, sharing in the service rendered by the humble lichens, the cells have become developed into rudimentary root, stem, and leaf, manifesting still further transition towards unlikeness in parts which is due to division of function. But the structure is still cellular, *i.e.* there are no tissues and fibres. The mosses represent the intermediate forms between the lowest and the highest cryptogams, between the green algæ, out of which liverworts were probably developed, and ferns, which arose out of liverworts.

In *Ferns* the larger number of cells have joined together to form fibrous vessels, lengthening or thickening in varying shape and texture according to the functions to be discharged by them, resulting in the woody tissue which enters into the structure of all the higher plants. The cells, thus converted into tissue, cease to grow; the formative protoplasm is always becoming the formed; 'tis 'an infinite dying, and in that dying is life,' since there is locked up in the compacted material a store of energy on which the higher organisms depend.

The ferns and club-mosses and horsetails of the present day are the puny representatives of the stately and luxuriant, although sombre, flowerless trees that composed the dense jungles of green vegetation in the Devonian and succeeding Primary periods, during which our fossil fuel was chiefly formed. The existing palm-like vegetation of the tropics more nearly approaches its Devonian prototype, but it falls far behind it in abundance as well as in size.

II. The *Phanerogams* have their flowers with stamens and pistils conspicuous, and are divided, according to the formation of their seeds, into—

1. Gymnosperms, or naked-seeded, the ovum not being enclosed within a seed-vessel or ovary, but carried

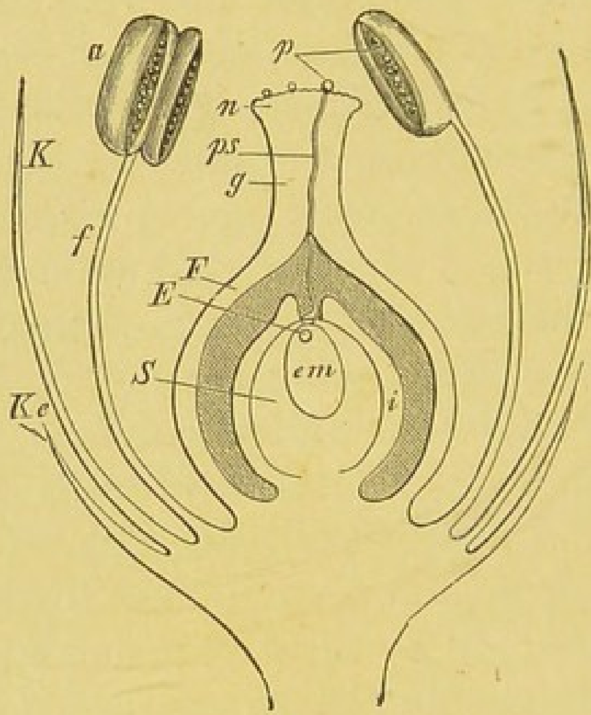


FIG. 30.—Diagram of a Flower.

Ke, calyx; *K*, corolla; *f*, filament of stamen; *a*, anther, showing pollen sacs open and pollen grains escaping; *F*, ovary; *g*, style; *n*, stigma, on which are pollen grains, one of which, *p*, is sending down its spermatozoid, *ps*, to the micropyle of the ovum, the central structure in *F*; *i* is the integument of the ovum; *S*, the nucleus; *em*, the embryo sac; *E*, the germinal vesicle, close to the pollen tube near the micropyle.

upon a cone, as in pines and allied species. The gymnosperms are the connecting link between the flowerless and the flowering plants.

2. Angiosperms, or cover-seeded, the ovum being enclosed within an ovary.

This group is subdivided into (*a*) plants having one cotyledon or seed-leaf, from which they are developed, as palms, lilies, orchids, and grasses; and (*b*) plants having two seed-leaves, as oaks, beeches, and all trees and shrubs not included in the foregoing.

In naked-seeded plants the pollen or male element falls on the exposed ova; in cover-seeded plants it falls on the stigma, passes down the pistil into the seed-vessel, and enters the ovum through an opening in it called the micropyle, or 'little gate.' It has been recently ascertained that malic acid is the agent by which the spermatozoids are guided to the ovaries.

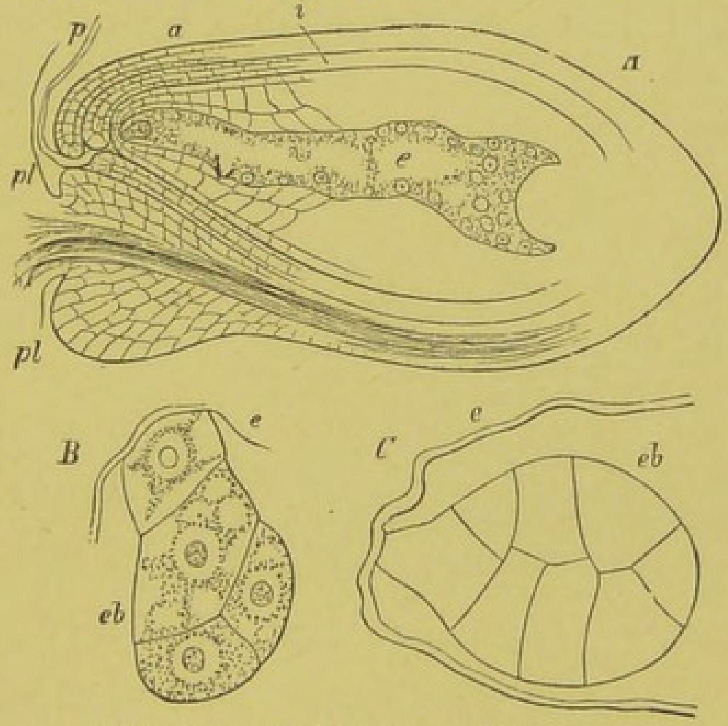


FIG. 31.—Fertilisation of Ovum.

A, section of ovum after fertilisation; *pl*, placenta; *a*, outer, and *i*, inner, integument; *p*, spermatozoid entering micropyle; *e*, embryo sac. *B*, apex of embryo sac, with *eb*, young embryo of three cells. *C*, same further developed.

Whilst the gymnosperms are, on the one hand, most nearly allied in the order of descent to ferns, the sombre flowers which they bear giving them only by strict botanical classification a place among phanerogams, they are, on the other hand, more complex in structure than the single seed-leaf plants, because their bark, wood, and pith are clearly defined, as in the double seed-leaf plants. Their lowest representatives comprise the cycads or palm-ferns, so called from their resemblance to palms, for which, with their crown of feathery leaves, they are often mistaken. Next in order is the much more varied and widely distributed conifer family, notably pines, firs, and larches, and, lesser in importance, cedars and cypresses. A still higher class, various in its modes of growth, marks the transition to angiosperms, the flowers of both having many features in common.

The single seed-leaf angiosperms have no visible separation of their woody stuff into bark, stem, and pith,

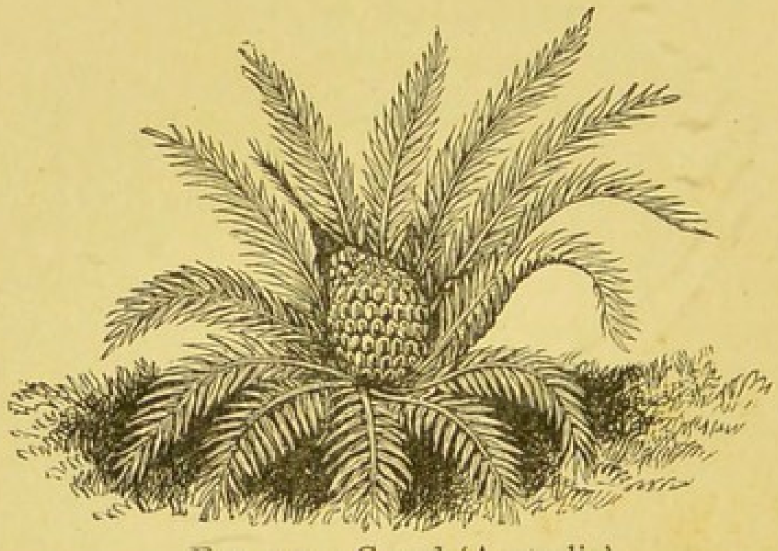


FIG. 32.—Cycad (Australia).

and have no rings of growth, the wood exhibiting an even surface, dotted over with small dark points. Their leaves have parallel veins or 'nerves,' as in the onion and tulip ; and the blossom-leaves, or petals, are most usually grouped in threes or multiples of three. Among their several representatives we may single out the lilies for their beauty and fragrance, and the cereals for their value and importance, both classes being in near connection, since the grasses from which man has developed wheat, barley, oats, rice, and maize are, in a botanical sense, degenerate descendants of the lily family.

The double seed-leaf plants include all the highest and most specialised varieties. Bark, stem, pith, and concentric rings of growth, by which the age of the plants may frequently be reckoned, are clearly defined; the leaves are netted-veined, and the petals are most usually grouped in fours or fives or multiples of those numbers. The lowest class, represented by the catkin-bearers, as the birch and alder, the poplar and the oak, and by plants allied to the nettle and to the laurel, are nearly related to the highest gymnosperms. Next in order are the crown-bearers, or flowers with corollas, as the rose family, which includes most of our fruit-yielders, from strawberries to apples; while the highest and most perfect of all are plants in which the petals are united together in bell shape or funnel fashion. Such are the convolvulus and honeysuckle, the olive and ash, and, at the top of the plant-scale, the family of which the daisy is the most familiar representative. Its position among plants corresponds to man's position among animals. As he, in virtue of being the most complex and highly specialised, is at their head, albeit many exceed him in bulk and strength, so is the daisy with its allies, for like reasons, above the giants of the forest.

The primary function for which the organs of plants known as flowers exist is not that which man has long assumed. He once thought that the earth was the centre of the universe, until astronomy dispelled the illusion; and there yet lingers in him an old Adam of conceit that everything on the earth has for its sole end and aim his advantage and service. Evolution will dispel that illusion. But our delight in the colours and perfumes of flowers will not be lessened, while wonder will have larger field for play, in learning that the coloured leaves known as flowers, together with their scent and honey, have been developed in furtherance of nature's supreme aim—the perpetuation of the species. For that alone the flowers blossom and the fruits ripen. And truly the contrivances to secure this which are manifest in plant-life are astounding, even to those who perceive most clearly the unity of function which connects the highest and lowest life-forms together. It is difficult to deny the existence of a rudimentary consciousness in the efforts of certain plants to secure fertilisation. For example, in a well-known aquatic plant, *Vallisneria spiralis*, the male flower with its matured pollen is detached from the stem and rises to the surface, where, as it floats, it comes into contact with and fertilises the ovary of the female flower, whose stalks then contract and carry the ovary to the bottom, where the seeds can ripen in safety. Most flowers are hermaphrodite, *i.e.* have their male and female organs within the same petals, and in some cases fertilise themselves by scattering the pollen from the bursting stamens on the stigma or head of the pistil. But nature is opposed to this; 'tells us in the most emphatic manner that she abhors perpetual self-fertilisation,'[1] with its resultant puny and feeble offspring; and we find a number of contrivances to prevent this, and to secure fertilisation by the pollen of another plant, to the abiding gain all round of the plant, whose blood, as we may say, is thus mixed with that of a stranger. Consequently, the most effective mode of reproduction is that in which two individuals are concerned. All organisms in which the sexes are separate have descended through many gradations from hermaphrodite ancestors, and it is to this division of function between male and female that not only a more vigorous offspring, but also progress among the higher animals, is, in the first instance, due. Were there no sex,

[1] Darwin's *Fertilisation of Orchids*, p. 359.

there would be no social instincts, no love, no dependence, no unity. This, however, by the way.

Two agencies are unwittingly concerned in the fertilisation of plants—insects, and the wind 'that kisses all it meets'; while in the dispersion of the matured seed, birds and other animals, and again the wind, play an important part.

Plants which are wind-fertilised have no gaily coloured petals or sepals, and do not secrete nectar. Such are the naked-seeded groups whose sombre flowers are borne on dull brown cones; and, among cover-seeded groups, grasses and rushes with their feathery flowers, and willows and birches with their long waving clusters of catkins. All of these provide against the fitfulness of the wind, which is as likely to blow pollen one way as another, by producing it in large quantities, so that it sometimes falls in thick showers, covering wide areas.

Plants which are insect-fertilised attract their visitors by secreting honey and developing coloured floral organs. The way in which this came about is probably as follows.

The common idea about flowers is that they are made up of petals and sepals, whereas the *essential* parts are the stamens and pistils, *i.e.* the male or pollen-producing organs, and the female or seed-containing organs. The earliest flowers consisted of these alone, having no coloured whorl of petals within another coloured whorl of sepals, and were only scantily protected by leaves, as are many extant species. These the food-seeking insects then, as now, visited for the sake of the pollen, to the detriment of the plant, which lost the fertilising stuff and gained nothing in return. Besides the pollen, most plants secreted the sweet juice called honey, especially when in the act of flowering, for the nourishment of the blossom. This juice was often stored in nectaries near the seed-vessels, where the insects could not get at it without covering their bodies with some of the pollen, which they unknowingly rubbed on the pistils of the plant next visited, and thus fertilised the ovum, provided that the plants were nearly related. Honey being

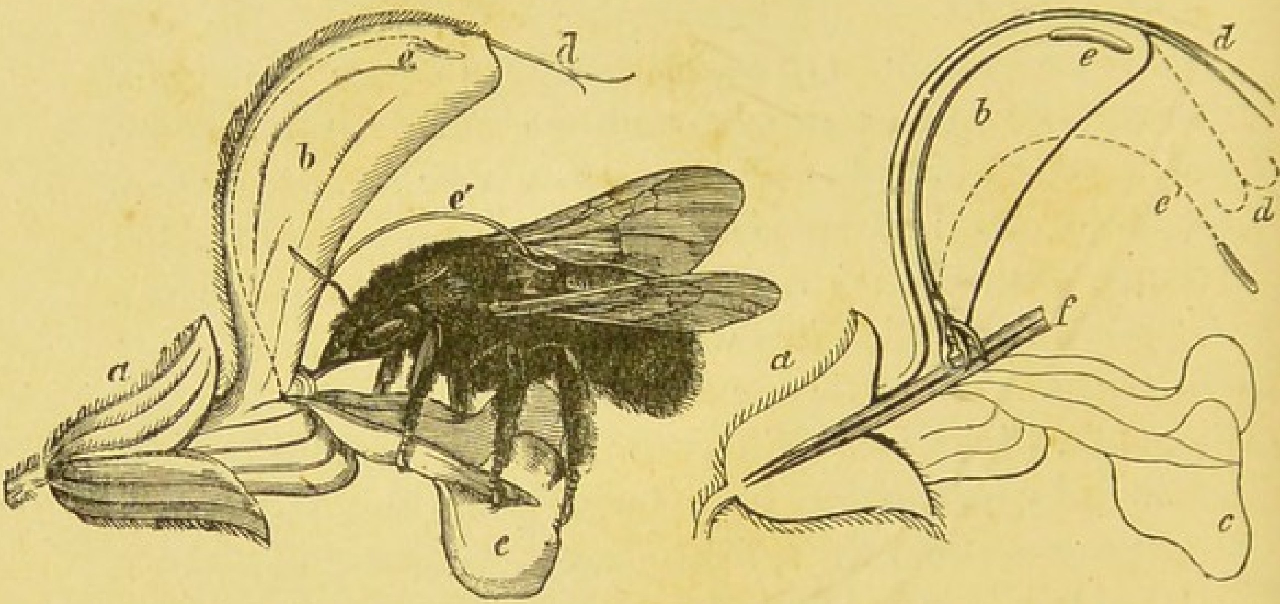


FIG. 33.—Fertilisation of Flower (Meadow Sage) by Insect.

a, calyx ; *b*, curved upper lip ; *c*, under lip, on which the bee stands while sucking the honey ; *d*, pistil ; *d'*, pistil at a later stage ; *e*, stamen ; *e'*, stamen shedding the pollen from its anther on the back of the bee ; *f*, bee's proboscis wherewith it reaches the honey.

sweeter to the taste than pollen, the plants that produced most honey stood the better chance of repeated visits from insects, and therefore of fertilisation, to the manifest advantage of their species over others. Thus, as first shown by Conrad Sprengel in 1794, there were developed in the course of long ages intimate relations between the two, and also marvellous contrivances to secure the visits of welcome insects of a certain form and size, and to prevent the intrusion of unwelcome insects, as well as to arrest the washing out of pollen by rain or dew. For as plants are rooted to one spot, they cannot act on the aggressive. They have to develop defensive structures to resist attacks of devouring enemies: hence their thorns, prickles, spikes, hairs, nauseous taste, and the like. Some plants have an eel-trap sort of arrangement of the hairs at the base of their petals to retain the desired honey-seeker till the pollen is rubbed on it, when the hairs relax and release it. Others have become specially adapted to certain insects by secreting the honey at the bottom of a tube (nearly a foot long in some rare orchids), and the insect has developed a correspondingly long proboscis to reach it. The one aim of all these modifications of structure is to economise the pollen and ensure its use for fertilisation, to the advantage of the plant in the struggle for life.

Still more were any plants favoured on which spots or patches of colour appeared, attracting the eye of the insect, and developing through its agency into tinted petals and sepals, which have changed the earth's once flowerless meadows into fields of cloth of gold. Both petals and sepals are modified or transformed stamens, which have exchanged their function of pollen-producers for that of insect-allurers; and as both stamens and pistils are leaves aborted or modified for the special function of reproduction, Wolff's generalisation that the leaf is the type or fundamental organ of the plant has a large measure of truth in it. But before speaking further about colour-development in plants it may be useful to say a little about colour itself.

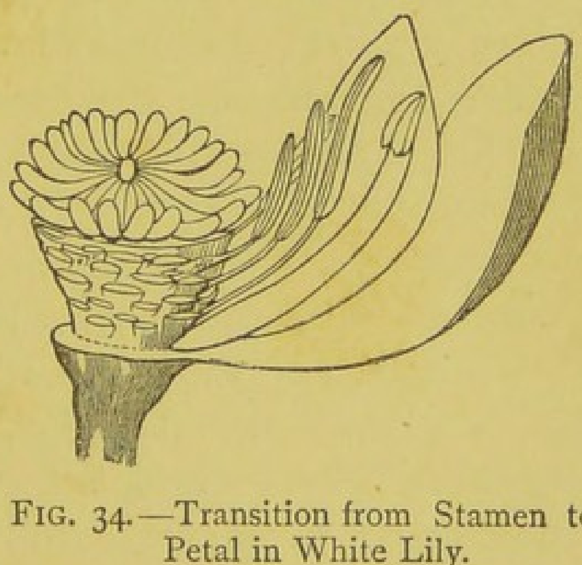


FIG. 34.—Transition from Stamen to Petal in White Lily.

Since everything is black in the dark, and moreover has no colour in itself, it follows that colour is in some way a property of light. Now light, which is itself invisible, is due to vibrations or oscillations set up in all directions by any luminous body—whether the sun or a rushlight—in the ethereal medium which pervades all space, and is composed of rays of different refrangibility, *i.e.* change of direction in passing from one medium into another, say from the ethereal medium to the denser atmosphere. White light is due to the combination of all these rays, which range through innumerable gradations of colour from red to violet, and it is to the absence of one or more of them that the infinite variety of colours is due. If a body is quite opaque, or otherwise so constituted as to absorb none of the rays, it appears white; if it absorbs them all it appears black; if it absorbs green, blue, and violet, and not red, it appears red; if it absorbs red, orange, and violet, and returns or reflects green, it appears green. The colours which bodies reflect are therefore regulated by their structure; the way in which their molecules are arranged determines the number and character of the light vibrations or ether waves which are returned to the eye, and which rule the colour we see. For example, charcoal and the diamond are both pure carbon; the dull opacity of the one and the trembling splendour of the other are solely due to the arrangement of the several molecules of each.

It is thus obvious that any change in the nature or structure of a thing is accompanied by change in its colour, and to this cause the various pigments in plants are to be referred.

All growth involves expenditure of the energy which the plant has stored within itself, and which becomes active when the hydrocarbons combine with oxygen, resulting in cellular change, and appearance of other colours than the green of the chlorophyll. Thus may be explained the colour of sprouting buds and young shoots, the more or less intensified colours of leaves and flowers, and the lovely tints of autumn ; one and all being due to oxidation, the minutest changes inducing subtile variations in colour. As the stamens of most flowers are yellow, the earliest flowers, being derived from stamens, were probably yellow also ; and all subsequent changes in colour take place in a regular order, yellow passing into white or pink, and then through red and purple into blue, but never in a reverse direction nor in any other order.[1]

Whichever plants made most show of colour would the sooner catch the eye of insects, however dim their perception of the difference in colours might be, and would thus get fertilised before plants which made less display. Thus have insects been the main cause in the propagation of flowering plants, the plants in return developing the colour sense in insects. The flower nourishes the insect ; the insect propagates the flower. Other contrivances to meet the need for fertilisation might be cited, as the markings upon the petals to guide the insect to the nectary ; the exhalation of scent by inconspicuous flowers, as mignonette, or by such as would attract visitors at night, as the night-smelling stock ; but enough has been adduced to show that the chief, if not the sole, function of flowers is to attract insects, and thus secure cross-fertilisation. Nor does the provision stop here. The fertilised seed is not left to chance, but, like the fertilising pollen, is entrusted to secondary agents, to the care of the birds and the breezes.

[1] *Colour of Flowers as illustrated by the British Flora*, pp. 17-60, by Grant Allen. (Macmillan.)

Where not scattered by the bursting of the ovary it is winged with gossamer shafts, as in the thistle and the dandelion, and floated on gentlest zephyr or rushing storm to a genial soil. Such wind-wafted seeds, like wind-fertilised flowers, are rarely coloured ; neither are the seeds of the larger trees, since their abundance ensures notice by food-seeking animals; nor the nuts which are protected by shelly coats. But other seeds enwrap themselves in sweet pulpy masses, called fruits, whose skins brighten as they ripen, and attract the eye of fruit-loving birds and beasts.[1] The seeds pass through their stomachs undigested, and are scattered by them in their flight over wide areas. As with the brightest hued and sweetest scented flowers, so it is with the brightest and juiciest fruits ; they sooner attract the visitors whose services they need, and thus gain advantage over less favoured members of their species, developing by the selective action of their devourers into the finest and pulpiest kinds. And, as Grant Allen shows in his delightful and exhaustive book on the colour sense, the origin and development of this sense in the sub-kingdom which includes man is due to the same cause, man being descended from a fruit-eating animal 'who shared the common vertebrate faculty of colour perception and the common frugivorous taste for bright hues.'[2] The subject is of course closely connected with the evolution of the sense of beauty, which, at first evoked by things connected with physical needs, was developed by leisurely contemplation of natural forms, colours, and groupings.

[1] Birds are much influenced in their choice of food by colour, for though white currants are much sweeter fruit than red, yet they seldom touch the former till they have devoured every bunch of the latter.—*White's Selborne*, '*Observations on Birds*.'

[2] *The Colour Sense* (Trübner & Co.), p. 221.

B. *Animals.*

All animals fall into two main groups: the structureless, or one-celled, called Protozoa; and the many-celled, called Metozoa.

The several types upon which they are constructed are usually classed under the following primary divisions, called sub-kingdoms:—

Invertebrata	Protozoa (Gr. *protos*, first; *zoon*, animal)	Simplest forms	*Ex.* Moneron, amœba
Invertebrata	Cœlenterata (Gr. *koilos*, hollow; *enteron*, bowel)	Hollow-bodied	*Ex.* Sponge, polyp, anemone, coral-builder
Invertebrata	Echinodermata (Gr. *echinos*, a hedgehog; *derma*, skin)	Spiny-bodied	*Ex.* Sea-urchin, star-fish
Invertebrata	Annulosa (Lat. *annulus*, a ring)	Joint-bodied	*Ex.* Worm, crab, spider, ant
Invertebrata	Mollusca (Lat. *mollis*, soft)	Soft-bodied (but usually protected by a shell)	*Ex.* Sea-squirt, oyster, snail, cuttle-fish
	Vertebrata (Lat. *vertebra*, joint)	Back-boned	*Ex.* Fish, and all other higher life-forms to man

Tabular forms are convenient for clear presentment, but their hard and fast divisions are apt to be mistaken for real lines of separation, whereas the several sub-kingdoms merge one into the other, like the colours of the rainbow. As further reducing the number of types, animals may be divided into three grades: the Protozoa, which have no body cavity; the Cœlenterata, which have a body cavity; and the Cœlomata, including all animals, from echinoderms to man, which have a digestive cavity separate from the body cavity. Any consecutive arrangement can only broadly indicate the relative order of the several life-forms, because development has not proceeded in direct line—*e.g.* the ant, which belongs to the Annulosa, is the highest of all invertebrates; but it is not therefore most nearly allied to the lowest vertebrate. The connecting link, as will be shown presently, is found in the double-necked, bottle-shaped sea-squirt, or ascidian (Gr. *askidion*, a little bottle), which is classed under the Mollusca, and for this reason that sub-kingdom is placed last but one in the ascending scale. If we go back far enough we find the common starting-point of all, whence they travelled for a while along the same road, and then diverged wider and wider apart, until it now seems difficult to believe that the lowest and highest, both of plant and animal, are one in community of origin.

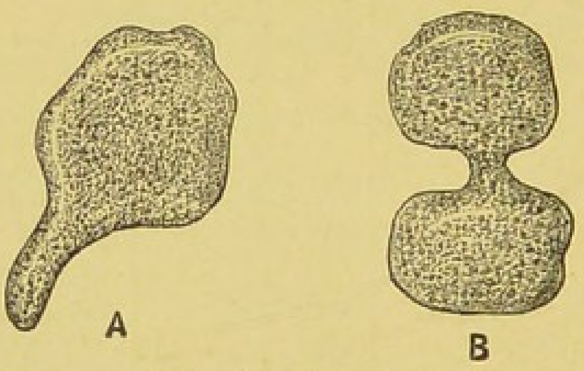


FIG. 35.—Monera, without nucleus. A, showing pseudopod. B, process of fission.

1. *Protozoa.*

The lowest member of this group—in other words, the lowest known animal, if we except certain parasites—is the *moneron* (Gr. *monos*, single). Like the lowest plants, it lives in water, the element in which life had beginning. It is an extremely minute, shapeless, colourless, slimy mass, alike all over, and therefore without any organs. When we say that it is alike all over we mean that our range of vision does not enable us to report otherwise, for doubtless the simplest and smallest living thing is very complex in structure. And we mean, further, that there is no differentiation, as it is called, *i.e.* no formation of specific organs for the performance of specific functions. The functions of living things are threefold—nutrition, reproduction, and relation; in other words, to feed, to multiply, to respond to the outer world; and all these the organless moneron discharges. Every part of it does everything; it takes in food and oxygen anywhere, and digests and breathes all over its body. Like the happy peptician of whom Carlyle tells, it 'has no system.' It literally 'gets outside' its food, having the power of throwing out blunt finger-like prolongations, called pseudopods or false feet, with which it propels itself and spreads over its prey, sucking the soft body even from shelly creatures, and casting away the refuse. So far as the function of nutrition, which includes digestion, circulation, and rejection of waste, and the function of reproduction are concerned, the moneron performs these as completely as the highest animals. For these, with their complex sets of organs—lungs, heart, stomach, &c.—cannot do more than nourish themselves and keep the body in health; very often they cannot, through folly or misfortune, do that. And in reproduction, which the moneron effects by dividing itself into two, as do the lowest plants, wherein, as in it, there is neither male nor female, it accomplishes in simple fashion what the higher life-forms can do only in a more complex way. So that the difference—and this only in degree, not in kind—between a slime-speck of protoplasm and the higher organisms is in the discharge of the function of relation.

Reference has been made to the response to stimulus from external things manifested by the lowest life-forms, although there is no trace of a nervous system in them; and now that we are treating of a living mass that not only feeds and digests and breathes all over, but likewise feels all over, a few remarks upon the function and origin of nerves may supersede the need for any detailed account of the several nervous systems in the representative animal types.

The function of the nerves is to bring the organism into relation with its surroundings; they are the special media of communication between the body and the external world, and between the brain and every movement of the parts of the body. Starting in the higher animals from the encased brain and ensheathed spinal cord, and diffused in the lower animals in less complex arrangement, they report from without to within. The vibrations of the ethereal medium that affect us as light enter the eye and pass along the optic nerve, which conveys the impulse to the brain, and it is the brain, not the eye, that sees. So with the air-vibrations that travel along the aural nerves, the sensation of sound resides in the brain, not in the ear; so with all the manifold sensations that we feel. The unity of the sensations is fundamental; the differences lie in the vibrations. The correlation of the senses, as we may term it, is shown in the familiar trick of getting a blindfolded person to tell whether he is drinking port or sherry, or whether the pipe he is smoking is alight or not.

Wherever there is sensitiveness to impressions, however dim and feeble this may be, there the function of relation is being exercised. This sensitiveness is exhibited by the moneron in its shrinking when touched, and in its grip of food; but the sensitiveness is diffused, and not located in any organs. In members of the same sub-kingdom there are faint traces of approach to nerve-structure, and the development of this is manifest in ascending scale, till in the highest life-forms among certain invertebrates, as ants, and vertebrates, as man, it reaches subtlest complexity.

Now, as every part of an organism is made up of cells, and as the functions govern the form of the cells, the origin of nerves must be due to a modification in cell shape and arrangement, whereby certain tracts or fibres of communication between the body and its surroundings are originated.

But what excited this modification? The all-surrounding medium, without which no life had been, which determined its forms and limits, and *touches* it at every point with its throbs and vibrations. In the beginnings of a primitive layer or skin exhibited by creatures a stage above the moneron, unlikenesses would arise, and certain parts would by reason of their finer structure be the more readily stimulated by, and the more quickly responsive to, the ceaseless action of the surroundings, the result being that an extra sensitiveness along the lines of least resistance would be set up in those more delicate parts. These, developing, like all things else, by use, would become more and more the selected paths of the impulses, leading, as the molecular waves thrilled them, to structural changes or modification into nerve-cells and nerve-fibres of ever-increasing complexity as we ascend the scale of life. The entire nervous system with its connections; the brain and all the subtile mechanism with which it controls the body; the organs of sense, with their mysterious selective power—the olfactory organs, probably the earliest developed, so acute in man as to detect the presence of the one-three-billionth of a grain of mercaptan (sulphuretted alcohol), and yet coarse by comparison with the antennæ of insects; the eye, to receive and sift vibrations travelling twelve million miles in a minute; the ear, with its three thousand strings of Corti, each vibrating in response to a particular sound-wave; the organs of taste, guarding the entrance to the digestive canal and refusing admittance to contraband food—alike begin as sacs formed by infoldings of the primitive outer skin. In contrast to the eyes of invertebrates, the sensitive elements of the eyes of vertebrates are formed from a paired outgrowth of the fore brain. The brain, trillion-celled seat of sensation, arose from the infoldings sinking down beneath the surface and finally becoming imbedded in other tissues; the eye and the ear, as their parts developed, were joined from within by outgrowths from the brain. Such, in fewest words, is that theory of the origin of nerves which, formulated by Herbert Spencer, has been confirmed by all recent biological research.[1]

Development by cell-modification applies to the body throughout—to bone, to cartilage, and sinew, as well as to the myriads of nerve-tissues, varying between the fifteen-hundredth and the twelve-thousandth of an inch in breadth, that keep us in touch with the universe. But, easy as it is to dissect and describe the nervous mechanism, the nature of the connection alike between nervous impulse and consciousness in a man, and between sensation and contractile action in a moneron, remains an insoluble mystery.

What has been said concerning the diffused sensitiveness of the lower animals adds force and suggestiveness to the fact that the plant limited the action of the outer world upon it when the protoplasm enclosed itself within a wall of cellulose. This isolation, or lessened susceptibility to the vibrations of air and ether, to changes of temperature, and a thousandfold subtile influences, the animal escaped by remaining mobile, and setting up no barriers between itself and its environment.

A short step upward from the moneron brings us to

[1] Cf. Balfour's *Comp. Embryology*, ii. pp. 400–4.

the *Amœba*, so called from its constant change of shape as it protrudes and withdraws the pseudopods. It shows approach towards unlikeness in parts in the modification of the protoplasm into a membranous skin at the surface, and in a nucleus near the centre, with an expanding and contracting cavity for distributing food and oxygen in the body—a primitive apparatus for digestion and circulation. Therein the beginning of a distribution of labour, leading to cell-modification into organs, is illustrated. The white corpuscles in the red blood of man and other animals are called 'amœboids' because they are like the

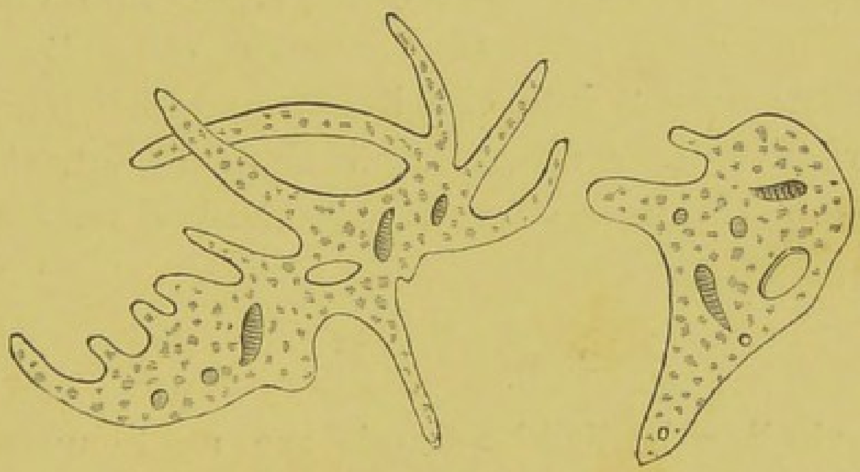


FIG. 36.—Amœbæ (highly magnified).

amœba in structure, size, and movements, changing their shape, living an independent life, and even taking-in food.

Some of the lowest amœbæ secrete, like the diatoms among plants, solid matter from the sea, building for themselves primitive organs of shelter and defence in the shape of exquisitely formed chambered shells pierced with holes, through which the soft body flows and the pseudopods are pushed for capture of food. Some form their skeletons of lime, others of flint, evidencing to the possession of a selective power or dim sentience by even the minutest creatures; and, as shown already, it is of these skeletons that vast deposits are composed.

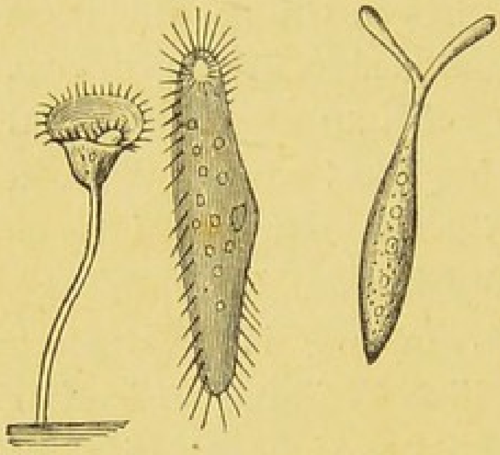


FIG. 37.—Three Ciliated Infusoria.

Still more marked advance towards unlikeness in parts is manifest in the *Infusoria*, so called because readily developed in infusions of exposed vegetable matter, where they crowd by myriads in the space of a water-drop. Instead of the pseudopods of the moneron and the amœba, we find vibrating filaments or cilia, by which supplies are swept into the body, which is furnished with a rudimentary mouth and short gullet, through which the food and oxygen pass to the body-cavity.

2. *Cœlenterata.*

The 'hollow-bodied' animals are made up of two layers of cells more or less modified. But they are still of low organisation, one evidence of which is that, like the Protozoa, they have no vital parts, and that there is no separate canal for absorbing food and carrying away refuse, the mouth still opening direct into the body-cavity.

The lowest members of this sub-kingdom are the *Sponges*. They were long regarded as colonies of amœbæ, and therefore classed among Protozoa, but fuller knowledge of their structure as many-celled organisms, some of the highest among which show slight traces of nerves and sense-organs, has caused them to be ranked in a division called Porifera (Lat. *porus*, a pore; and *fero*, to bear). Very lovely are the skeletons which some of them secrete, such as Venus's flower-basket, with its graceful fretted spirals; but more familiar to us are the useful fibrous and porous domestic sponges, woven of material said to be chemically allied to that spun by silkworms. Being rooted to one spot, the sponge-cells

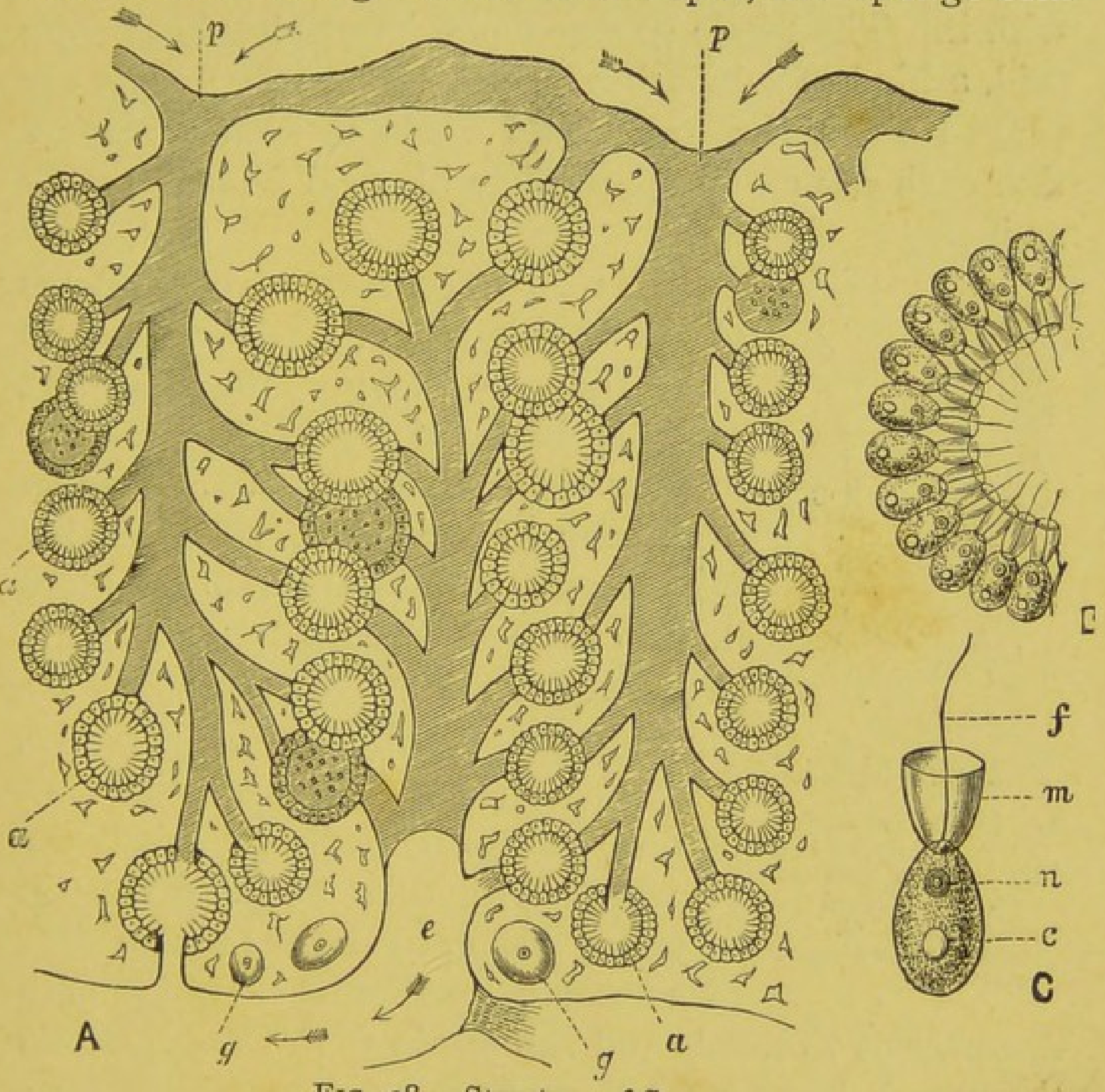


FIG. 38.—Structure of Sponge.

A. Vertical section of outer layer magnified 75 times. *p*, pores or openings of canals for conducting water, which flows to *a*, sacs; *e*, canal for expulsion of water; *g*, early stages of spores.
B. Sac transversely divided (800 diameters), showing sponge-particles with cilia.
C. Sponge-particle highly magnified. *f*, cilium; *m*, collar; *n*, nucleus; *c*, contractile vesicle.

have become specially modified for ingathering food and oxygen. Only the cells on the outside of the horny or flinty skeleton can procure food and oxygen easily; those living in the inside effect this by means of cilia, the whip-like action of which drives the water, charged with food and oxygen, through the innumerable canals, whence, having served its purpose, it is driven out through other canals, carrying the refuse of the colony with it. The whole sponge represents, as has been aptly said, a kind of submarine Venice, 'where the people are ranged about the streets and roads in such a manner that each can easily appropriate his food from the water as it passes along.'

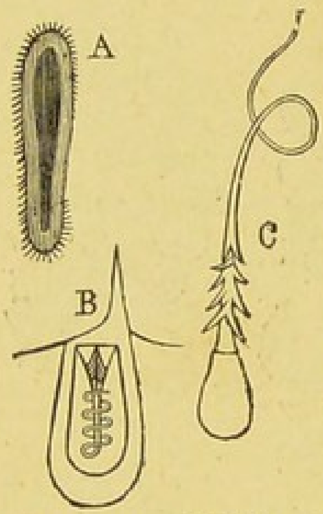


FIG. 39.—Hydra.

A. Planula or earliest stage of a hydroid on its emission from the egg. B. Thread-cell undisturbed. C. The same with the filament protruded.

Cilia also cover extensive surfaces of the higher animals. They abound about the eyes, the ears, the windpipe, and the brain of man; mysteriously moving independently of any other part, even of the nervous system, but fulfilling much less important functions than in the bodies of the lower animals.

Next in rank above the sponges are the tiny cup or tube-shaped, jelly-like, green-hued (because chlorophyll-containing) polyps named *Hydra*, colonies of which, with their bud-like clusters of young—soon to start in life on their own account—are found clinging mouth downwards to weeds and rubbish in fresh water. From the mouth hang a number of tentacles containing cells, in which lie barbed threads coiled up in a poison-fluid. When anything touches these tentacles they contract, the cells burst and fling the thread, lasso-like, around the prey, poisoning it with the fluid. From some of the marine species which secrete tubes of flint, and project themselves therefrom like flowers, so that the sea depths are covered with their waving, plant-like forms, the buds detach themselves and become the beautifully tinted

Medusæ or *jelly-fish*. These produce eggs which become rooted polyps, so that the offspring never resembles its parents, but always its grandparents. All living matter is largely made up of water, the average proportion ranging from seventy to ninety per cent., but in the jelly-fish it is about four hundred to one. Yet, fragile as is the creature, its structure is complex. Canals traverse

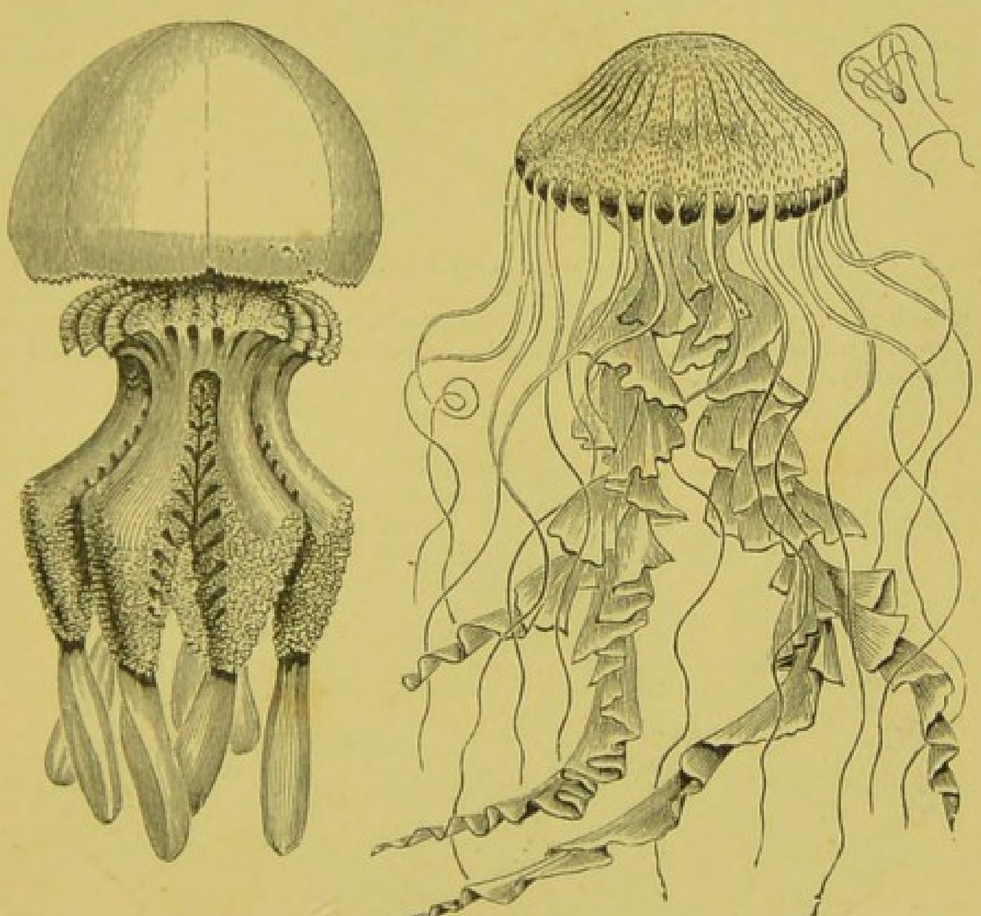


FIG. 40.—Jelly-fish.

the swimming-bell, and carry food and oxygen to every part; rudimentary muscles in the shape of contractile tissues propel the animal along in rhythmic grace of motion; a nervous system runs round the margin of the bell; there are rudimentary eyes in bead-like pigment-spots, and rudimentary ears in small sacs along the margin; and the hanging tentacles are charged, as in its fresh-water ally, with deadly fluid.

Lovelier still, and of slightly more complex structure, are the variously coloured *Sea-anemones*, with their petal-like tentacles; while nearly allied to these are the

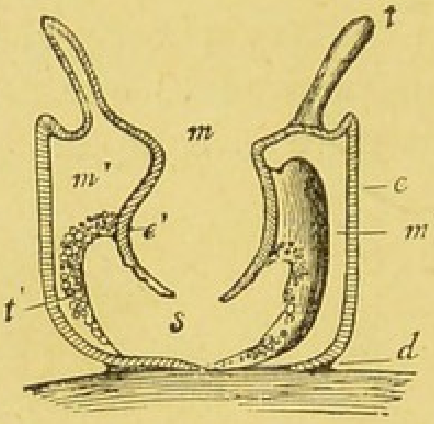


FIG. 41.—Vertical Section of Common Sea-anemone.

m, mouth; *m'*, primary cavity; *m''*, secondary cavity; *e*, ectoderm or outer skin: *e'*, endoderm or inner skin; *t*, tentacle; *t'*, ovary; *d*, disc of attachment; *s*, body-cavity.

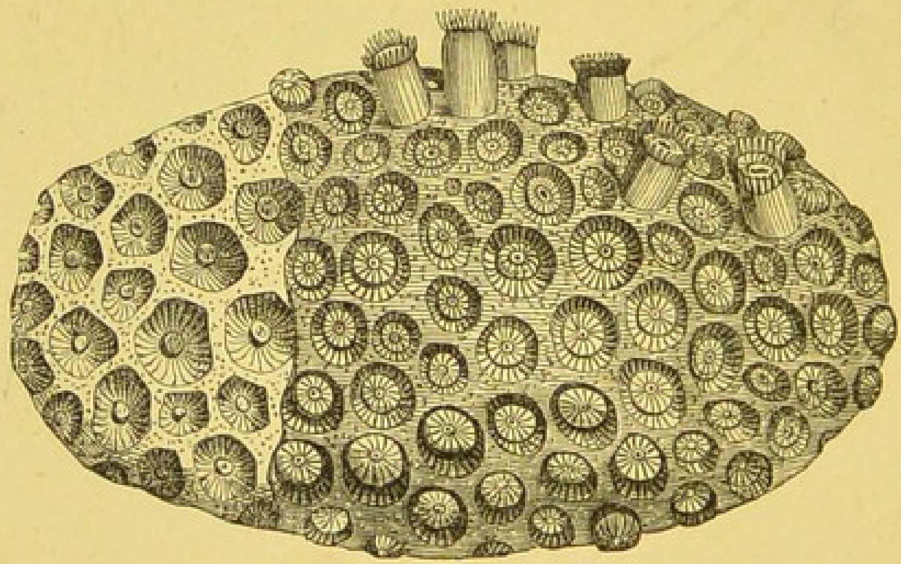


FIG. 42.—Coral.

The left side of the figure shows the coral denuded of soft parts; on the right the animal matter is shown, while at the upper part several of the polyps are seen projecting.

colonies of *Coral-builders*, which, despite the surging wave and drifting current, raise their tree-like structures, foundations of solid land on which the bird builds her nest and man sets his dwelling.

3. *Echinodermata.*

This division includes all rayed animals, the skin being hardened by the secretion of jointed or leathery plates, or of spines or hedgehog-like prickles. In some, as the *star-fish*, the rays spring from a common centre; in others, as the *Sea-urchin*, they are coiled to form a globular body; in the *Sea-lilies*, which abounded as

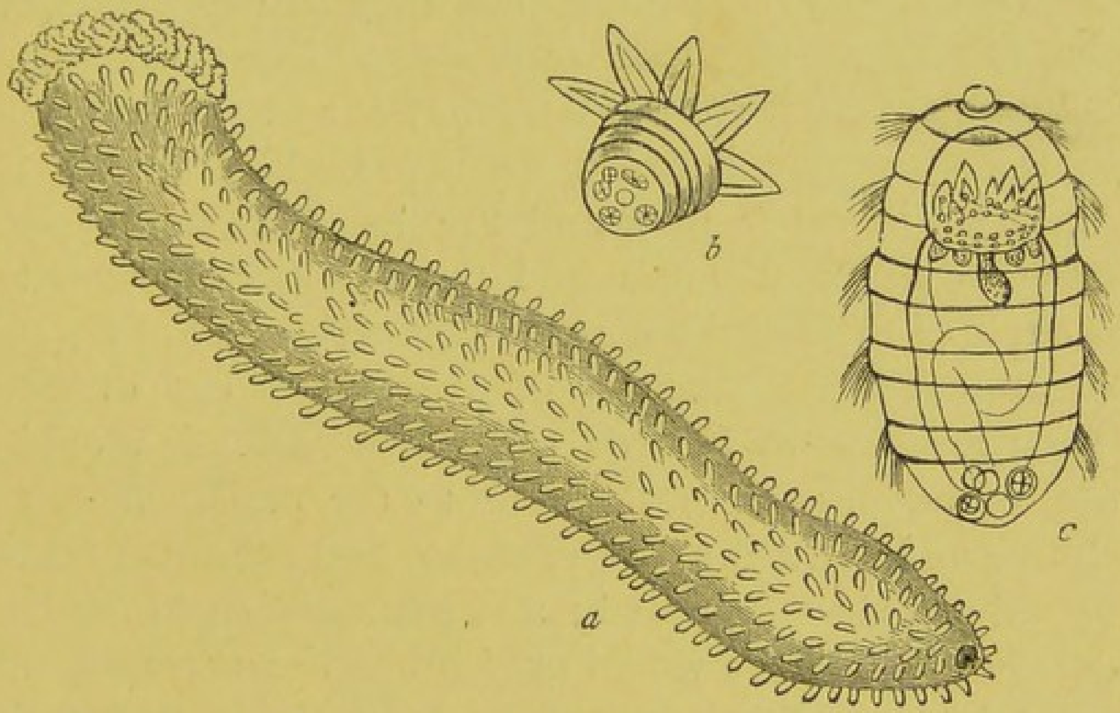


FIG. 43.—*a*, Sea-cucumber; *b* and *c*, young stages of the same.

far back as Silurian times, but which are now limited in range, they spring, flower-like, from the end of a fixed stalk; in the slug-like *Sea-cucumbers*, which possess the power dyspeptics may envy of throwing away the inside of the body and growing it anew, the skin is tough, the limy matter being secreted in scattered spicules.

The echinoderms show marked advance towards unlikeness of parts in having a digestive canal shut off from the body-cavity, affording special provision for nutrition. This is effected by a number of canals which communicate with the outside of the body, and through which the sea water is driven by cilia, as in the sponges. The water is also pressed from the canals into numerous little suckers, by which the animal crawls along—nature's first essay in locomotion on solid ground. There is a distinct nervous system, the fibres of which in the star-fish run along each ray, at the tip of which is an eye having about two hundred crystal lenses, and a primitive eyelid in the form of a filmy covering.

Thus far an intimate relation may be noted between the life-forms of the invertebrates. The differences between the secretions of limy matter by the amœba and by the sea-urchin, between the contractile action of the moneron in every part and the localisation of nerve-function in the medusa and the star-fish, between the vacuole of the amœba and the digestive canal of the sea-cucumber, are differences of degree and not of kind. They are one and all due to cell-modification arising out of advance from the like to the unlike, from the simple and general to the complex and special, from the organless to the organised ; and any addition to the bare details given above would only bring the more prominently into relief the fact of an indissoluble, underlying unity.

4. *Annulosa.*

The common structural feature which gives its name to the numerous classes of animals, comprising four-fifths of existing species, grouped in this sub-kingdom, is the division of the body (which is developed from three layers of cells) into more or less well-defined rings or segments. It is also, like the body of vertebrates, bi-laterally symmetrical, *i.e.* double and correspondent, so that if it were split lengthways the two halves would be seen to be almost exactly alike. The nervous system, which runs along the belly, consists of two fine cords, knotted at different points into ganglia or masses of nerve-cells, the first pair of ganglia being above the gullet, so that the cords which join the second pair form a collar round it. The important part which the mouth plays as the immediate channel between the animal and its surroundings accounts for the development of the higher organs of communication near it; the anterior or front segments most completely undergo concretion, and in this way the portion that carries the mouth, the chief nervous

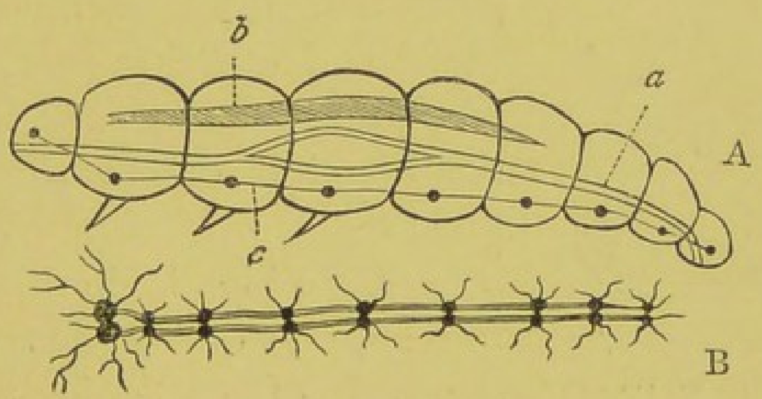


FIG. 44.—Diagram of Annulose Animal.

A. *a*, digestive canal; *b*, heart; *c*, nervous system.
B. Nervous system enlarged, showing double cord and ganglia.

centre or brain, and the sensory organs, as eyes, ears, antennæ, is formed. Hence the position of the head or skull, as the protecting structure round the more specialised parts, is ruled by the position of the mouth. The heart, which is tube-shaped, lies along the back, and the digestive canal lies between the heart and the nervous system. This arrangement distinguishes both earthworms and wasps, leeches and crabs, centipedes and beetles, lobsters and ants—in fine, all but the very lowest classes. But the advance in complexity of structure—in other words, in division of labour—is especially shown in the more elaborate arrangements for the conveyance of nutrition throughout the body as compared with that exhibited in the lower sub-kingdoms: *e.g.*, in the moneron food and oxygen enter at any and every part; in the amœba they are driven throughout the body by means of a pulsating vacuole; in the polyp they are brought by the water which flushes it within and bathes it without; in the sea-urchin and the star-fish the nutriment is carried by canals in their bodies which communicate direct with the water. In the higher Annulosa the oxygen and food are circulated by a more highly organised fluid called blood, which carries them to every part, and likewise removes the waste and effete matter, the immediate motor power by which the blood is driven through the body being the heart. The aëration of the blood—in other words, the supply of oxygen and the removal of carbonic acid — is effected by its passage through the respiratory organs. Only the back-boned animals breathe through the nostrils, the lower animals breathing through pores or sacs in their sides, which subdivide into countless tubes.

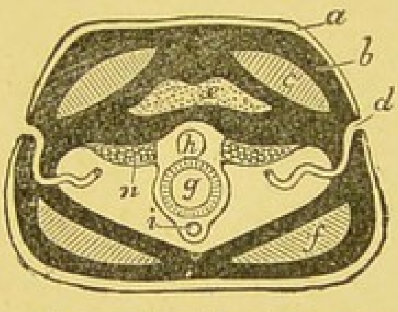


FIG. 45.—Section of Second Segment of Worm.

a, outer or skin layer; *b*, dermal connective layer; *c*, muscle plates; *d*, segmental organ; *h*, arterial blood; *i*, venous blood; *g*, intestine; *n*, ovary.

The Annulosa may be divided into the footless, comprising worms and leeches; and the footed, comprising crabs and other crustacea, spiders, scorpions, centipedes, and all insects. The jointed organs of locomotion known as limbs, and which have been developed from muscle-fibres, are arranged in pairs.

Among the lowest members of the Annulosa, with which the higher animals are more or less connected in descent, are *Vermes*, or worms; these including a number of degraded forms which live as parasites inside the bodies of nearly all animals, man having his full share of them.

Midway between worms and crustaceans may be placed the minute *Rotifers*, so called because of the ceaseless wheel-like movements of the cilia round the mouth. These degenerate specks, many of which are visible to the naked eye, are highly organised. They have a nerve ganglion which sends out threads to the ruby eye or eyes and antennæ; they have jaws and teeth, often a hard skeleton; the females have one and sometimes two stomachs, but the poor male has none. They can remain for years in a state of suspended animation.[1]

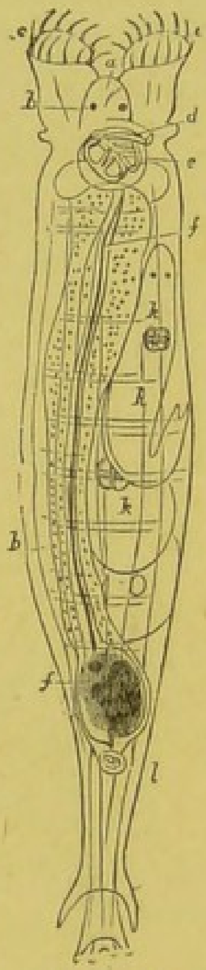


FIG. 46. Common Rotifer.

a, mouth; *b*, eye-spots; *d*, chewing organ; *f*, alimentary canal; *k*, developing embryos; *l*, anus.

The typical form—head, thorax or chest, and abdomen or belly—of the numerous varieties of the widely diffused *Crustacea*, or hard-shelled class, whose three-lobed ancestors, the trilobites, flourished in the seas of the Cambrian and later periods, is the same, with infinite modifications in detail, as that of the remaining classes, from spiders to beetles and ants. But in *Insects* these three divisions are sharply marked, the chest to which the legs and wings are attached, and the belly, being sometimes joined by a mere thread, whence the name given to that class, *Insecta*, 'cut into.'

Some authorities regard insects and crustacea as derived from a remote common ancestor. Whether this

[1] Cf. Hudson and Gosse's magnificent monograph, *The Rotifera*, pp. 9, 139 (Longmans).

be so or not, the aquatic origin of insects is certain. Their wings have been developed from organs which were adapted for breathing in the air as the necessity arose, and they ultimately became organs of flight when the creature left the water for the land. Here, as in aught else, the process was gradual, only such as were

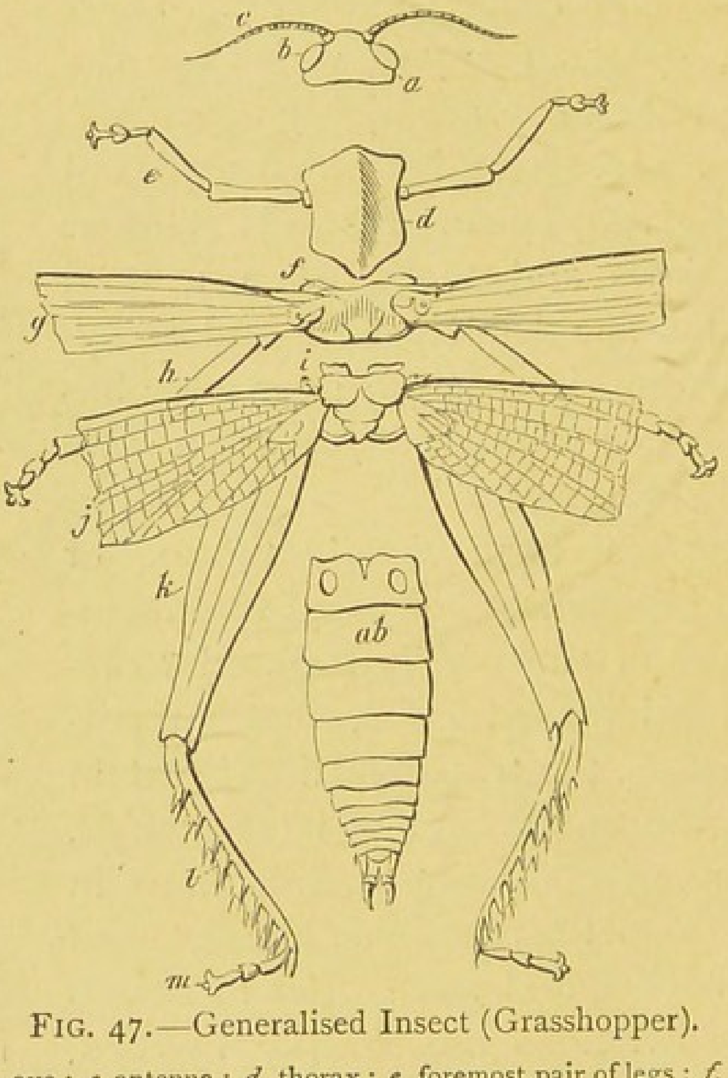


FIG. 47.—Generalised Insect (Grasshopper).

a, head ; *b*, eye : *c*, antenna ; *d*, thorax ; *e*, foremost pair of legs ; *f*, middle segment of thorax ; *g*, foremost pair of wings ; *h*, second pair of legs ; *i*, hindmost segment of thorax ; *j*, second pair of wings ; *k*, femur of third pair ot legs ; *l*, tibia (corresponding to shin-bone) ; *m*, tarsus (flat part of foot) ; *ab*, abdomen.

able to exist for a time out of the water winning in the struggle for life.

The larger number of animals pass through well-marked series of changes, but these take place within the egg, the food-store of which suffices for their development. Through lack of this supply most insects quit the egg in an immature condition, passing through the metamorphoses of grub, chrysalis, and imago. Like the rotifers, they rebuke the vulgar notion that bigness is greatness, and that wonder is to be proportioned by the size of the thing which arouses it. For the infinitely small is as fully charged with mystery as the infinitely great; the movements of forces and energies in both cell and crystal are more complex than the motions of the giant bodies of the heavens; the ultimate analysis of the atom is more elusive than that of the mass which it makes up.

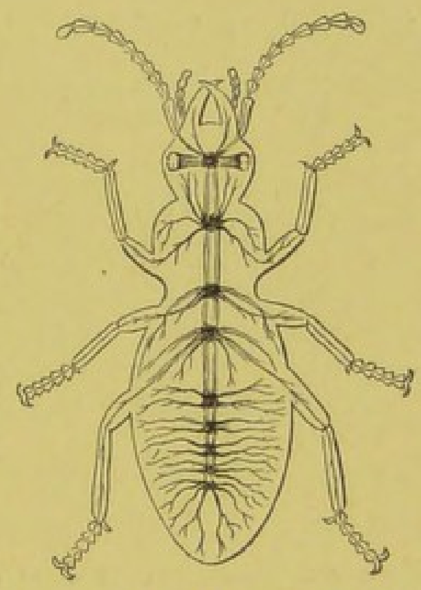


FIG. 48.—Nervous System of Beetle, showing double nerve-cord and chain of ganglia.

In the beauty and delicacy of insect structure—notably in the wings, more perfect for flight than those of birds; in the infinite division of organs; the spider, with its six hundred teats, spinning its web of as many strands;[1] the dragon-fly, with its twelve thousand eyes, each with its own lens, cone, and rod; the caterpillar, with its fifteen hundred air-tubes—we learn that magnitude is not necessary to complexity. In the high nervous organisation of insects, and the variety of functions, many of these quasi-human, which they discharge; in the dexterity of their actions, and the manifest adaptation of means to ends; in the social order of certain species, notably the ant commonwealth, with its division of labour, its slave and fighting population, its farmers and

[1] At the Melbourne Observatory a breed of spiders is kept the strands of whose web are used for micrometers.

miners,[1] its nurseries for pets and weaklings, its burial customs, its political and industrial order, which has not, like ours, to readjust itself by peaceful or bloody revolutions to changing conditions—we have striking evidence of the interrelation of all living things and of the unreality of the distinctions which man has set up between instinct and reason : in fine, evidence of fundamental correspondence between the nervous systems of the lowest and the highest. Complexity, not size; mental, not physical power, mark advance in the organism ; and it is in the specialisation of the nervous system, and in the proportion of its controlling centre, the brain, to the rest of the structure, that the mechanical explanation of intelligence lies.[2] Darwin remarks that the brain of an ant, which is proportionally larger than that of any other insect, although itself not so large as the quarter of a small pin's head, 'is one of the most marvellous atoms of matter in the world, perhaps more so than the brain of a man.'[3]

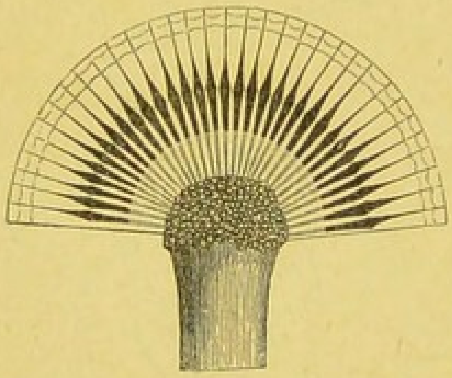


FIG. 49.—Section of Eye of Insect.

There is much force in the argument that the long period of infancy, with its consequent dependence on parental love and care, through which man, and in lesser degree the highest apes and other animals, pass, has tended to develop the feeling of sympathy and of its

[1] Cf. Bates's *Amazons*, pp. 350-360, and Belt's *Naturalist in Nicaragua*, pp. 17-27, on foraging ants.

[2] In the cockchafer the proportion of brain to body is 1 to 3,500 ; in the worker bee, 1 to 174 ; in the whale, 1 to 3,000 ; in the chimpanzee, 1 to 50. But, as evidenced by the large brain of the porpoise and the dolphin, the convolutions, more than the volume of brain, are the measure of capacity.

[3] *Descent of Man*, p. 54, 2nd ed.

expression in service of the helpless by which the family is knit together, and out of which has grown the social instinct which forms tribes and nations. Nor does the argument stop here. The longer the baby stage, the more intelligent is the animal; for where there is a complex nervous system its specialisation goes on after birth; whereas in the case of an animal with low capacities all the nervous connections are formed before birth, so that it begins life in lusty independence, fully equipped for work, and therefore with no tie to bind it to its parents, while its isolated life is fatal to mental development.

Now the ant, with other communal insects, as bees and wasps, has to pass through a relatively long grub-hood, and in this we may have the explanation of its high social organisation, which has had measureless time for its development, since the remains of Hymenoptera are found as far back as the Jurassic age. And if the argument has any force in the case of man, the evolutionist is bound to apply it to the ant, with the important difference that the limits of the ant's development were reached long ago, the capacity to change varying inversely with the persistence of inherited qualities.

But in the highest members of the Annulosa we arrive at the extremity of one branch of the life-tree, and we must descend to reach the starting-point which leads us to the loftier branch whose topmost twig is man.

5. *Mollusca.*

This sub-kingdom, the importance of whose fossil remains has been indicated, includes a wide range of organisms, any common definition of which is difficult. Many of them appear, like the fallen angels, not to have 'kept their first estate'—as, *e.g.*, the lowest class, which resembles polyps, and was formerly erroneously grouped with them. In the larger number of molluscs symmetry of form is more the exception than the rule, and in one class we have the nearest known ally of the vertebrates.

Some Mollusca have neither heads nor hearts, or at least quite imperfect ones; others have heads and chambered hearts; some grow together in colonies, others live an independent life; but all are alike soft-bodied, lacking the segmented or jointed structure which distinguishes the Annulosa. Some, as the sea and land

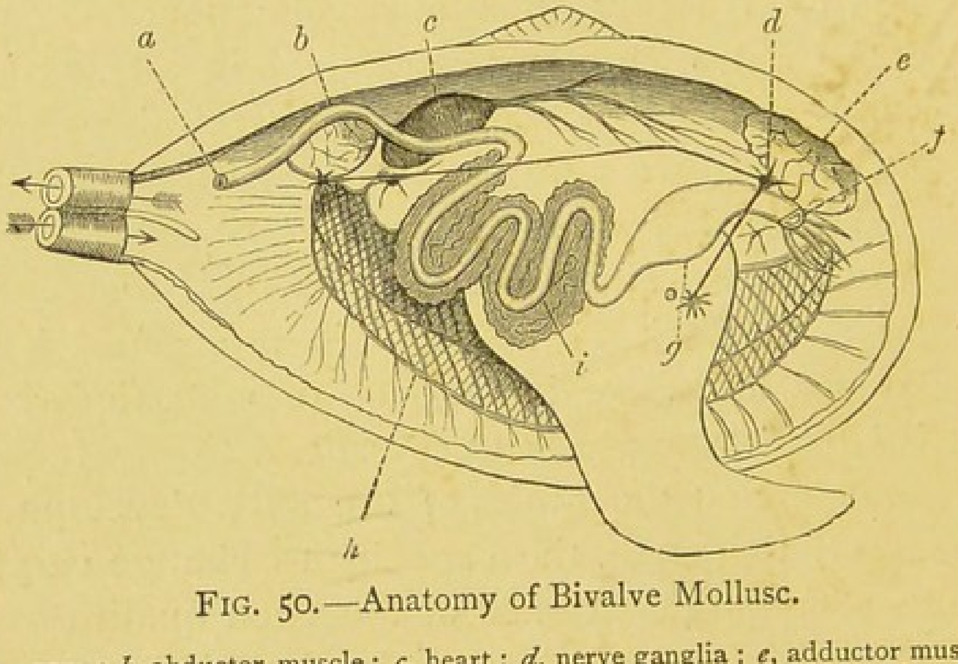


FIG. 50.—Anatomy of Bivalve Mollusc.

a, anus; *b*, abductor muscle; *c*, heart; *d*, nerve ganglia; *e*, adductor muscle; *f*, mouth; *g*, stomach; *h*, gills; *i*, intestine surrounded by liver. The tubes marked by arrows are the canals of the siphon. The water enters by the lower and leaves by the upper tube.

slugs, are naked, although furnished with a delicate shell when young; others have a leathery or gristly covering; the rest, the shell-fish proper, are protected by single or double valves, which in their spiral forms and fadeless colouring sometimes surpass the loveliest flowers, or which, as in the pearl oyster, yield the lustrous substance which, according to ancient fable, is formed of rain-drops falling into the open valve, where some mysterious agency transmuted them. The power of secreting matter from the surrounding water for the construction of their shells is one of the most persistent characteristics

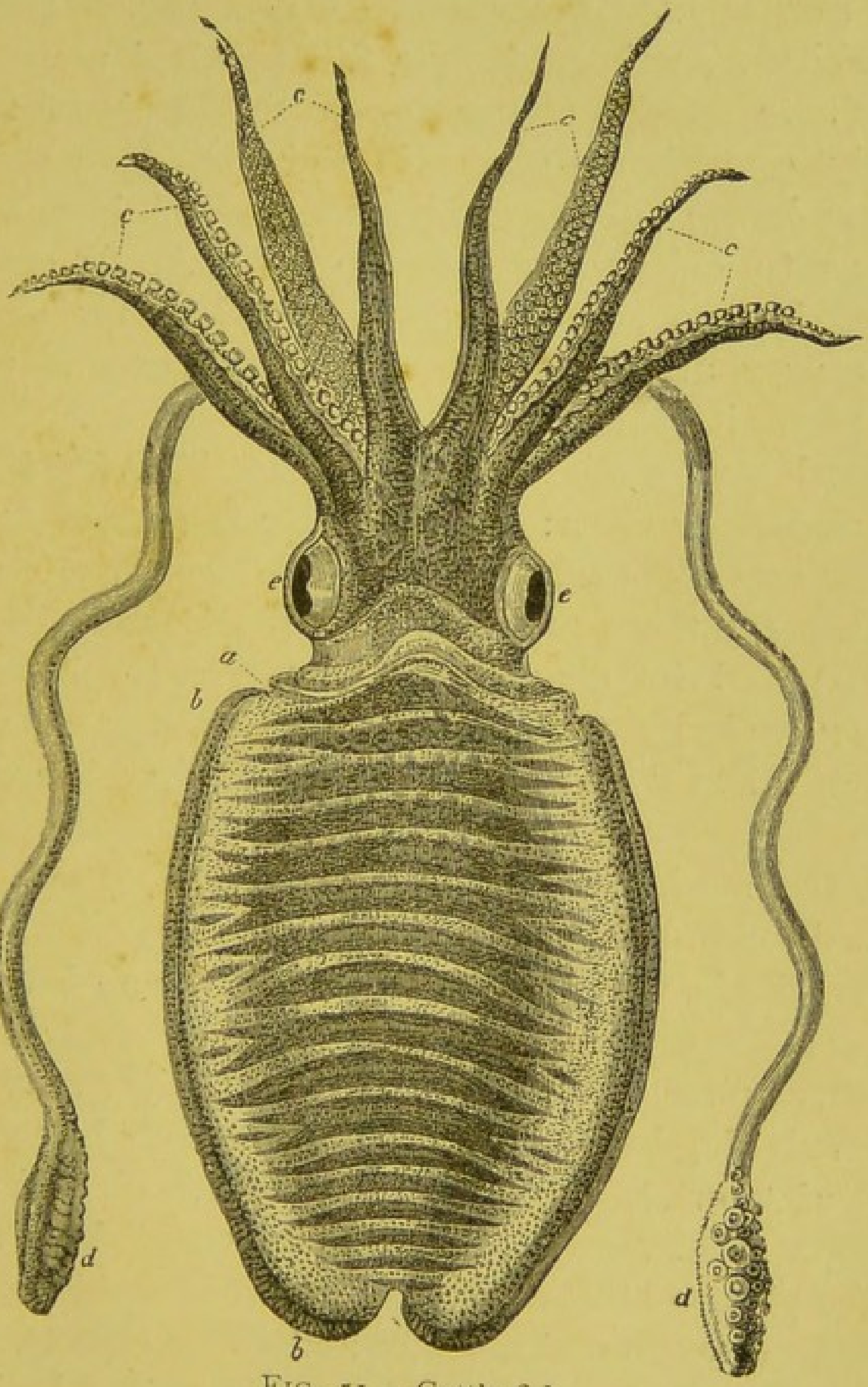


FIG. 51.—Cuttle-fish.

c, arms bearing the suckers; *d*, tentacle-like arms; *a*, mantle; *b*, lateral fins; *e*, eyes.

of the Mollusca, the shells (which are not cast periodically, as with the crustacea) being formed along the surface of the thick flexible skin called the 'mantle,' the crumpled line of which determines their shape. They range in size from the enormous Tridacna of tropical seas, which sometimes weighs five hundred pounds, to the minute species of our coasts, thousands of which scarcely exceed an ounce in weight. One species, the *Clio borealis*, about an inch long, which is so abundant as to colour the surface of the Arctic seas for leagues, has no less that 360,000 suckers for capture of its prey attached to the wing-like organs which spring from its head.

The lowest molluscs are the plant-like, fixed *Sea-mats* and *Sea-mosses*; the highest are represented by the Briareus-like *Cuttle-fish*, from the common species of our seas to the octopus, with its rudimentary internal skeleton and its chameleon-like power to change its colour; and by the pearly *Nautilus*, the sole survivor of an ancient family that swarmed in the waters of the Jurassic and Cretaceous periods. Between these range the more familiar shell-fish, notably the oyster, which, in common with all bivalves, is headless; and the periwinkle, whose land congener is the air-breathing snail.

But, as already hinted, the interest of the evolutionist in this sub-kingdom centres in the transparent bag-shaped *Sea-squirts*, or *Ascidians*, which, although classed under Tunicata (Lat. *tunica*, a cloak), are entitled to a distinctive place. Most of the species are immobile, attaching themselves to rocks, shells, and other objects, sometimes growing separately, and sometimes in colonies on a common stem.[1] Of the two openings in their gristly covering, which is largely made up of cellulose, a charac-

[1] There is a very fine collection of ascidians in the Aquarium at Naples, which no traveller to that city should omit to see.

teristic element in plants, one is the mouth and the other the vent. The mouth opens into a breathing sac, furnished with numerous gill-slits and cilia, and leading through the gullet to the digestive organs—stomach and intestine—which are connected by a sharp bend

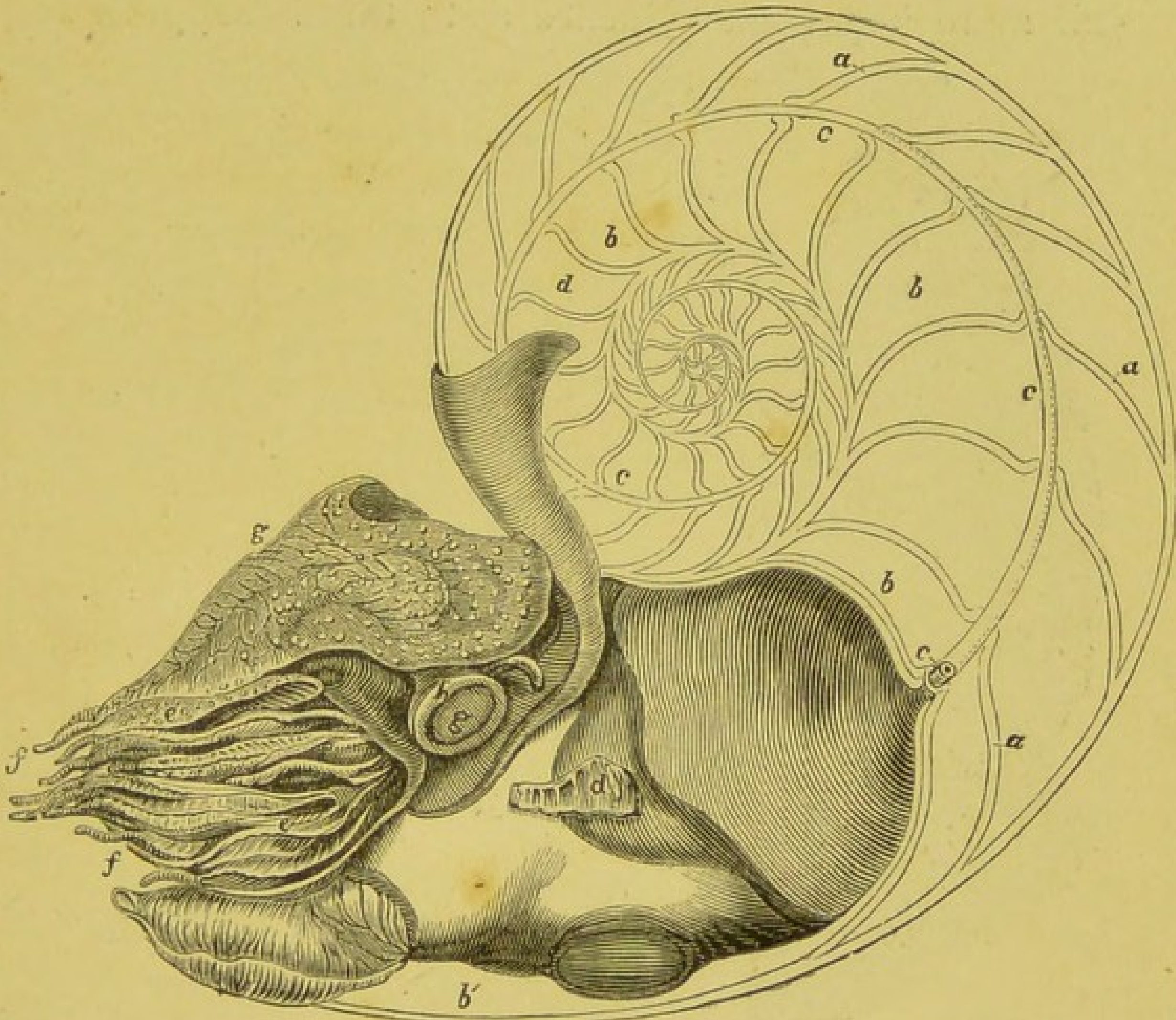


FIG. 52.—Pearly Nautilus, cut open.

a, shell partitions ; *b*, air-chambers ; *c*, tube between them ; *d*, muscles attached to shell ; *e*, hollow arms ; *f*, tentacles ; *g*, membranous disk at head ; *h*, eyes.

with the vent, whence the inhaled water, after giving up its oxygen to the blood, is expelled. The heart, a tube-shaped organ, is placed at the lower end of the body-cavity, which fills the space around the intestine. The circulation forms a remarkable exception to that of every other known animal, the current being reversed after the heart has beat a certain number of times. The nervous system, consisting of a single ganglion, lies between the mouth and vent. The position of this ganglion gives a valuable clue to the connection between the ascidians and the vertebrates, but still more important evidence as to this is supplied in

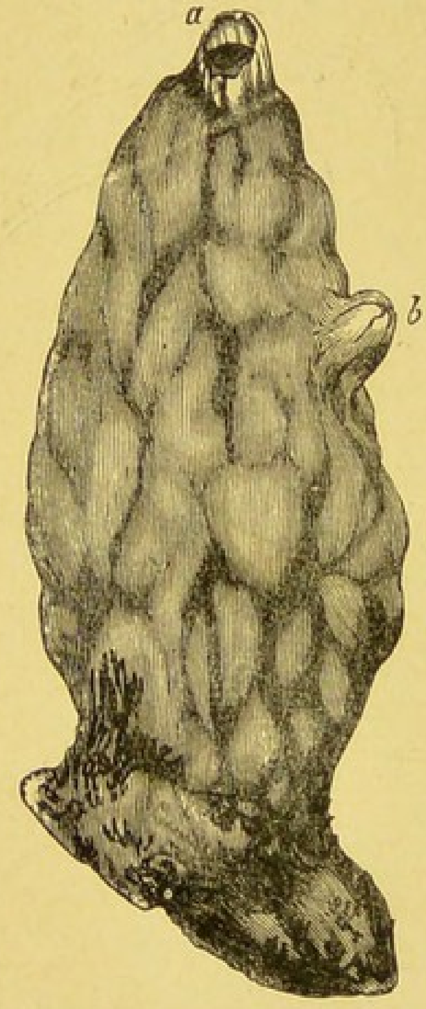


FIG. 53.—Sea-squirt.

a, mouth; *b*, vent.

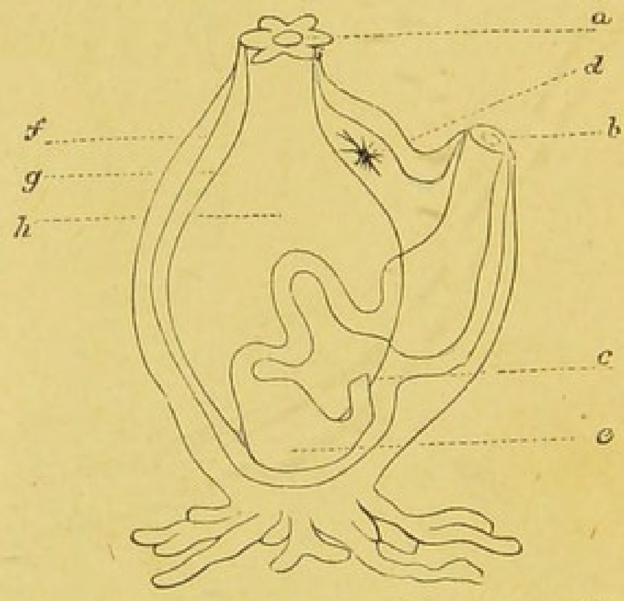


FIG. 54.—Diagram of Structure of Sea-squirt.

a, mouth; *b*, vent; *c*, gullet-opening; *d*, nerve-ganglion; *e*, stomach; *f*, test or outer layer; *g*, tunic or inner layer; *h*, branchial sac.

the early stages of the ascidian's development. In certain species the egg gives rise to a larva resembling the tadpole of a frog, both outwardly and inwardly —a resemblance 'reaching absolute identity when we examine the way in which the various organs arise from the primitive egg-cell,' the only important difference being that the ascidian has but one eye. In connection with this Mr. W. B. Spencer's important discovery of a small eye beneath the skin on the top of the head of the Hatteria lizard, the representative of reptiles whose fossils occur in the Trias, may be noted. The larvæ of the ascidian and of the frog alike possess four structures which are common to every back-boned animal at some stage of its development, and the possession of which is explicable only on the theory of the descent of sea-squirts and vertebrates from a common ancestor. These four structures are—(1) the throat with its gill-slits; (2) the primitive back-bone—a gristly rod called the notochord developed from the alimentary canal, and which is found in no invertebrates except the ascidians; (3) the brain and spinal cord; and (4) the eye, which is *inside* the brain. In all invertebrates which have eyes the retina or sensitive part is developed from the outer skin, and its outgrowth from the brain in vertebrates is ingeniously accounted for by Professor Ray Lankester[1] on the theory that the original vertebrate was a transparent animal, through every part of whose clear skin the light passed and acted on the tissues of the inlying brain. But as the skin became tougher and denser, and functions consequently more localised, the eye-bearing part of the brain had to grow outwards till skin-vesicle and brain-vesicle met, and the eye was formed at the surface.

Similar as are the larvæ of the tadpole and the sea-squirt, they diverge at later stages. While the one advances from the fish-like form to the amphibian, exchanging giils and tail for lungs and limbs, and, in fine, epitomising in its development the series of forms through which its ancestors passed, the other fixes itself by suckers to stone or plant. Tail, notochord, nerve-cord, and eye disappear, the brain remains small, the throat enlarges, the

[1] Cf. *Degeneration*, pp. 47–49, Nature Series (Macmillan).

gill-slits increase in number, the skin becomes hard and leathery, and the eyeless, footless thing sinks, as its manufacture of cellulose markedly shows, well-nigh to the plant level, its vegetating mode of nutrition sealing its degeneration.

The tailless amphibian frog and its allies are, however, not among the earliest vertebrates, which were wholly aquatic; and the more complete evidence of the near relationship of the sea-squirt to them must be sought in comparison between it and the lowest known quasi-vertebrate, a small degenerate fish called the lancelet or amphioxus.

6. *Vertebrata.*

We now reach the last and highest of the divisions of animal life, the sub-kingdom of the *back-boned*, which includes man.

Professor Cope says that 'the simplest expressions which shall cover all organs are the solid segment, the hollow sac and tube.'[1] The back-boned animals witness to this; they have fundamentally the same organs and parts as earthworms, passing through the same grades of structure. But while all invertebrates, except the lowest, consist of a single tube or cavity containing the nervous and vascular systems in common, and have an *outside* skeleton, which is simply a hardening of the skin, vertebrates consist of two tubes or cavities, the smaller of which encloses the central parts of the nervous system, or the brain and spinal cord, and the other the vascular system, or the organs of digestion and circulation, and have an *inside* skeleton. The most important part of this is the spine or back-bone, which separates the tubes, and is made up of a number of jointed bones or vertebræ.

[1] *Origin of the Fittest*, p. 185.

united by remains of the cartilaginous notochord, which give flexible action to the whole column. The advantage of this combined strength and ease of movement is seen in fishes as they dart through the water, in the gliding of the snake, the leap of the antelope, and the spring of the lion; while, as compared with animals which are either naked, or covered by a rigid horny skeleton, cumbersome as the armour of our ancestors, vertebrates have an enormous superiority in their internal framework of living bone, which adapts itself to, as well as nourishes and protects, the softer parts. Vertebrates, like the Annulosa, are bilaterally symmetrical, and are composed of segments placed one behind the other; but the lines of junction have become hidden by overlying muscles or effaced by structural modification—as, *e.g.*, in the formation of the skull, which is composed of nine or more coalesced segments. The threefold division of the body into head, chest, and belly, characteristic of crustacea and insects, is, however, more obvious. The limbs never exceed four in number, and are in pairs, whether as fins of fish (not reckoning the unpaired fins as limbs), wings and legs of birds and bats, fore and hind legs of quadrupeds, or arms and legs of man; all being modifications of one type, as in the prolonged bones of the bat's wing, which correspond to our fingers.

Such, in crude outline, are the principal features of the highest animals, but no general description can cover the infinite variety of vertebral forms. The sturgeon and the shark have a gristly spine; the frog has no ribs; the tortoise is encased in a shield composed of the hardened skin of its back and belly; and even in the marked division of vertebrates into cold-blooded, embracing fish and reptiles, and warm-blooded, embracing birds and mammals, exceptions occur in warm-blooded fish, as the tunny and the bonito. But no differences in detail can obscure the fact that vertebrates are all modifications of a common type, the variations in structure being due to

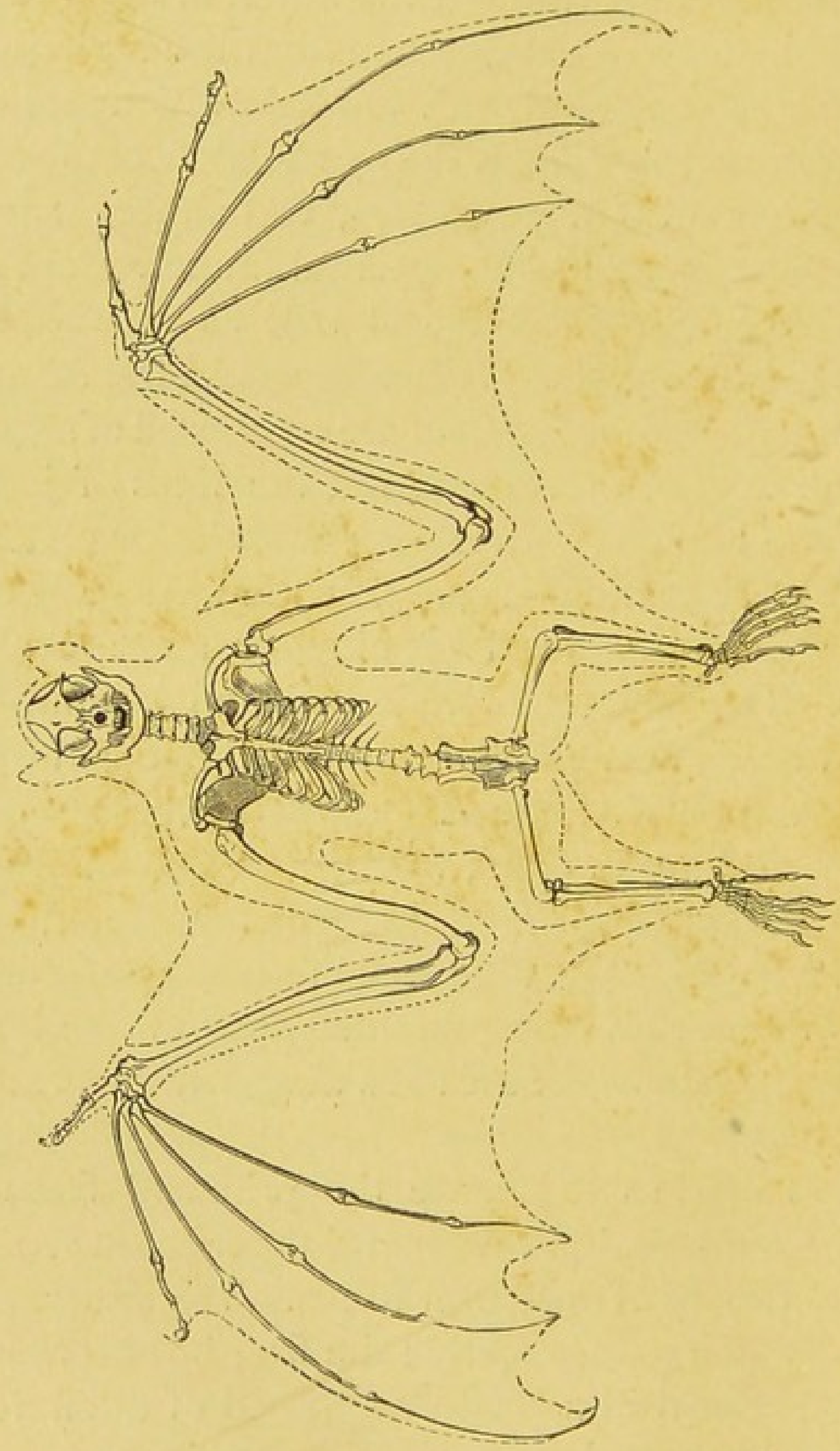


FIG. 55.—Skeleton and Outline of Bat.

differences of function determined by unlike modes of life. Moreover, details obscure relations; and since it is with the relation of all life-forms that we are chiefly concerned, we may pass to further evidence of connection between the highest invertebrate and the lowest animal of vertebrate character. This, as stated above, is furnished by the *lancelet* (so called from its lance-like shape), or *Amphioxus* (Gr. *amphi*, both ; and *oxus*, sharp, both ends being nearly alike). The mouth of this headless, one-eyed, semi-transparent animal has cilia for driving in the food-carrying water, and opens through the breathing slits into a wide gullet, in which the water, after giving up its oxygen to the colourless blood, enters and is expelled at the vent. There being no muscular heart, the blood is circulated by contractions of the vessels.

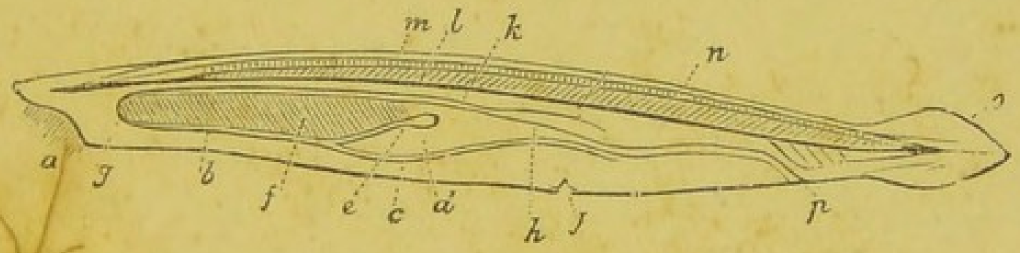


FIG. 56.—Lancelet.

a, mouth ; *b*, *e*, heart ; *d*, liver ; *g*, respiratory organs ; *h*-*p*, digestive canal ; *l*, notochord ; *m*, spinal marrow ; *o*, tail fin.

Now this boneless creature is classed among back-boned animals because it has the primitive gristly notochord from which the spine is developed in all true vertebrates. Above this rod lies the nervous system, composed of a single cord, which bulges slightly as a primitive brain near the mouth. The short notochord and single nerve-ganglion of the ascidian correspond, as far as they go, to like organs in the lancelet ; and if they were lengthened, so as to run along the whole of the back of the ascidian, the positions in the two animals would be found to agree exactly. This certainly points to their common descent.

Fishes, as the least specialised vertebrates, although by no means so stupid as is commonly thought, are placed in the lowest class, many species, as sharks, rays, and sturgeons, representing in their gristly back-bones, uneven tails, and spiny or plated skins, the armoured ganoids which mark the gradations between cartilage and bone in structure. All fish breathe by means of gills, the structure of which varies a good deal in the different orders, but are essentially the same in having like functions to discharge.[1]

Just as we had to retrace our steps in search of a link between vertebrates and invertebrates, so we must again go back a step or two to find the intermediate forms between aquatics and amphibians. These forms, the evolution of which is probably due to their occasional exposure to the atmosphere, developing in them different organs of breathing, are represented by certain fishes called *Dipnoi*, or 'double-breathers,' because, while they have gills for taking up the oxygen from the water, they can also breathe on land by means of the air-bladder or sound, which thus discharges the functions of a lung. Such are the *mud-fish* of the Amazons, and the *jeevine* of Australia, both of which show tendency towards modification of the paired fins into limbs,[2] those of the mud-fish being thong-like, and those of the jeevine being jointed, for locomotion on land. Other fish, as eels and the climbing perch of India, can also leave the water, their breathing being effected by modification of the gills.

Here, then, we find another intermediate step between land-dwellers and water-dwellers, the most perfect and

[1] In his *Naturalist in North Celebes* (1889), Dr. Hickson gives an account (p. 30) of certain jumping fishes which breathe mainly by the tail, the greater part of their lives being spent with head and gills out of the water.

[2] Cf. Professor Ray Lankester's preface to Gegenbaur's *Comp. Anatomy*, p. xi, 'On the Origin of Limbs.'

familiar example of which is supplied by the common frog's life-history. The gill-breathing, limbless, tailed plant-eating, aquatic tadpole develops into the lung-breathing, four-legged, web-footed, tailless, animal-eating, amphibian frog, unable, save when torpid, to live in water without coming to the surface for air. Some amphibians possess both lungs and gills throughout life, but all the higher vertebrates, whether they live in water or not, breathe through lungs, which arise, like the air-bladder of fishes, as sac-like outgrowths of the primitive gullet.

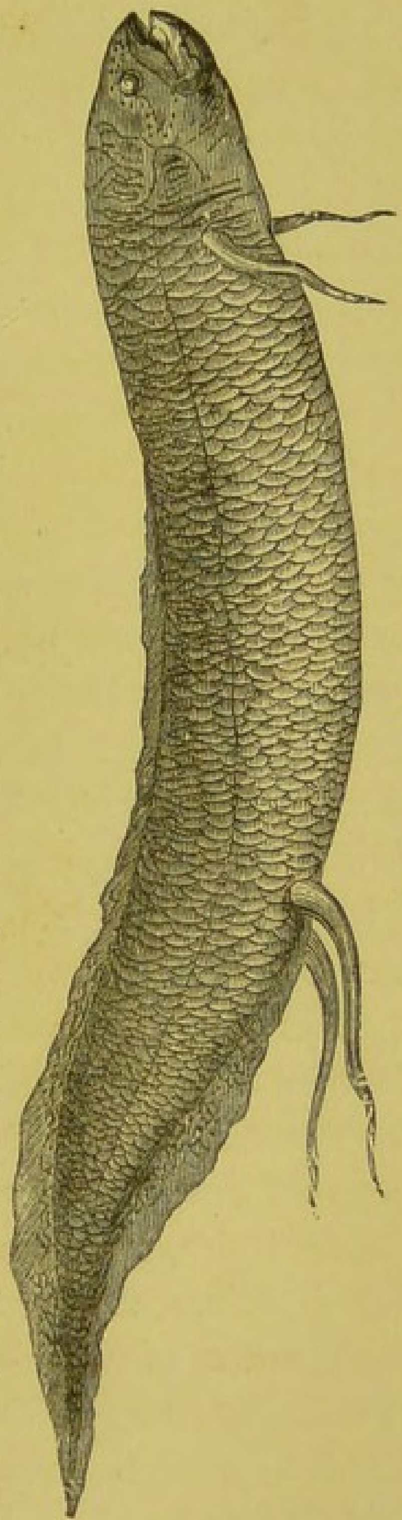


FIG. 57.—Mud-fish.

Reptiles, which include forms as diverse as the nimble lizard, the sluggish crocodile, and the limbless snakes, are for the most part the relatively insignificant descendants of the monsters of the land, air, and water, that flourished in the Age of Reptiles amidst the dense vegetation of a swampy world, until conditions fatal to them, and favourable to the development of more plastic life-forms, supervened.

Birds, at the head of which our best authorities place the crow family, possess a number of special characters, chiefly connected with the power of flight, from the path of which Roman augurs drew their omens of good or evil, as do the Papuans of to-day. Their exact sequence in the development of vertebrates is unknown, but their descent from reptiles is certain. Not, as might be thought, from the flying species, for these were featherless, and more like bats than birds in the membranous wings which stretched from limb to body, but from species that walked upon the land. But, although structural likenesses between birds and reptiles survive to attest this former close relation—as, *e.g.*, the union of the skull to the spine by a single joint, instead of by two joints, as in most amphibians and in all mammals, and the union of the skull to the jaw by the quadrate bone, which enables the jaws to be opened very widely—manifold causes, working through long periods, have brought about marked differences of external and internal structure. Notable among these is the modification of the three-chambered heart of nearly all reptiles into the four-chambered heart of birds and mammals, by which the fresh and used-up blood are kept separate, and the higher temperature of the body is maintained. The scales of the one, and the feathers or downy covering of the other, are alike modifications of the outer skin; for although the intermediate stages between the plumage of birds and the horny plates of reptiles are missing in fossil remains, it is certain that these and kindred structures, as hairs, claws, nails, and hoofs, are all outgrowths of the skin. Even teeth, the variety of form and arrangement of which render them of great value in determining the habits and general structure of the animal to which they belonged, are secreted from the skin. It has been shown already that the nervous system and sense-organs are also formed from the skin; nor should the variety of function which it discharges, and therefore the variety of structure into which it is modified, surprise us when we reflect how continuous has been the action of the medium with which it is in immediate contact upon the external surface of all organisms, so that

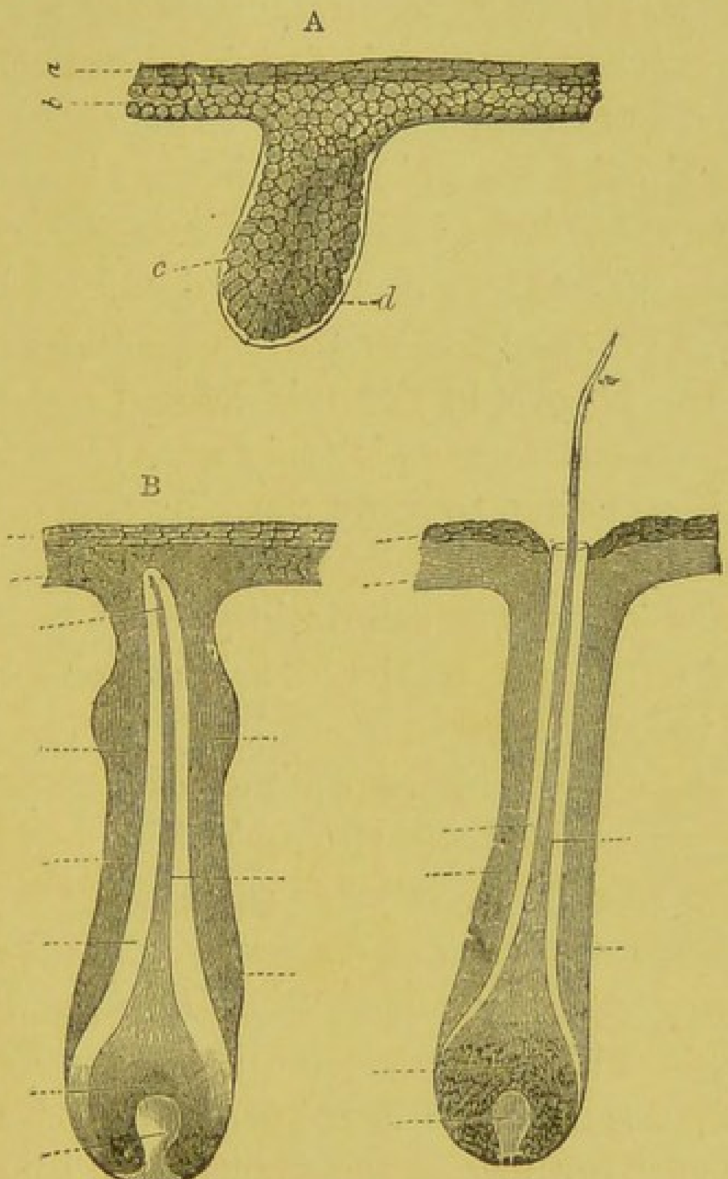


FIG. 58.—Growth of Hair.

A. Hair-rudiment from an embryo of six weeks. *a*, horny layer of cuticle; *b*, mucous layer of cuticle; *c*, cells of the future hair; *d*, basement membrane.
B. Hair-rudiment with the young hair formed, but not yet risen through the cuticle.
C. Hair protruded.

the slight film or integument of the lowest has developed into the complex layers which enclose the highest.

Space prevents more than bare reference to the varied and helpful material furnished to the evolutionist by birds, and to the significant evidence of their development as compared with their reptilian ancestors in larger proportion of brain to body, with the intelligence which this connotes. A remarkable proof of this may be seen in the wide range and method of their migrations, involving powers of vision and memory exceeding that possessed by man. On this instinct, about which we know very little, but which probably had its origin in the search after food, Darwin remarks, 'How a small and tender bird coming from Africa or Spain, after traversing the sea, finds the very same hedgerow in the middle of England, where it made its nest last season, is truly marvellous.'

It is interesting to note that in the oldest known picture in the world, a fresco in the Boolak museum at Cairo taken from a tomb dating about 3000 B.C., three species of geese are depicted, two of which are so well drawn as to be readily identified.

The lowest members of the diversified group of *Mammals* or milk-givers resemble birds in being toothless, and in having a common sac into which the intestines and other organs open, for which reason they are called *Monotremes*, or one-vented. These quasi-mammals are represented by the ornithorhynchus,[1] or duckbill, a beaver-like creature with a horny bill, the feet being furnished with both webs and claws; and by the echidna, or spiny ant-eater, which resembles a large hedgehog, being snouted and covered with prickles. Each is found in Australia, that land of primitive forms, and recent discoveries invest them with the greatest importance as links in the chain of mammalian descent. For they both lay eggs like reptiles and birds, the duckbill laying

[1] *Ornithorhynchus paradoxus*, the older naturalists named it; for when they were assured that the creature was not a fraud of the stuffer, they thought it must be a freak of nature.

two at a time, which she deposits in her underground nest, and the echidna laying one, which is probably hatched in her pouch. And the eggs further correspond with those of birds and reptiles in containing not only the protoplasm from which the embryo is formed, but also

FIG. 59.—Duckbill.

the food-yolk on which it is nourished until hatched, when it lives on the milk obtained from the mammary glands in some way not yet fully ascertained. Now an animal that unites in itself these reptilian and mammalian features is to be classed among the interesting anomalous and intermediate forms which Darwin has happily termed 'living fossils.' Whether monotremes are descended in direct line from reptiles, with the internal structure of which they have much in common, and

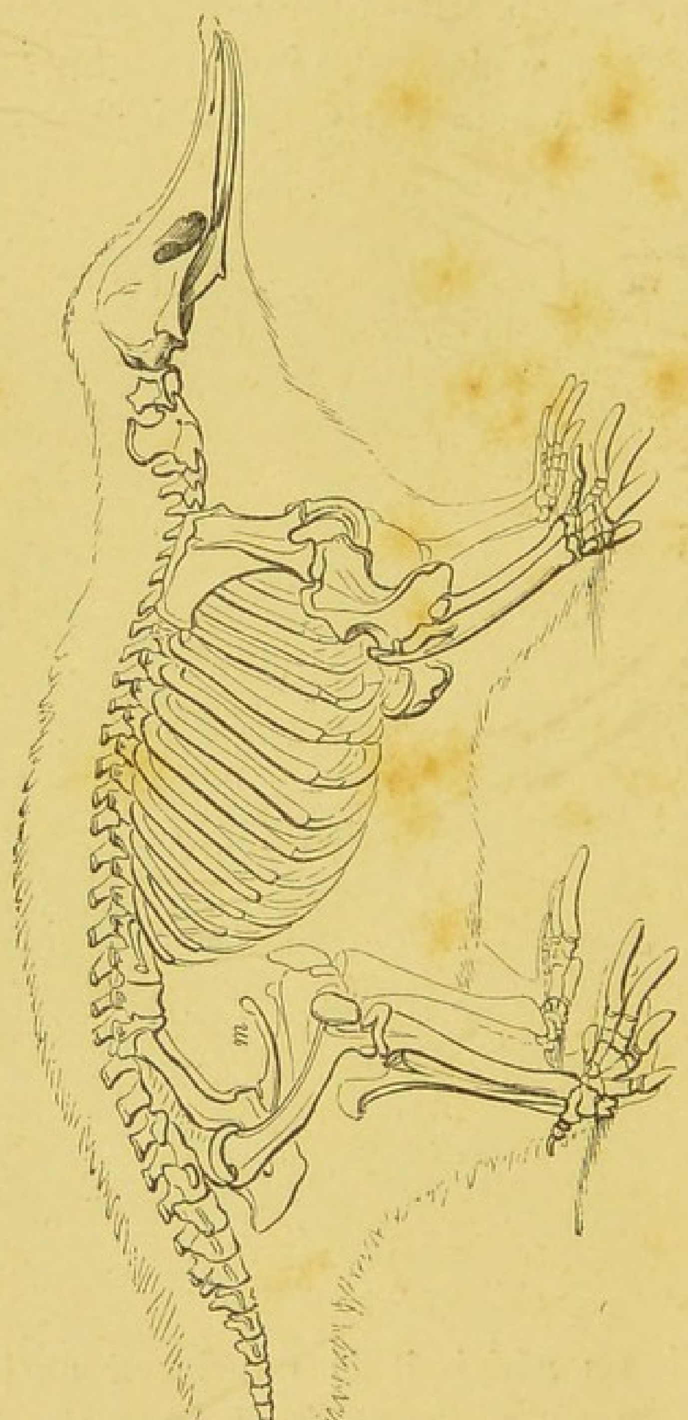


FIG. 60.—Spiny Ant-eater.
m, marsupial bones.

mammals from monotremes, or whether there was an ancestral form or rootstock from which both reptile and mammal branched off, so that mammals are as old as reptiles and older than birds, is not clear, although the rocks may one day reveal it. But the interrelation of reptiles and mammals is proven beyond question.

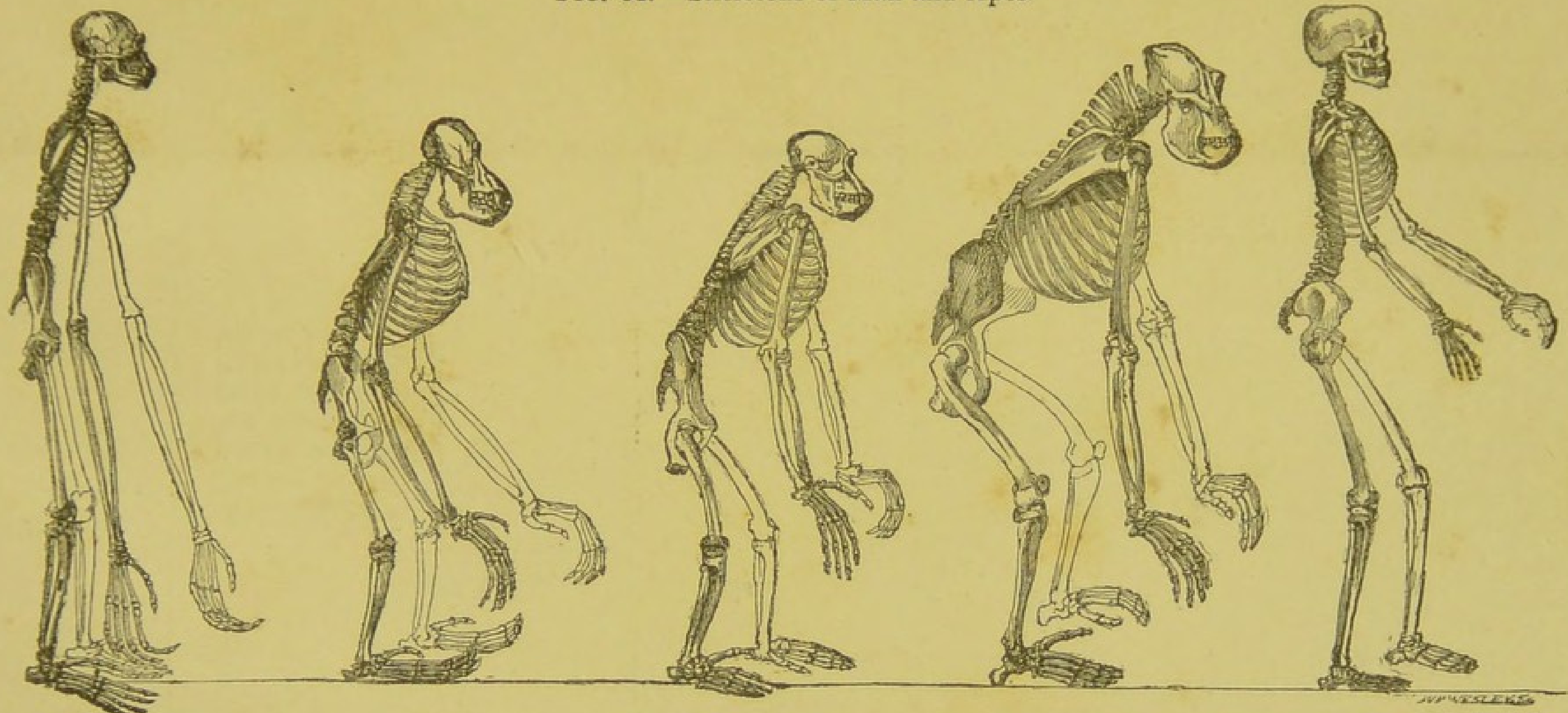
The next stage in mammalian development is marked by the *Marsupials*, or *pouched milk-givers*, as kangaroos and opossums, the young of which are born in an imperfect condition, and nourished and kept in the mother's pouch till they can run alone. Their fossil remains evidence a wide range in Triassic times, and the Post-Pliocene beds of Australia yield bones of marsupials as large as elephants; but their habitats are now limited to that island continent, and to lands similarly long isolated.

In all other mammals the young are born fully formed, being attached during the time of their development within the mother to a structure called the *placenta*, through which they are nourished by her, whence the general term placental mammals, of which the insect-feeders appear to be the primitive type. Starting thus more or less fully equipped in the struggle for life, the chances in their favour were incomparably greater than those of animals which are precariously hatched or born in an imperfect state; hence, among other causes, the dominance of the placentals, and their development into the highest organisms yet reached. They are usually divided into the following classes, which indicate structural characters common to the animals included under each, and not the exact relative place of the class in the sub-kingdom. No linear arrangement of classes, nor even of species, is possible, for the succession of forms is not as that of steps of a ladder, but as of a many-branched tree.

1. TOOTHLESS (*Edentata*) .	Sloths; ant-eaters; armadillos. These show affinities linking them nearer to monotremes than to marsupials. (The term *Edentata* is misleading, as only two members of the order, the Great and the Scaly Ant-eater, are without teeth.)

2. SIRENS . . (*Sirenia*) So called from their fancied resemblance to mermaids or sirens.	Dugongs and manatees, or sea-cows; fish-like in form, the fore limbs modified into paddles, the hind limbs absent: both these are plant-feeders.
3. WHALE-LIKE . (*Cetacea*)	Whales; dolphins; porpoises; also adaptation of structure to aquatic life.
4. HOOFED . . (*Ungulata*)	Very numerous and valuable order. Divided into the *odd-toed*—as the horse, the tapir, and his near relation the rhinoceros; and the *even-töed*—as swine, and their near relation the hippopotamus; camel; deer; sheep; ox: all these are plant-feeders.
5. HYRAX, or ROCK-RABBIT . . (*Hyracoidea*)	Represented by a small animal, the coney of the Bible. The shape of the teeth points to affinities with hoofed animals on the one hand and gnawing animals on the other.
6. TRUNKED . . (*Proboscidea*)	Represented only by the elephant, the longest-lived and most acute of plant-feeders.
7. FLESH-FEEDERS . (*Carnivora*)	Seals; bears; weasels; wolves and other members of the dog family; lions and other members of the cat family.
8. GNAWERS . . (*Rodentia*)	Hare; rat; beaver; squirrel. A very widespread class.
9. INSECT-FEEDERS (*Insectivora*)	Mole; hedgehog; shrew.
10. FINGER-WINGED (*Cheiroptera*)	Bat, highly organised, closely allied to insect-feeders.
11. LEMURS . (*Lemuroidea*)	The lemurs are sometimes grouped with monkeys in the order of the 'four-handed,' a division falling into disuse; but they have marked affinities with marsupials, gnawers, and insect-feeders. The 'flying lemur,' or colugo, a squirrel-like creature with webbed hands, appears to be an interesting link between insect-feeders and Primates.
12. PRIMATES . .	Monkeys; baboons; man-like apes (gibbon, orang-outang, chimpanzee, gorilla), big-jawed, small-brained, stooping posture; MAN, big-brained, erect posture—divided into races according to shape of skull, colour of skin, nature of hair.

FIG. 61.—Skeletons of Man and Apes.



Gibbon. Orang. Chimpanzee. Gorilla. Man.

Reduced from diagrams of the natural size (except that of the gibbon, which was twice as large as nature).
(From Prof. Huxley's *Man's Place in Nature*, Frontispiece.)

RACES OF MAN.

- Primitive Man
  - Woolly-haired. (Nearly all long-headed)
    - Tuft-haired variety
      - Papuans
      - Hottentots
    - Fleece-haired variety
      - Kaffirs
      - Negroes
  - Straight-haired. (Nearly all broad-headed; but the Esquimaux and Australians are long-headed)
    - Stiff-haired variety
      - Australians
      - Malays
      - Mongols
        - Chinese
        - Tatars
        - Finns
        - Lapps
        - Turks
        - Hungarians
      - Arctic
        - Esquimaux
        - Greenlanders
        - Hyperboreans
      - Native American
    - Curly-haired variety
      - Dravidas
      - Nubians
        - Nubians
        - Foulahs
      - Mediterranean
        - Basques
        - Caucasian
        - Semitic
          - Egyptians (?)
          - Jews
          - Arabs
        - Aryan
          - Aryo-Romanic
            - Indians
            - Persians
            - Greeks
            - Romans
          - Slavo-Germanic
            - Slaves
            - Scandinavians
            - Teutons
            - Celts

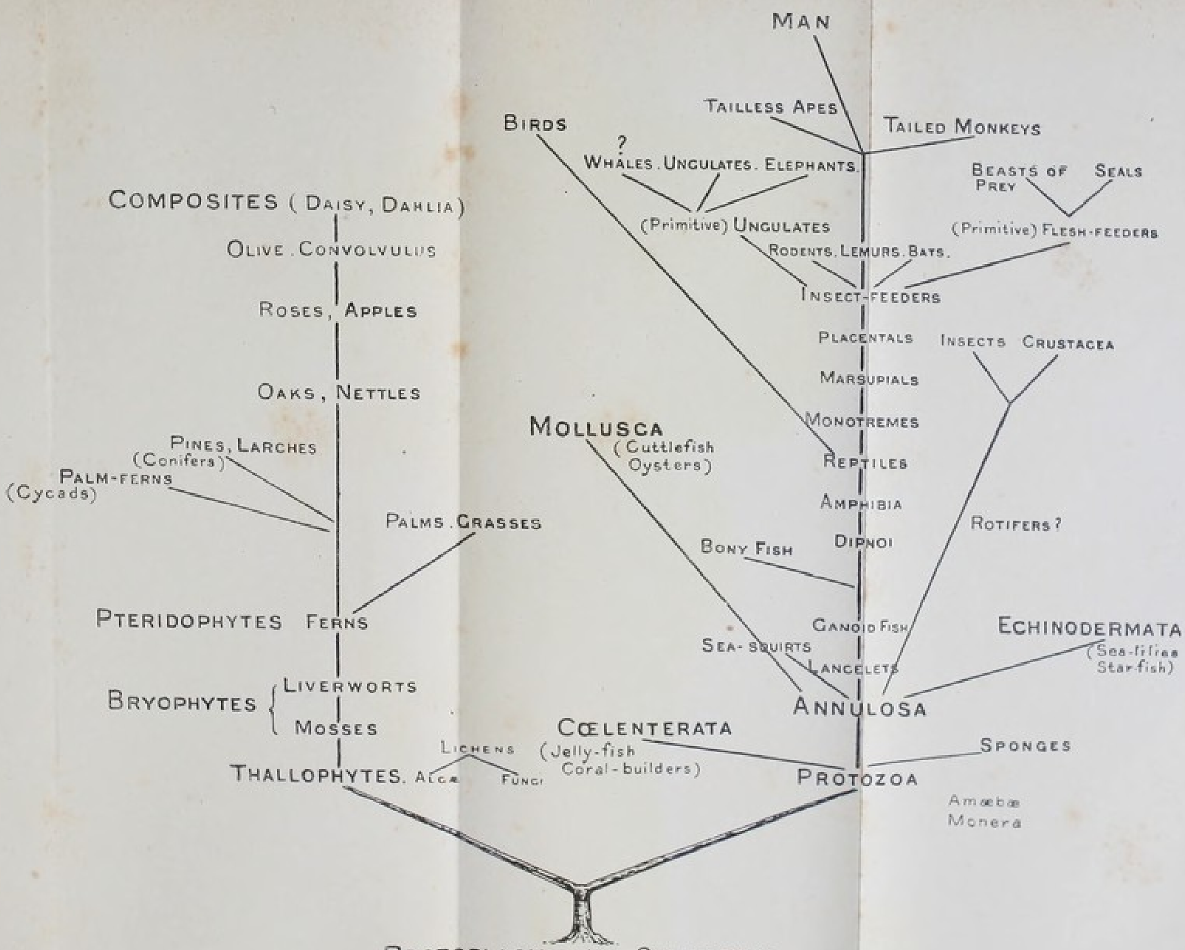


FIG. 62.—Diagram of Development.

The ascent of the higher life-forms from the lower is more lateral than the lines indicate, but the diagram is only a rough attempt to show the relative places of the leading groups.

In the foregoing survey of past and present life-history no break in the continuity of life, or in its fundamental unity, is found. In the unstableness of the first living matter lay the tendency to that variation which, acted upon by manifold agencies in the production of unlikeness, both seen and unseen, has resulted in ever-increasing complexity of forms. But, strive as we may not to overlay with detail, it is not easy to keep clear and constant before the mind the relationship between all life that is and that has been, as well as the identity of that life with, and its dependence upon, the not-living. Perhaps this interrelation may be made more apparent in the exposition of the theory of evolution which is now to follow the description of the things evolved

PART II.—EXPLANATORY.

CHAPTER VI.

THE UNIVERSE: MODE OF ITS BECOMING AND GROWTH.

It must be so, for miracles are ceased;
And therefore we must needs admit the means
How things are perfected.
Archbishop of Canterbury, *Henry V.*, act i. sc. 1.

The gases gather to the solid firmament; the chemic lump arrives at the plant and grows; arrives at the quadruped and walks; arrives at the man and thinks.—EMERSON.

IN the first chapter a summary account was given of the materials which make up the universe. These were comprised under the terms Matter and Power, as convenient names for an observed order of facts of whose ultimate nature we know nothing. Power is that which acts upon matter in the production or destruction, the increase or decrease, of motion; and, as explained already, it is upon this twofold and opposite action that we base our assumptions as to the nature of matter—*i.e.* as consisting of atoms of infinite minuteness.

That form of Power which draws the atoms together into larger or smaller masses, and which resists their separation, we call Force; that form of Power which drives the atoms apart, and resists their combination, we call Energy. Both Force and Energy are, like matter, indestructible; in other words, the sum-total of each is a fixed quantity. Force inheres in, and cannot be taken from, each atom of weighable matter; but Energy passes from atom to atom, and from mass to mass, its vehicle being that unweighable ethereal medium which, it is assumed, fills the spaces between bodies and between the particles of bodies. In this diverse way each is ceaselessly acting, Force aggregating the particles round various centres, Energy separating them and passing into space, only fractions of it striking intervening bodies, as, *e.g.*, in the interception of the sun's radiant energy by the planets. And the certain result, however immeasurably distant, is that all the Energy of the universe will be dissipated, and that all the matter of the universe will become cold, solid, and inert under the aggregating and unopposed action of Force.

The problem we have now to consider is this:—Given Matter and Power as the raw materials of the universe, is the interaction of Power, under its two forms of a combining Force and a separating Energy, upon Matter, sufficient to account for the totality of non-living and living contents of the universe?

Of the beginning, of what was before the present state of things, of what will follow the end of it, we know nothing, and speculation about it is futile. Science is concerned with the universe as we find it, the mobile vehicle of orderly succession; the Evolved, or Unfolded; *das Werden*, as the Germans say, or the Becoming: not less wrapped in mystery because we describe it as a mechanical process, and do not fall back upon unknown agencies or assume unknown attributes of Matter or Power to explain it.

But since everything points to the finite duration of the present universe—for what it now is it once was not, and its state is ever changing—we must make a start somewhere. And we are therefore compelled to posit a primordial nebulous, non-luminous state, when the atoms, with their inherent forces and energies, stood apart from one another. Not evenly distributed, else Force would have drawn them together as a uniform spherical mass round a common centre of gravity, and Energy, awakened by the collision of atom with atom, would have passed profitlessly in the form of heat to the ethereal medium; but varying in position and character, with special gravitation towards special centres. This theory of unstableness and unlikeness at the outset squares with the unequal distribution of Matter, with the movements of its masses in different directions and at different rates, and with the ceaseless redistribution of Matter and Power. All changes of state are due to the rearrangement of atoms through the play of attracting forces and repelling energies, resulting in the evolution of the seeming like into the actual unlike, of the shapeless into the shapely, of the simple into the more and more complex, till the highest complexity is reached in the development of living matter. If all that is, from fire-fused rock to the genius of man, was wrapped up in primordial matter, with its forces and energies, we can speak of simplicity only in a relative sense as contrasted with the infinite variety around us which has been evolved.

1. *Inorganic Evolution.*—Under this head we may apply the foregoing principles to the earliest stages of cosmical change, to the *Evolution of Stellar Systems.*

The existence of nebulous or cloud-like objects in space, which the telescope, aided by the analysis of the spectroscope, proves to be immense masses of glowing gas, goes far to justify the assumption of a yet more discrete state of the atoms which formed the material universe at the outset. But, although we are familiar with matter in an invisible state, as, *e.g.*, in the element oxygen, which, in a combined state, forms nearly half the solid framework of the globe, we can form no conception of the extreme rarefaction of the primitive atoms. Upon this Helmholtz remarks that 'if we calculate the density of the mass of our planetary system at the time when it was a nebulous sphere which reached to the path of the outermost planet, we should find that it would require several millions of cubic miles of such matter to weigh a single grain.' Given, however, the play of force and energy upon this diffused matter, the mechanics of the process which resulted in the visible universe are not difficult of explanation. The Force bound up in each atom, acting as affinity, combined the atoms as molecules ; acting as cohesion, it united the molecules into masses ; acting as gravitation, it drew the masses toward their several centres of gravity. One of these masses, by no means the largest, became the nucleus of our solar system, which may be taken as a type of all other masses whose evolution into stellar systems is as yet complete.

As the atoms rushed together, Energy, which had hitherto existed in a state of rest as passive separation, became active in *molar* and *molecular* form. As *molar* energy it imparted motion to each mass—a motion of rotation on its own axis ; and a motion in an orbit, as in the proper motion of double stars, and of the planets round the sun. As *molecular* energy it imparted a rapid vibratory backwards and forwards motion to the molecules, which motion was forthwith converted into the radiant energy of heat and light, rendering the mass self-luminous. From the moment of their conversion the dissipation of both forms of energy ensued. The friction of the ethereal medium slowly retards the orbital motion of every mass, the molar energy thus lost passing into that medium, until finally the orbital motion will be stopped, and the force of gravitation, no longer resisted by energy, will draw the smaller masses to the larger, as vagrant meteors are being ceaselessly drawn to planets and sun. Moons will gravitate to their planets, planets to their suns, and so on, until the matter of the universe, with intermediate outbursts of energy, becomes cold, inert, and solid, and Force will have subdued all things unto itself. The molecular energy likewise passes, but more rapidly, into the ethereal medium, throbbing ceaselessly in all directions to the farthest marge of space, if any marge there be. Small portions of it are intercepted by each mass, but of these the larger proportion is reflected back, the remainder setting up separative motions on the surface, as, *e.g.*, in the familiar case of the action of the sun's radiant heat on the earth. Of this solar energy, which is radiated equally in every direction, the earth does not intercept much more than the two thousand millionth part. And of this the larger proportion is reflected back, only a fraction, to be itself finally dissipated, being used to maintain the earth as the theatre of atmospheric and superficial changes whose highest result is life.

Such, with much detail left out for clearer presentment of the subject, is the mode in which the shining hosts of stellar systems appear to have been evolved from nebulous matter. In this exposition students of astronomy will recognise the 'nebular theory' of Kant and Laplace, but with important modifications due to the doctrine of the conservation of energy, which was unknown in their day.[1] That theory does not admit of demonstration, but justifies itself as the only tenable explanation of the several states and distribution of bodies in space. It is the only alternative to theories condemned by the Law of Parsimony, as Sir William Hamilton called the law which forbids us to invoke the operation of higher causes to account for effects which lower causes suffice to explain.

2. *Evolution of the Solar System.*—We may now leave the general for the particular, and apply the theory to the evolution of that particular stellar system to which we belong, and to that portion of it which we call the earth. If the explanation of the origin of the sun and planets repeats somewhat of the foregoing, it will only bring home to us the uniformity of the process, and show that what is true of the whole holds good for every part, and for the parts of every part down to the unseen atoms of which all things consist.

[1] For a lucid criticism of the defects of Laplace's theory, more especially in its failure to account for the peculiar distribution of the larger and smaller planets, the reader may study with advantage Mr. Proctor's essay on 'How the Planets grew' in his *Expanse of Heaven.*

While these sheets are passing through the press, there appears in the *Times* of November 18, 1887, a summary of a paper on the 'Spectra of Meteorites,' read by Mr. Norman Lockyer before the Royal Society. As the result of a large number of experiments, the conclusion at which Mr. Lockyer arrives is that 'all self-luminous bodies in the celestial spaces are composed of meteorites or masses of vapour, produced by heat brought about by condensation of meteor swarms due to gravity;' in fine, that meteorites are the primordial stuff of the universe. The experiments are interesting as further evidencing the identity of many of the elements of cosmic bodies, but they do not warrant the larger inference to which the *Times* gives prominence. Two obvious objections occur: 1, that, thus far, only about one-half the known terrestrial elements have been detected in meteorites, so that, dealing with the earth alone, the source of the remainder must be accounted for; and 2, that meteorites, as complex bodies, represent a relatively advanced stage in the process of aggregation.

Two striking pieces of evidence of the common origin of the sun and planets may be cited at the outset : (1) They are made of like materials ; (2) they have like motions.

(1) The spectroscope has revealed to us the chemical constitution of several of the fixed stars, their enormous distance not affecting the trustworthiness of the analysis. It evidences the existence of substances in the glowing vapours of their atmospheres akin to those which feed the fires of the sun ; and if such identity of stuff is proved to exist between the sun and other stars, we may with reason look for still closer identities of material between him and his family of planets, moons, and erratic bodies. In fact, the sun is known to consist of materials largely represented in our earth.

(2) The planets and, with rare exceptions, their satellites, revolve round him in the same direction ; they also, so far as is known, rotate on their axes in the same direction, and very nearly coincide in the shape and planes of their orbits, which are almost in a plane with the sun's equator. Now, since the consequences would be the same were these motions, both on axis and in orbit, in the reverse direction, the inference is obvious that there was a uniform motion of rotation of the mass from which they were severally formed.

As with the primitive nebula from which that mass was detached, so with the mass itself ; there were differences of density throughout. On no other theory is its segregation into a multitude of bodies explicable. As the rotation of the mass quickened with the indrawing of the particles towards the common centre of gravity, the energy of molar separation acted most powerfully in the region of the bulging equator, and, overcoming the force of cohesion along the line of least resistance detached certain portions one after another at irregular intervals from the central mass as it retreated within itself. These portions were the nuclei of the planetary groups, in which the like processes of contraction and rupture were repeated, the masses detached becoming moons, or, as in the case of Saturn, rings of satellites. In respect of the diffused and highly energised fugitive masses, as comets and meteors, Mr. Proctor has adduced cogent reasons in support of the theory that they are 'products of expulsion from suns, from giant planets, and from orbs like our earth when in the sun-like state.'

The origin of the planets and their moons being found in the mode described above, it is obvious that in their primitive state they were molten, and shone by their own light. All hot bodies part with their heat to cooler bodies ; and when equilibrium of temperature is reached, all separative motions cease—no work can be done. The smaller the body, the sooner would its molecular energy be dissipated ; in other words, the quicker it lost its heat. The present in a large degree interprets the past, and explains the several stages of the members of our system, according to their bulk. The sun, whose mass exceeds the combined mass of all the planets more than 700 times, is still slowly contracting, and therefore still radiating energy. In this lies the most probable explanation of the maintenance of this energy, which at the present rate of dissipation would cause his whole diameter to contract 220 feet yearly, or four miles in a century, so that the sun may become as dense as the earth in a few million years. The cloud-laden atmospheres of the larger planets, as Jupiter and Saturn, are torn by cyclones only second to those of the sun in their fury, and the molten centres feed volcanic outbursts to which those of Vesuvius and Krakatoa are mere squibs.

But as for the smaller bodies, their turmoil is calmed and their light extinguished; the store of energy is exhausted; the forces of affinity and cohesion have gained the upper hand and drawn the particles together into the solid form. Thus it is with the moon, on whose dead and barren surface we may read the future of the giant planets and the sun himself. For the history of one is the history of all; each has passed, or is passing, from the indefinite nebulous state, through numberless modifications, to the definite and solid state, by decrease in volume and increase in density. What the earth is, the moon was; what the moon is, the earth will be.

3. *Evolution of the Earth.*—To this passage from the sun-like to the solid state the earth bears witness. Its flattened poles, its bulging equator, its spheroidal shape, are the effects of rotation on a fluid or viscous mass; whilst the geologically oldest parts of the crust—for there is no primogeniture in matter—are of a structure which is producible only by the fusion of particles under intense heat. As that crust, thin and mobile at the outset, continued to cool and thicken, it evidenced more strikingly the play of forces and energies within, and of energies and, in lesser degree, of forces without. The cooling and shrinking of the internal mass, as the stored-up energy slipped away, caused tension of the crust, which, yielding to the force of gravitation, was drawn inwards, and cracked and crumpled into mountains and valleys, and into the deep depressions which the great oceans have filled since the time when their waters were first condensed from the thick primitive vapours that swathed the cooling earth. Then the continuous action of the sun's radiant energy, operating through air and water upon the increasingly rigid crust, dissolved its superficial particles, and re-deposited them as stratified

rocks, in endless beauty and variety, over the surface of the globe. And herein lies the major cause of our earth's present condition as a possible abode of life. For its native supply of energy—that of position derived from the momentum given it when thrown off from the parent mass ; and the still unspent, but always lessening, store of internal heat manifest in the volcano and the earthquake—would not suffice to arrest effeteness and the wrapping of the globe in a winding-sheet of ice. It is the imported supply from the sun which alone does that, for in its absence the trivial tidal energy due to the moon would be futile, because the seas and oceans would be solid. Opposing the force which attracts everything into inert union, the solar energy sets up the separative motions, the ceaseless redistributions, which give rise to the grand climatal and vital phenomena of nature. Expanding the air, it causes the inrush to which winds and storms are due ; heating the water, it excites the warm currents, and draws heavenward the aqueous vapour, which, driven by the wind, returns, when its energy is lost, as rain and snow, those silent yet mightiest agents of mechanical, chemical, and vital changes. But the full significance of the work done by the sunbeams that strike the earth's surface will appear when we treat of the relation of the living to the non-living.

CHAPTER VII.

THE ORIGIN OF LIFE.

THE fascination which the question of the origin of life possesses is not lessened by the slow abrasion of the artificial lines which divide the living from the non-living. Round it, like planet tethered to sun by the invisible force of attraction, the mind of man revolves, unable to disentangle itself and escape into a larger orbit, whence the truer proportions of things may be seen; nor will the undue importance accorded to the living vanish until there is deepened within us that sense of the unbroken interrelation of all things to which science brings her 'cloud of witnesses.'

It is agreed that there was an 'azoic' or lifeless period in the history of the earth—therefore that life had a beginning; and it is with the evidence as to continuity or gap between the azoic and the zoic epochs that the present chapter is concerned.

The azoic stage is evidenced by the primordial temperature of the globe, which, taking the present temperature of the sun as a fair standard of comparison, is computed to have been 14,000 times hotter than boiling water. Under such highly energetic conditions chemical combinations of the vaporous particles were impossible, and, *a fortiori*, vital combinations. But with the slow cooling consequent upon the continuous passage of the earth's molecular energy into space, the combining forces came into more and more active play, forming first the extremely simple and more stable compounds, as water; then the more complex and less stable, as salts; and so on in increasing complexity of material and unlikeness of structure. Obviously an enormous fall in the temperature took place before the superheated mass became cool enough to permit the formation of an outer crust. It was into the depressions of this crust that the vapours which floated over it fell as they condensed, forming water, which at first was probably at the temperature of a dull red heat.

Thus far, in broad outline, the material foundation for the superstructure of life.

When, *where*, and *how* did life begin?

As to the *time*, we have no evidence whatever. Life is enormously older than any record of it. Even the higher forms were developed long before the periods in which we first find their remains.

As to the *place*, probably in polar regions, as Buffon suggested in his 'Epoques de la Nature.'

As the globe cooled, those regions would be the earliest to reach a temperature under which life is possible. The Comte de Saporta, whose researches give large support to Buffon's theory, remarks that the richest fossil-yielding rocks are found in northern latitudes of 50° to 60° and beyond, and show that far back as Silurian times the north pole was warm enough to maintain life of a tropical character, and that it was the centre of origin of successive forms down to the Tertiary epoch; the Miocene flora, which has now to be sought 40° farther south, being profusely represented. In Carboniferous times a warm, moist, equable climate prevailed over the whole globe, due, as De Saporta argues, to arrest of radiation by a highly vaporous atmosphere, and also, perhaps, to the greater diffuseness of the sun's light by reason of his larger volume. Thiselton Dyer says that all the great assemblages of plants seem to admit of being traced back at some time in their history to the northern hemisphere with its preponderating land-surface.

It is therefore to the north pole, more than to the south pole, whose secrets, however, no man has yet wrested, that all evidence points as the area of the origin and distribution of life. The great land-masses radiate southwards, forming, with their alternations of submergence beneath shallow seas, and of upheaval, channels of migration for life-forms, the modifications in which have arisen from causes to be dealt with presently. In contrast to this, the south pole, through its isolation by the deep oceans, whose beds have never been dry land since the waters filled their cavities, has maintained only a slender connection with the continents and large islands tapering towards it, and its plants and animals have been unable to make headway against the ceaseless life-stream from the north. So that given time, evolution, continental continuity, changes of climate and elevation of the land, and it would appear that the dominant types may be traced back to the northern hemisphere.[1]

[1] Cf. the Comte Gaston de Saporta's *L'Ancienne Végétation Polaire*, in *Compte Rendu* of the International Congress of Geography held in Paris, 1875 (published 1877); extracts from Sir J. D. Hooker's Address to the Royal Society, 1877, in *Proceedings of Royal Geog. Soc.*, vol. i., 1879, from which the following is quoted: 'Perhaps the most novel idea in Count Saporta's essay is that of the diffused sunlight which (with a densely clouded atmosphere) the author assumes to have been operative in reducing the contrast between the polar summers and winters. If it be accepted, it at once disposes of the difficulty of admitting that evergreen trees survived a long polar winter of total darkness, and summer of constant stimulation by bright sunlight: and if, further, it is admitted that it is to internal heat we may

As to the *mode*, let us approach the problem by treating of what is common to both the lifeless and the living. Now, in brief, there are no elements in the one which do not occur in the other. The most complex plant and animal, and the lowest living germ, so apparently devoid of structure that it can only by courtesy be called an organism, are alike made of materials derived, directly or indirectly, from earth and air and water. These materials are oxygen, carbon, hydrogen, nitrogen, with a little sulphur and phosphorus, and still fainter traces of other elements, combined in extreme and elusive complexity. Of the several elements entering into this subtile combination, carbon is probably the element to which the most prominent part is to be assigned. Its affinity for itself, and its faculty of uniting in manifold relations both of number and weight, cause its compounds to be more numerous and important than those of all the other elements taken together. Combining with the foregoing elements, it gives rise to protoplasm, from which by successive modifications, slow in their operations, the teeming variety of living things has been developed. These, as explained already, are made up of myriads of cells, each of which is a life-centre, their combination being the sum-total of the life of the organism. As the cell itself is an organisation formed from proto-

ascribe the tropical aspect of the former vegetation of the polar region, then there is no necessity for assuming that the solar system at those periods was in a warmer area of stellar space, or that the position of the poles was altered, to account for the high temperature of pre-glacial times in high northern latitudes; or, lastly, that the main features of the great continents and oceans were very different in early geological times from what they now are.' Also Wallace's *Island Life*, ch. xxiii. *passim*; Thiselton Dyer's lecture on 'Plant Distribution as a Field of Geographical Research,' *Proc. Royal Geog. Soc.*, xxii. 415, 1878; Grant Allen's *Vignettes from Nature*, 'The Fall of the Year;' and Sir J. W. Dawson's *Geol. Hist. of Plants*, pp. 221, 257.

plasm, and marks the first stage in visible structure, the question as to the mode of origin of life narrows itself to the origin, not of complex organisms, nor of cells, but of protoplasm. Given the matter which composes it, and the play of forces and energies of which that matter is the vehicle, wherein lies the difference which gives as one result non-living substance, and as another result living substance? The answer obviously is that, *the ingredients being the same, the difference must lie in the mixing.*

We are already familiar in the inorganic world with the existence of the same element in more than one form, but with different characteristics—*e.g.*, of carbon, as diamond, graphite, and charcoal; the difference being doubtless due to molecular arrangement. Chemistry also reveals intimate likeness of materials in the compounds known as isomeric, in which the physical and chemical properties vary considerably. It has also manufactured organic compounds, as starch, urea, and alcohol, the production of which was once thought impossible; and if the experiments to produce the living out of the non-living by decoctions of hay and extracts of beef have failed, as we might expect they would, this failure can have no weight against the argument that we cannot think any limit to the possibilities of nature's subtile transmutations during the vast periods that the earth has been a possible abode of life. And is not the transmutation of the inorganic into the organic ceaselessly going on within the laboratory of the plant under the agency of chlorophyll?

The ultimate cause which, bringing certain lifeless bodies together, gives living matter as the result, is a profound mystery. 'The transition between the organic and the inorganic energies may be possibly found in the electric group. Its influence on life, its production of contractions in protoplasm, and its resemblance to nerve-force, are well known. It also compels chemical unions otherwise impracticable.'[1] But, although the living thing affects us much more nearly than lifeless stones and rain, it hides no profounder mystery than they. The 'affinities,' as in our ignorance we name them, which lock the elements into beautiful crystalline forms, are no whit less wonderful than the motions in matter through which the same elements manifest the phenomena of life. The origin of life is not a more stupendous problem to solve than the origin of water. Both protoplasm and water have properties that do not belong to the individual atoms which compose them, and the greater complexity of the living structure does not constitute a difference in kind, but only in degree. It does not seem, after all, such a far cry from the crystal to the amœba as from the amœba to Plato and Newton. The crystal and the amœba take their place as independent products of physical and chemical change, and cannot do other than obey the law of their development. The crystals of rock-salt, determined by the mutual action of the attractive and repellent poles of their atoms, dispose themselves as cubes; the crystals of snow as hexagons; of sulphur as rhomboids; and the protoplasmic atoms, obeying their polarities and charged with separating energies, dispose themselves 'each after his kind.' But whilst the crystal grows by accretion at the surface, although even this distinction has its rare exceptions, the cell grows by assimilation or intussusception, *i.e.* by inflowing of nutrition amongst all its parts,[2] the new replacing the old,

[1] Cf. Cope's *Origin of the Fittest*, p. 436.

[2] The so-called precipitation cells or mineral organisms known, after their discoverer, as Traube's cells, are spoken of with contempt by Sachs,

yet maintaining its structure and composition, like the fabled ship of Theseus, which remained the same although repaired so often that not an original plank was left.

Speaking relatively—for nothing is absolutely motionless—the crystal is stable, irresponsive: the cell is plastic, unstable, responsive, adapting itself to the slightest variation; it 'stoops to conquer,' and so undergoes ceaseless modification by interaction with its ever-changing environment. Life involves delicacy of construction; hence the transient nature of the organic in contrast to the abiding nature of the inorganic. And, strange as it may seem, separation is life; integration is death. For life is due to the sun's radiant energy, which, setting up separative movements, enables the plant to convert, through its mysterious alchemy, the lifeless into the living, thus forming energetic compounds, which are used partly by the thrifty plant for its own vital needs, and largely by the spendthrift animal for its nutrition, to repair waste and maintain functions. Ultimately the energy thus derived from the sun, directly by the plant and indirectly by the animal, passes into space, and 'the dust returns to the earth as it was.' For life is only a local and temporary arrest of the universal movement towards equilibrium.

Turning to mental phenomena, from its lowest manifestations in the simplest reflex action of the amœba or the sundew when touched, to its highest manifestations in consciousness or self-knowledge, we find the connection between it and the bodily movements a greater *crux* than the connection between the inorganic and the organic. We know that all the thoughts we think, and all the emotions we feel, involve a physical process; that

who says that their resemblance to living cells has been much exaggerated. (Cf. *Lect. on Physiol. of Plants*, p. 215.)

is to say, they are accompanied by certain chemical changes or molecular vibrations in nerve-tissue, involving waste or large expenditure of energy, which is repaired by food. We know that the healthy working of the brain depends upon nourishment, upon abstinence from excess, upon freedom from injury. Starve, or stun, or stupefy a man, let palsy or paralysis afflict him, and the complex machinery is thrown out of gear. And we know that the larger the proportion of brain to body, and especially the more numerous and intricate the furrows and creases in the grey matter of the brain, the higher in the life-scale are the mental powers.

But the gulf between consciousness and the movements of the molecules of nerve-matter, measurable as these are, is impassable; we can follow the steps of the mechanical processes of nerve-changes till we reach the threshold which limits the known, and beyond that barrier we cannot go. We can neither affirm nor deny; we can only confess ignorance. 'If any one says that consciousness cannot exist except in the relation of cause and effect with certain organic molecules, I must ask how he knows that; and if he says that it can, I must put the same question.'[1] That is the impregnable position of physical science as defined by its greatest living expositor. 'Soul is only known to us in a brain, but the special note of soul is that it is capable of existing without a brain, or after death.'[2] That is the unverifiable assumption of dogmatic theology.

[1] Professor Huxley on 'Science and Morals,' *Fortnightly Review*, December 1886.

[2] Principal Tulloch, *Modern Theories in Philosophy and Religion*, p. 328.

CHAPTER VIII.

THE ORIGIN OF LIFE-FORMS.

MOISTURE as well as heat is essential to life; therefore life had its beginnings in water,[1] but whether as plant or animal is a difficult question to answer. The fossil-yielding rocks tell us nothing about it, and the lowest and simplest organisms have so much in common that any attempt to gather evidence from them on the matter must fail. But, however closely the earliest life-forms were related, there is, as noted already, fundamental difference to be drawn between their successors in the *mode of nutrition*, a difference which may throw some light upon the problem of priority, and which is not effaced by the existence of certain flesh-eating plants and vegetating animals, since this witnesses to the interchange of modifications of which protoplasm is capable.

It has been shown that the plant alone has the power to convert the elements of lifeless matter into the living solid state, thereby storing up energy for its own use in

[1] 'It was in the littoral region that all the primary branches of the zoological family tree were formed; all terrestrial and deep-sea forms have passed through a littoral phase, and amongst the representatives of the littoral fauna the recapitulative history in the form of series of larval conditions is most completely retained'—Professor Moseley, *Nature*, September 3, 1885. And the primary condition of animal development was the development of plant-life in the same region.

growth and germination, and for the use directly or indirectly of the animal. This the plant is enabled to do solely in virtue of its chlorophyll, which absorbs certain sun-rays, and sets up chemical action by which carbon is separated from oxygen in carbonic acid gas, and hydrogen from oxygen in water, forming hydrocarbons in which energy is stored up. Now, if the animal is entirely dependent upon the plant for this energy, it would seem that plants were developed first.

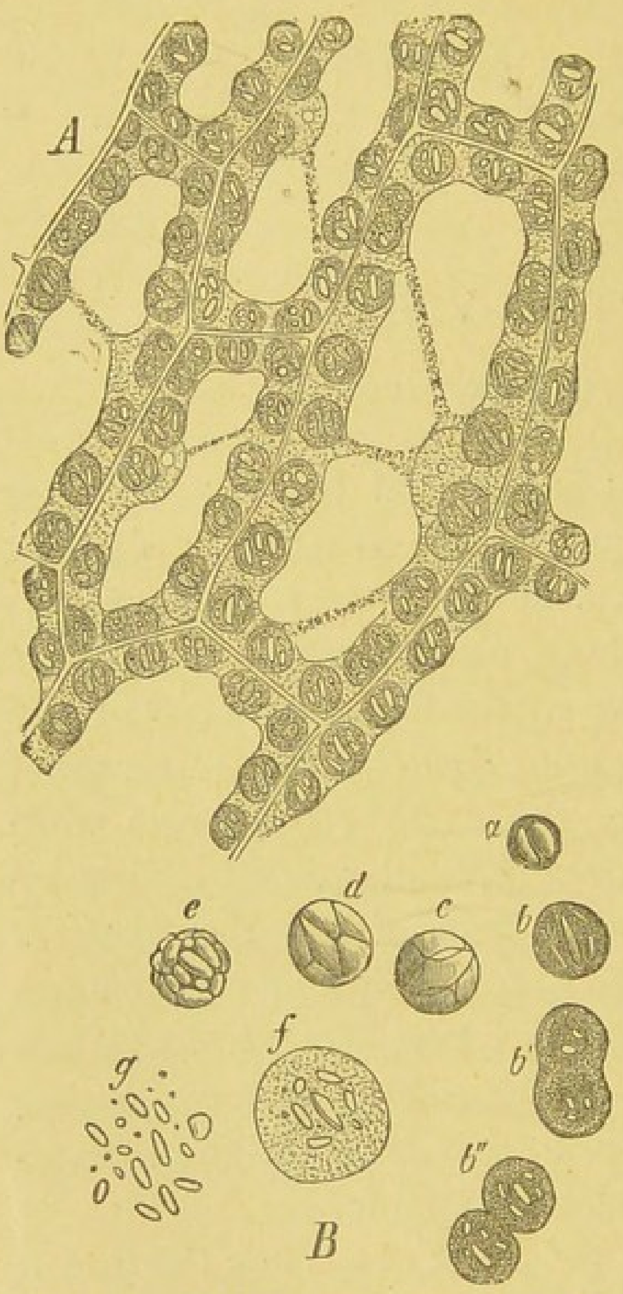


FIG 63.—Chlorophyll Granules in Leaf-cells (magnified 550 diameters).

A Granules of chlorophyll, with starch grains imbedded in the protoplasm of the cells.
B. Separated granules. *a*, *b*, young granules; *b'*, *b''*, granules dividing; *c*, *d*, *e*, old granules; *f*, granule swollen by water; *g*, starch granules in which water has destroyed the chlorophyll. (After Sachs.)

For, remarks Professor Sachs, 'as all animals are devoid of chlorophyll - containing organs, and are thus unable to form organic substance from carbon dioxide and water, although they build up their bodies from such substance, it follows obviously that the substance of the bodies of all animals is originally produced in the chlorophyll cells of plants. The few lower animals which apparently contain chlorophyll—certain *Infusoria*, *Sponges*, and *Planariæ*[1]—contain chlorophyll as a matter of fact, not as a proper constituent of the body, but, as Brandt has recently shown, have vegetable cells (Algæ) containing chlorophyll in their bodies; by means of the assimilation of these green bodies such animals may be nourished under certain circumstances.'[2]

Grant Allen has marshalled the facts in support of the priority of plants in a paper of great force and clearness, which has apparently received but scant attention from biologists.[3] He submits that as the solar rays are, in the absence of chlorophyll, powerless to set up the separative action resulting in the material on which alone life can be sustained, the inference is obvious—no chlorophyll, no life. In other words, life being due to energy radiated from the sun, which energy is inoperative without chlorophyll, protoplasm *plus* chlorophyll is the physical basis of life.

Against this we have the opinion of authorities of the rank of Professor Ray Lankester among zoologists, and of Thiselton Dyer among botanists, that the earliest protoplasm was destitute of chlorophyll. They contend that since chlorophyll is a modification of certain parts

[1] The following list of chlorophyllian animals has been drawn up by Professor Ray Lankester:—

Foraminifera.
Radiolaria.
Rhaphiophrys viridis.
Heterophrys myriapoda.
Infusoria.
Stentor Mulleri, &c.
Spongida.
Spongilla fluviatilis.
Cœlentera.
Hydra viridis.
Anthea smaragdina.
Vermes.
Mesostomum viride.
Bonellia viridis.
Chætopterus Valenciennesii.
Crustacea (Isopoda).
Idotæa viridis.

[2] Sachs, pp. 298-99.

[3] *Gentleman's Magazine*, June 1885, art. 'Genesis.'

of the protoplasmic cells, it is not a thing of primary origin, but a later acquirement slowly attained. Both authorities incline to regard certain forms of fungi as representing 'more closely than any other living forms the original ancestors of the whole organic world[1] . . . which existed before plants possessed chlorophyll at all.' But fungi 'draw their nutriment from compounds derived from other organisms, and therefore in a higher state of aggregation than those the green plants make use of, so far approaching animals in the mode of their nutrition.'[2] That is to say, fungoids are like animals; they use up the energy which the plants accumulate, and fill a secondary place in the succession of life-forms. The strength of the argument in support of plant-priority lies in this, that *viewing life as a product of Power operating under its separating action of Energy upon Matter*, an energy-storing organism

[1] *Encyclop. Brit.*, arts. 'Protozoa,' p. 832, and 'Biology,' p. 691.

[2] 'Looking back through the prodigious vista of the past, *I find no record of the commencement of life*, and therefore I am devoid of any means of forming a definite conclusion as to the conditions of its appearance. Belief, in the scientific sense of the word, is a serious matter, and needs strong foundations. To say, therefore, in the admitted absence of evidence, that I have any belief as to the mode in which the existing forms of life have originated, would be using words in a wrong sense. But expectation is permissible where belief is not; and if it were given me to look beyond the abyss of geologically recorded time to the still more remote period when the earth was passing through physical and chemical conditions, which it can no more see again than a man may recall his infancy, I should *expect to be a witness of the evolution of living protoplasm from not-living matter.* I should expect to see it appear under forms of great simplicity, *endowed, like existing fungi, with the power of determining* the *formation of new protoplasm from such matters as ammonium carbonates, oxalates and tartrates, alkaline and earthy phosphates, and water, without the aid of light.* That is the expectation to which analogical reasoning leads me; but I beg you once more to recollect that I have no right to call my opinion anything but an act of philosophical faith.'—Huxley's *Critiques and Addresses*, p. 238. (The italics are mine.)

must have come first. If the first protoplasm lacked chlorophyll, it had within it the possibilities which permitted its secretion at an early stage; it was, to use an unavoidably long word, chlorophyllaceous. The ques-

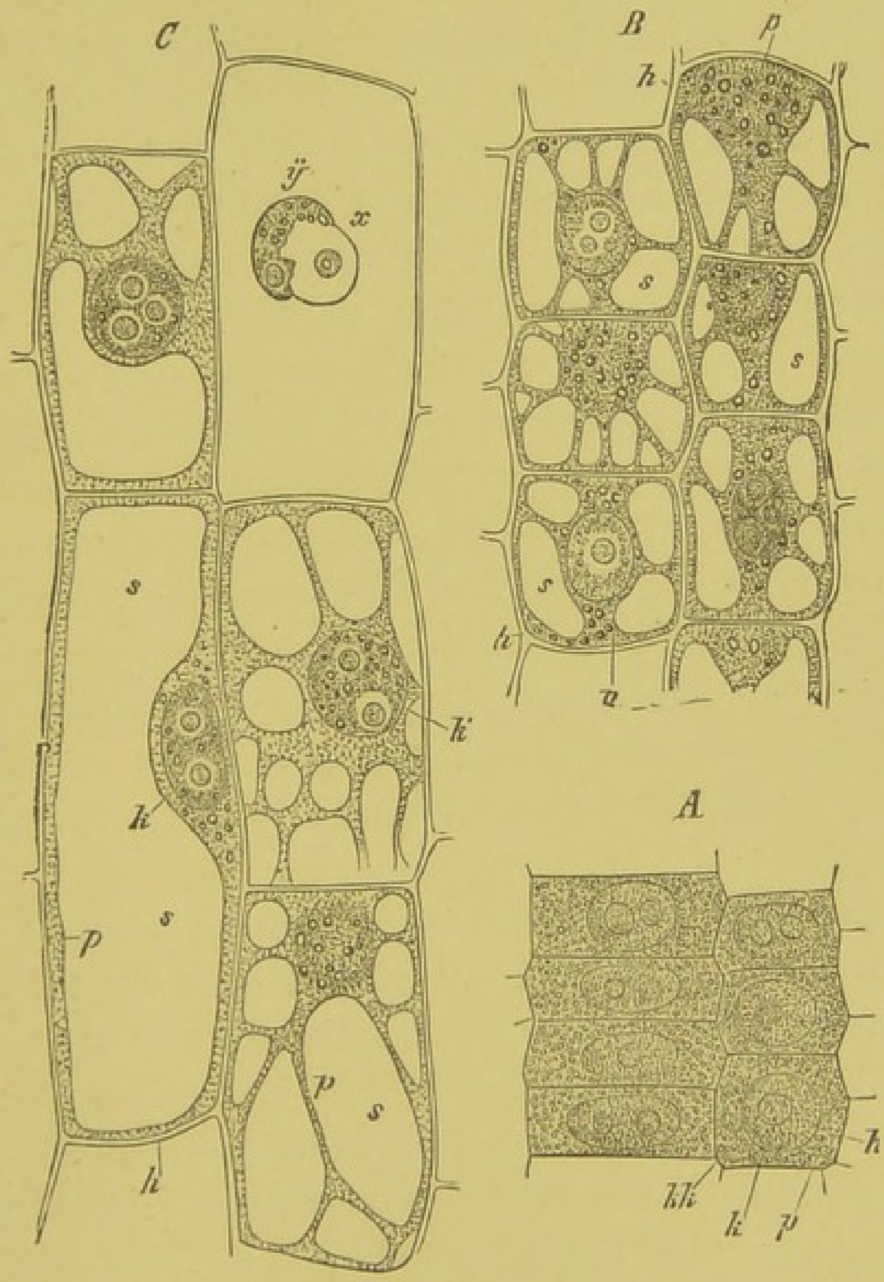


FIG. 64.—Cells of Root of Fritillary (magnified 550 diameters).

A. Very young cell from near apex.
B. From two mm. above it.
C. From about eight mm. *h*, cell-wall; *p*, protoplasm; *k*, nucleus; *kk*, nucleoli; *s*, vacuoles and cell-sap cavity. (After Sachs.)

tion, however, is of no serious importance in view of the common evolution of living things, and we may pass to less debatable ground in inquiry into the causes which have developed them in countless variety from specks of relatively formless protoplasm.

The cell is the structural starting-point of all life. The nucleus which it encloses is the result of the first visible approach of protoplasm to unlikeness of parts, and is the chief centre of activity. Every cell arises by separation from a pre-existing cell, and every living organism is made up of one cell or of many cells. The single cell of which the lowest organisms are composed does everything appertaining to life: it feels, moves, feeds, and multiplies. In the complex or many-celled organisms these functions are divided among the cells, each of which is independent, but nevertheless adapts itself for the work it has to do, acting in common with its fellow-cells. Division of labour causes difference of structure—stem, root, sap, leaf, and seed in the plant; bone, muscle, nerve-tissue, blood, and egg in the animal: all are communities of cells of astounding minuteness variously modified. The organism is the sum of life of all the cell-units.

The one-celled forms increase by division. Growth is the balance of repair over waste; and when through assimilation of food into its substance the cell reaches a certain size, the force of cohesion is overcome by the release of the energy derived from food, and the cell divides equally at the kernel or nucleus. The slimy protoplasm distributes itself around each nucleus as the two part company, to grow and divide again in like manner *ad infinitum.* To these lowest Protozoa we may apply the words, 'thou art the same, and thy years shall have no end,' at least till all life here has end; for they were the Alpha, and may be the Omega, in the earth's life-history; neither is one before nor after the other, since there is no descent amongst them, but only lateral multiplication. In many Protozoa a small portion of the parent is detached—a process known as generation by budding; but this and other modes of whole or partial fission are classed together as reproduction by multiplication.

The next stage in structure is when the cells in

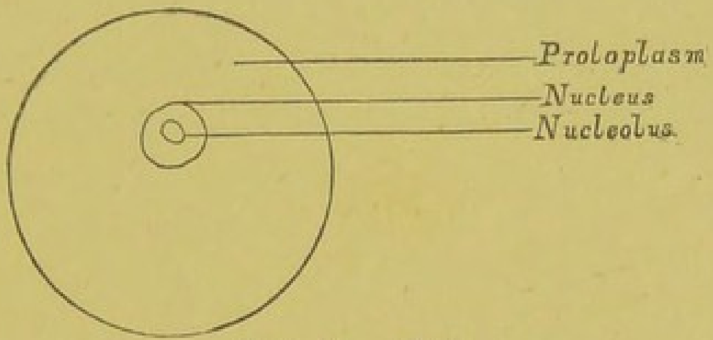


FIG. 65.—Cell.

dividing remain, to their common advantage, grouped together, as in all animals above the Protozoa.

The cells divide[1] in definite order into two, then into four, eight, sixteen, and so on, clustering together in a

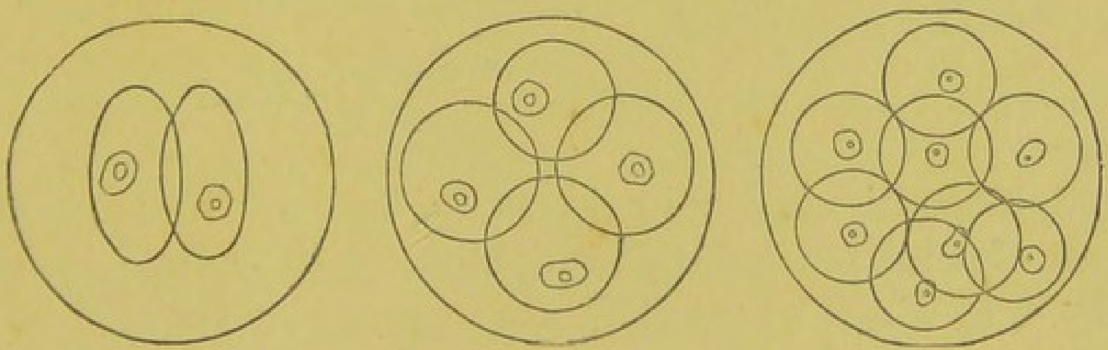


FIG. 66.—Stages of Cell-division.

morula, or mulberry-like mass, in which a cavity filled with fluid is formed, the cells being parted and driven to the surface. Mutual pressure, as they continue to subdivide, causes them to flatten and range themselves

[1] Cell-division does not extend to the food-yolk which the eggs of birds, reptiles, and many other animals contain for the nutriment of the embryo.

side by side in a single layer, forming what is called a blastosphere (Gr. *blastos*, a bud). By a process which is somewhat obscure (for we are dealing with the movements of very minute bodies), but which corresponds to the conversion of a small india-rubber ball, having a pinhole in it, into a two-walled cup by pushing it in with the finger, the single-layered sphere becomes changed into a double layered hood- or horseshoe-like structure, called a gastrula (Gr. dim. of *gaster*, stomach).[1] The

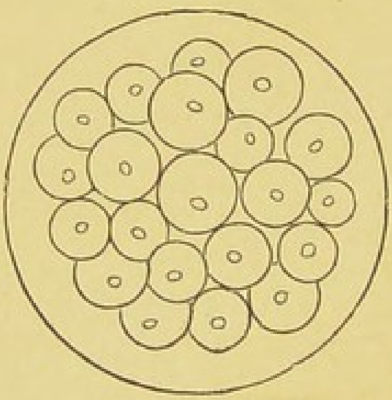


FIG. 67.—Morula Stage.

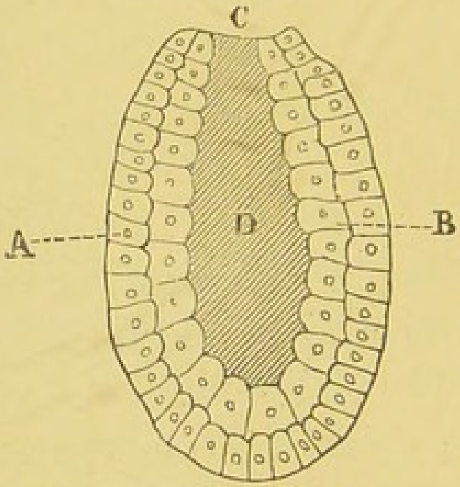


FIG. 68.—Gastrula Stage.

A, upper cell layer; B, lower cell layer; C, primitive mouth; D, body-cavity.

simpler stationary animals, as sponges and polyps, do not advance beyond this stage, but in all animals above them, in which bilateral structure, probably through free movement in a given direction, is developed, a third layer larger and more complex arises. The other two layers apparently take an equal share in its formation, and from its subdivision the greater number of organs of the body be it of a worm or a man, are developed. Passing over much technical detail, it must suffice to say that the upper layer gives rise to the skin, the

[1] On the variations in the gastrula type, see Hæckel's *Evolution of Man*, i. 231, and plates 2 and 3, pp. 240–2.

nervous system, and organs of sense; the lower layer to the intestinal canal and appendages; and the middle layer to the general skeleton, the heart, and other important organs. Thus does the future animal emerge from the gastrula stage, and pass into the embryo stage, until an advanced period of which the embryos of vertebrates, whether fish, tortoise, dog, ape, or man, cannot be distinguished from one another, so close are the likenesses both in outward form and structure.

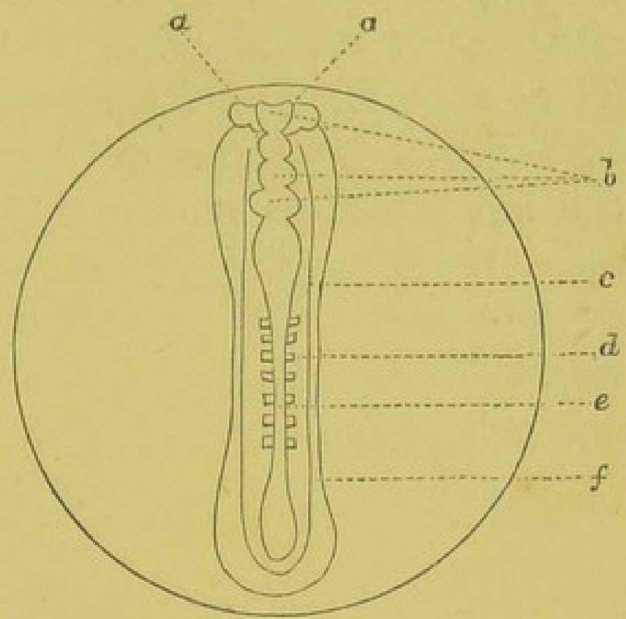


FIG. 69.—Embryo Stage.

a, *b*, brain vesicles; *c*, blastoderm; *d*, primitive vertebræ; *e*, medullary cord; *f*, upper layer or body-wall.

All plants and animals above the lowest are reproduced by the agency of special cells, the impregnation of the nucleus of the germ or egg-cell of the female by the nucleus of the sperm-cell of the male being necessary to set up the series of changes which result in the future animal.[1] There are numerous variations in the organs of reproduction, but whatever unlikenesses exist in detail do not affect this general statement; alga and oak,

[1] At the present time the cell theory, in consequence of recent investigations into the structure and metamorphosis of the *nucleus*, is undergoing a new development of great significance, which, among other things, foreshadows the possibility of the establishment of a physical theory of heredity on a safer foundation than those which Buffon and Darwin devised. (Huxley, art. 'Science,' *Reign of Queen Victoria*, ii. 376.) 'The pith of the matter is that structural elements of the male nucleus appear to be associated with those of the female in the fecundated ovum and all its derived cells.' (Extract from a letter from Professor Huxley to the Author.) And cf. Wiedersheim's *Comp. Anat. of Vertebrates*, pp. 4, 300.

sponge and man, are alike developed from germs variously called spores, sacs, seeds, and eggs. The structure of the fertilised egg of the parent determines the structure of the offspring, which to some extent reproduces the series of forms through which its ancestors passed as it progresses to its adult state. In other words, the individual, as it develops from the egg-cell, epitomises the history of the ancestral forms of its species.

The transmission of parental form and structure, as well as of mental character, to offspring, being clear, the question suggests itself, How have variations, resulting

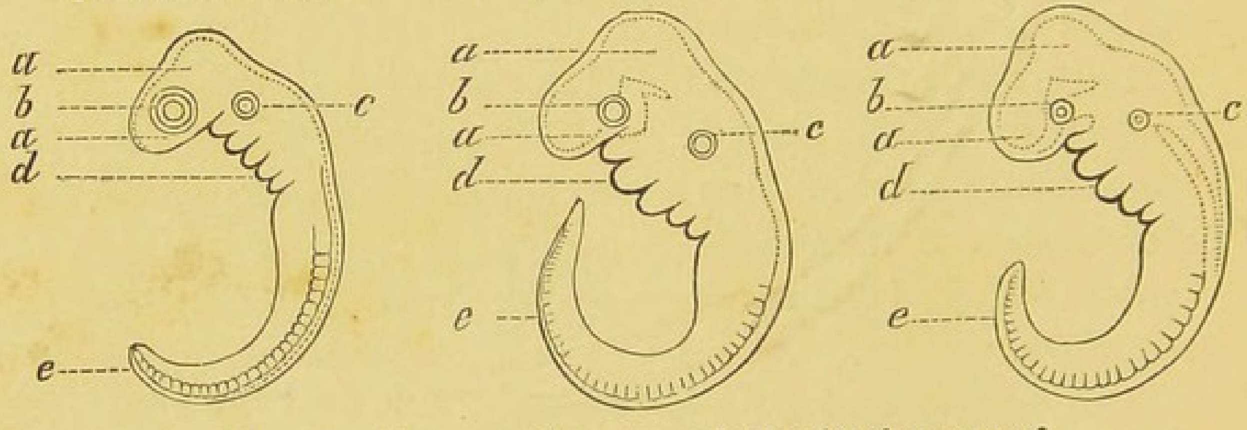


FIG. 70.—Corresponding stages in the development of
Fish Dog Man
a, brain ; *b*, eye ; *c*, ear ; *d*, gills ; *e*, tail.

in millions of past and present species of plants and animals, arisen ?

Professor Huxley says that 'the great need of the doctrine of evolution is a theory of variation.'[1] When, however, we consider the mobility and minute complexity of structure of living things invisible to the naked eye, and their response to every shiver of energy from without, we have sufficing factors to produce unstableness which will result in unlikeness of parts. Given a body which, although a minute speck, contains billions of molecules performing complicated movements

[1] *Critiques and Addresses*, p. 299 ; and cf. *Science and Culture*, p. 307.

of immense rapidity, and sensitive in an inconceivable degree to the play of vibrations impinging upon them at the rate of hundreds of trillions per second, would not the marvel be if these quivering particles of the structure, shaken by energies within, and by still more potent energies without, did not undergo continuous redistribution?[1]

The position may be thus stated:—The organism has—(1) Infinite complexity of structure; (2) inherited tendencies; (3) mobility and continuous motion, therefore capacity to vary. (4) Variations are induced by the surroundings on which, as vehicles of energy, life depends; (5) when the surroundings change, the organism adapts itself or not to the change; (6) such as fail to adapt themselves perish; (7) such as adapt themselves vary in greater or lesser degree; (8) these variations, being transmitted, are stages in the development of different life-forms. To put the matter briefly, likenesses are inherited, variations are acquired.

This brings us to the theory linked with Darwin's name, which explains by what operation of natural causes the highest plants and animals have descended by true generation and slow modification from less complex life-forms, and these in ever-lessening degrees of complexity and unlikeness, until the common starting-point from the lowest or one-celled organism is reached.

Following Lyell's method of explaining the past by

[1] 'What organism can pass through life without being subjected to more or less new conditions? What life is ever the exact fac-simile of another? And in a matter of such extreme delicacy as the adjustment of psychical and physical relations, who can say how small a disturbance of established equilibrium may not involve how great a rearrangement?'—*Luck or Cunning?* p. 273, by Samuel Butler.

agencies still in operation, and adapting hints from Malthus[1] and other writers in the clearing up of questions suggested by observations extending over many years, Darwin propounded a theory which, in the judgment of every biologist unfettered by predilections or prejudices, accounts in large degree for the origin of species.[2]

[1] See Darwin's Letter to Hæckel, *Hist. of Creation*, i. 134; also Darwin's *Life and Letters*, i. 83.

[2] 'I am satisfied that natural selection is a true cause; and whatever may be the final result of our present inquiries—whether animated nature be derived from one ancestral source or from many—the publication of the *Origin of Species* will none the less have constituted an epoch in the history of biology. But how far the present condition of living beings is due to that cause; how far, on the other hand, the action of natural selection has been modified and checked by other natural laws, by the unalterability of types, by atavism, &c.; how many types of life originally came into being, and whether they arose simultaneously or successively—these and many other similar questions remain unsolved, even admitting the theory of natural selection.'—Lubbock's *Origin, &c., of Insects*, p. 83; and cf. Spencer's *Factors of Organic Evolution*, *passim*, for discussion of the limitations of Darwin's theory.

CHAPTER IX.

THE ORIGIN OF SPECIES.

THE history of the slow but sure preparation of the scientific world for the reception of a theory displacing the old notions of the fixity of species—the record of the kings and prophets who foreknew the coming day, but who died 'without the sight'—are told by Grant Allen in his monograph on 'Charles Darwin.' Commending the reading of that book, especially of the fifth chapter, as superseding the need for repeating the story here, we may pass to a rapid summary of the evidence as to the mutability of species.

It should be noted at the outset that 'species' is a convenient term to denote groups of individuals having certain characters in common, but that no one definition of 'species' has satisfied all naturalists. The term 'variety' is almost equally difficult to define; but practically, when a naturalist can unite by means of close intermediate links any two forms, he treats the one as a 'variety' of the other, ranking the most common, but sometimes the one first described, as the 'species,' and the other as the 'variety.'[1]

1. *No two individuals of the same species are exactly alike; each tends to vary.* Of this obvious fact every

[1] Cf. *Origin of Species*, p. 33, 6th ed.

species, with their several varieties, from man downwards, supplies abundant illustration. Of the hundreds of thousands of faces that we meet in the course of the year in any large city, each has some feature to mark it from every other; the practised eye of the shepherd recognises each sheep in his flock, of the Laplander each reindeer among the herd crowded 'like ants on an anthill,' and of the gardener each hyacinth among a thousand bulbs. Children of the same parents vary in size, feature, complexion, character, and constitution, often very obviously, but sometimes too obscurely for cursory detection; and this law of general resemblance, with more or less variation in detail, applies to all animals and plants.[1] The tendency to vary, which in our ignorance of its ultimate causes we say 'inheres' in the organism, and of which what are called 'sports' furnish the best illustration,[2] is fostered by the change of condition in which the animal or plant may be placed, as shown in its more marked tendency to vary in a domesticated than in a wild state. For example, when the common ringed snake, which in its natural state is oviparous, is confined in a cage in which no sand is strewn, it becomes viviparous.

Throughout these pages stress has been laid on the fact that the organ adapts itself to the work which it has to do; hence changes of structure in a species are necessitated to fit it for an altered state of things. This implies increased or lessened activity on the part of certain organs, the use or disuse leading, under the action of natural selection working through long ages, to their development or suppression.

2. *Variations are transmitted, and therefore tend to*

[1] Cf. *Animals and Plants under Domestication*, i. 445; ii. 238, 2nd ed.

[2] *Origin of Species*, p. 8: *A.* and *P.*, i. 397.

become permanent. In other words, what is peculiar to the parent plant or animal reappears in the offspring. This is known as 'descent with modification,' the import of which will be shown later on.

3. *Man takes advantage of these transmitted unlikenesses to produce new varieties of plants and animals.* He selects certain individuals possessing variations which he wants to preserve, and allows only them to breed together, by which means in the course of time he produces varieties differing greatly from the parent form with which he started. The stock example of this is the pigeon. All our domestic pigeons, exceeding in number a hundred well-marked races, are descended from the ordinary blue rock pigeon of the European coasts. Variations as marked as the fan-tail, the tumbler, and the pouter have been produced by the breeder selecting birds with certain peculiarities, and choosing from each successive brood only those which exhibited the same peculiarities in more marked form, the result being, after a long time, the production of entirely new varieties. The same method has given us different races of dogs, sheep, horses, and other domestic animals. The fleetest horses are chosen to breed together; then the fleetest offspring of these in succession, until horses are produced whose swiftness far exceeds that of the originally selected pairs. In the development of the cart-horse, strength, not speed, is the quality selected; while in the marked unlikeness between dogs we see the result of artificial selection in producing such varieties as the bloodhound, the terrier, and the spaniel. What varieties in flowers, vegetables, and fruits—as, for example, the development of the numerous kinds of apples from the small, sour crab species—the like method has induced, is too well known to need detailed reference here. When we see how

successfully this choice of slight variations has brought about plants and animals best adapted to the service of man, we may desire the time when man shall so realise his duty to the race that the multiplication of the rickety, both physically and morally, will cease, and only men and women of the highest type reproduce their kind.

Now the important work which Darwin did was to show that what man does on a small scale within a limited range of time, nature does on a large scale during countless epochs; with the further difference that the action of nature is not purposive, as is the action of man, but involved in the necessities of things. We may quote what Darwin says on this matter:—

'As man can produce, and certainly has produced, a great result by his methodical and unconscious means of selection, what may not natural selection effect? Man can act only on external and visible characters: Nature, if I may be allowed to personify the natural preservation or survival of the fittest, cares nothing for appearances, except in so far as they are useful to any being. She can act on every internal organ, on every shade of constitutional difference, on the whole machinery of life. Man selects only for his own good: Nature only for that of the being which she tends. Every selected character is fully exercised by her, as is implied by the fact of their selection. Man keeps the natives of many climates in the same country; he seldom exercises each selected character in some peculiar and fitting manner; he feeds a long and a short-beaked pigeon on the same food; he does not exercise a long-backed or long-legged quadruped in any peculiar manner; he exposes sheep with long and short wool to the same climate. He does not allow the most vigorous males to struggle for the females

He does not rigidly destroy all inferior animals, but protects during each varying season as far as lies in his power, all his productions. He often begins his selection by some half-monstrous form, or at least by some modification prominent enough to catch the eye or to be plainly useful to him. Under Nature the slightest differences of structure or constitution may well turn the nicely balanced scale in the struggle for life, and so be preserved. How fleeting are the wishes and efforts of man! how short his time! and, consequently, how poor will be his results, compared with those accumulated by Nature during whole geological periods! Can we wonder, then, that Nature's productions should be far "truer" in character than man's productions; that they should be infinitely better adapted to the most complex conditions of life, and should plainly bear the stamp of far higher workmanship?'[1]

4. *More organisms are born than survive.* To quote Darwin once more, 'there is no exception to the rule that every organic being naturally increases at so high a rate that, if not destroyed, the earth would soon be covered by the progeny of a single pair. Even slow-breeding man has doubled in twenty-five years, and at this rate in less than a thousand years there would literally not be standing room for his progeny.'[2] If all the offspring of the elephant, the slowest breeder known, survived, there would be in seven hundred and fifty years nearly nineteen million elephants alive, descended from the first pair. If the eight or nine million eggs which the roe of a cod is said to contain developed into adult cod-fishes, the sea would quickly become a solid mass of them. So prolific is its progeny after progeny, that the common house-fly is computed to produce twenty-one

[1] Cf. *Origin of Species*, p. 65. [2] *Ibid.*, p. 51.

millions in a season; while so enormous is the laying power of the aphis, or plant-louse, that the tenth brood of one parent, without adding the products of all the generations which precede the tenth, would contain more ponderable matter than all the population of China, estimating this at five hundred millions!

It is the same with plants. If an annual plant produced only two seeds yearly, and all the seedlings survived and reproduced in like number, one million plants would be produced in twenty years from the single ancestor. Should the increase be at the rate of fifty seeds yearly, the result, if unchecked, would be to cover the whole globe in nine years, leaving no room for other plants. The lower organisms multiply with astonishing rapidity, some minute fungi increasing a billionfold in a few hours, while the protococcus, or red snow, multiplies so fast as to tinge many acres of snow with its crimson in a night. But we need not give further examples of this fecundity whereby nature, 'so careless of the single life,' secures the race against extinction.

5. *The result is obvious: a ceaseless struggle for food and place.* In that struggle the race is to the swift, and the battle to the strong; the weaker, be it in brain or body, going to the wall, the vast majority never reaching maturity, or, if they do arrive at it, attaining it only to be starved or slain. As, amongst men, competition is sharper between those of the same trade, so throughout the organic world the struggle is less severe between different species than between members of the same species, because these compete most fiercely for their common needs—plants for the same soil, carnivora for the same prey. But whether the battle is fought between allied or unallied species, the victory is never doubtful; it is assured

to the plant or animal that has some advantage, however slight, which its opponent lacks. Among plants growing in a dry soil, those whose leaves have thicker hairs upon them will absorb more moisture from the air than plants with less hairy leaves, and, competing successfully with these, will survive to transmit their advantageous variations. Again, such as are better able to resist the depredations of burglarious insects by protection of thorny or prickly stems, or by nauseous taste, will thrive and multiply, while plants lacking these defences dwindle and become extinct. So with those which by showy colours of their flowers and sweeter nectar attract insects whose visits are desired as carriers of pollen from stamens to pistils. These secure propagation, while plants less attractive remain barren. The birds that are strongest on the wing reach the land whither they migrate, while the weaker perish by the way. The lions of sharper sight and more supple spring, the wolves of keener scent, secure their prey, while the feebler members starve. It is with man as with the organisms below him : the quickest in intellect, and those with greater power of endurance, distance the weak or the stupid, who fall behind, and finally slip out of the ranks altogether. Sometimes the area of struggle is narrowed, and survival secured by retreat, as of the sloth to trees, and of digging and burrowing animals underground.

The subtlety and variety of the conditions upon which natural selection seizes escape the keenest observers. Of their success, however, in tracing the varying fortunes of species Darwin gives a striking illustration in his explanation of the absence of wild oxen and horses in Paraguay. This is due to the action of a small fly which lays its eggs in the navel of newly born calves and foals, the maggots hatched from the eggs causing the death of the young animals. Now, supposing this parasitic fly to be destroyed by an insect-eating bird, oxen and horses would abound in a wild state, and, as they would eat certain plants, the vegetation would be altered, and these changes in the flora and fauna would involve changes of increasing complexity.

The interrelation between the proportion of old maids and an abundance of red clover is not, *primâ facie*, quite as obvious. But it may be proved in this wise. The clover is fertilised by humble-bees, the number of which is determined by the number of field-mice, which destroy their nests. The number of field-mice, again, is determined by the number of cats, and the number of these, finally, by the number of old maids who keep them! Therefore, as red clover is excellent food for cattle, and cattle are excellent food for man, elderly spinsters are benefactors to their species!

The important part played by colour and mimicry[1] in the struggle for life has been demonstrated by Darwin, Wallace, Bates,[2] Belt, and other acute observers. The

[1] This word is not used as implying conscious imitation, but as conveniently grouping resemblances which, in the degree that they are protective or helpful, give advantage and security to the individual exhibiting them.

[2] *Contributions to an Insect Fauna of the Amazons Valley* (Trans. Linn. Soc., November 1861), of which Darwin says, in a letter to Mr. Bates (*Life and Letters*, ii. 391): 'It is one of the most remarkable and admirable papers I ever read . . . solving a wonderful problem.' So delightful a paper should not be allowed to lie buried in a learned society's Transactions, for the illustrations of mimetic analogies between members of widely distinct families and between insects and their surroundings which it gives are, as Darwin adds, 'truly marvellous.' Such are those of moths, whose wings are coloured and veined like the fallen leaves on which they lie motionless, of hunting-spiders which mimic flower-buds, and of large caterpillars which resemble poisonous snakes.

more closely that an animal approximates in form and hue to its surroundings, the easier does it escape detection by its pursuer, and the easier does it avoid the notice of the prey which it pursues. In conformity with this we find that most animals are protectively coloured, while those which are not are so constituted as to render such protection needless. As illustrative of the operation of natural selection in this matter, we may borrow an admirable example from Grant Allen's 'Charles Darwin.'

'In the desert, with its monotonous sandy colouring, a black insect or a white insect, still more a red insect or a blue insect, would be immediately detected and devoured by its natural enemies, the birds and the lizards. But any greyish or yellowish insects would be less likely to attract attention at first sight, and would be overlooked as long as there were any more conspicuous individuals of their own kind about for the birds and lizards to feed on. Hence in a very short time the desert would be depopulated of all but the greyest and yellowest insects; and among these the birds would pick out those which differed most markedly in hue and shade from the sand around them. But those which happened to vary most in the direction of a sandy or spotty colour would be most likely to survive, and to become the parents of future generations. Thus, in the course of long ages, all the insects which inhabit deserts have become sand-coloured, because the least sandy were perpetually picked out for destruction by their ever-watchful foes,

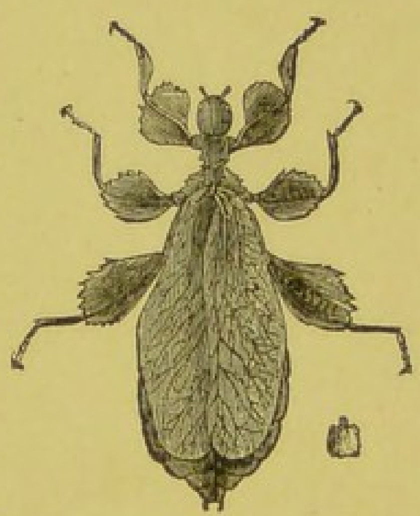


FIG. 71.—Leaf Insect and its Egg.

while the most sandy escaped, and multiplied and replenished the earth with their own likes.' [1]

Thus, then, is explained the tawny colour of the larger animals that inhabit the desert, the stripes upon the tiger, which parallel with the vertical stems of bamboo, conceal him as he stealthily nears his prey, the brilliant green of tropical birds, the leaf-like form and colours of certain insects, the dried twig-like form of many caterpillars, the bark-like appearance of tree-frogs,

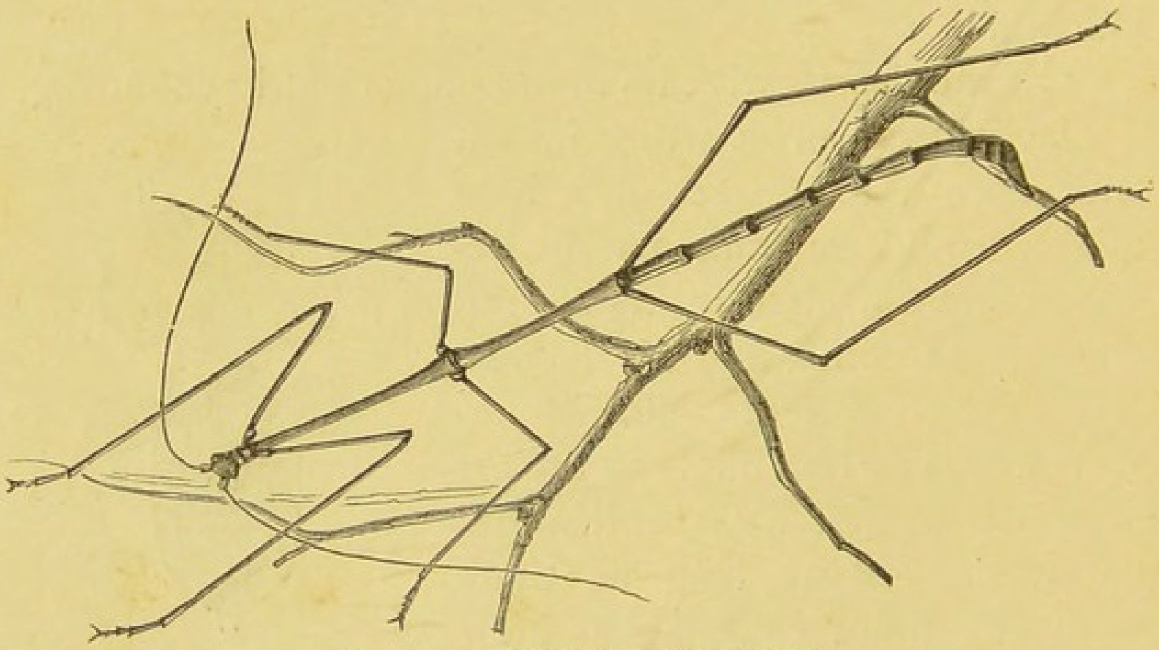


FIG. 72.—Walking-stick Insect.

the harmony of the ptarmigan's summer plumage with the lichen-coloured stones on which it sits, the dusky colour of creatures that haunt the night, the bluish transparency of animals which live on the surface of the sea, the gravel-like colour of flat-fish that live at the bottom, and the gorgeous tints of those that swim among the coral reefs.

Among the secondary causes of modification of species among animals Darwin gives prominence to 'sexual selection,' or the struggle between males for the

[1] P. 97; and cf. G. A.'s art. 'Mimicry,' *Encycl. Brit.* xvi. p. 341.

possession of females; the result being that the stronger males secure mates, and transmit the qualities which have given them the mastery to their offspring. Every farm-yard combat illustrates the truth of Gilbert White's prose [1] and Schiller's poetry:—

> Meanwhile, until Philosophy
> Sustains the structure of the world,
> Her workings will be carried on
> By hunger and by love,

and among the larger animals—as stags and deer, and notably sea-lions [2]—the deadliest combats take place at certain seasons for possession of the females. But there is competition less fierce in character, if not less fatal to the weaker or unendowed, strength giving place to grace of form, brightness of colour,[3] and witchery of song, the females making choice of the male who by his beauty of form, colour, odour, or voice, attracts them most, or who, as among the highest species, has wealth or good social position. These last condone infirmity and ugliness.

It is clear that sexual selection largely explains the development of special features, which, transmitted in in-

[1] White's *Selborne*, letter xi., to Hon. Daines Barrington.

[2] Cf. Elliot's *An Arctic Province*, ch. x., for a vivid account of the battles between the males for priority on the breeding-grounds of the Pribylov Islands.

[3] 'As colours seem to be the chief external sexual distinction in many birds, these colours do not take place till sexual attachments begin to obtain. And the case is the same in quadrupeds, among whom, in their younger days, the sexes differ but little; but as they advance to maturity, horns and shaggy manes, beards and brawny necks, &c. &c., strongly discriminate the male from the female. We may instance still farther in our own species, where a beard and stronger features are usually characteristic of the male sex: but this sexual diversity does not take place in earlier life; for a beautiful youth shall be so like a beautiful girl that the difference shall not be discernible.'—White's *Selborne*, letter vi., to Hon. Daines Barrington.

creasing degree through a series of generations, have contributed to the survival of the fittest. For whatever these features may be, whether weapons of defence or attack, plumage and song of birds, colour of butterflies, perfume as of the musk-deer, or acrid taste as of the toad, their presence is explained by their utility, since, as with the flowers and scents wherewith plants attract insects to secure fertilisation, the primary function of colour, form, ornament, and whatever else has given advantage to plant or animal over its competitors, is its service to the organism, and not, as man in his fond delusion has assumed, the delight or profit which it has given to him.

6. *Natural selection tends to maintain the balance between living things and their surroundings. These surroundings change; therefore living things must adapt themselves thereto, or perish.*

In treating of the obscurity which hangs around the ultimate causes of variation, stress has been laid on the ceaseless and elusively complex interplay between organisms and the medium which surrounds, quickens, and nourishes them. As Gegenbaur remarks,[1] the energies which cause change in the organism either lie without it, or for the most part are to be sought for without it, the range of variation of the plant being, by reason of its fixed conditions, limited as compared with that of the locomotive animal.

It has been shown already that the *touch* of the medium was the first quickener of variation in the rise of the earliest approach to unlikeness at the surface, as in the membranous film which envelops the lowest life-

[1] *Comp. Anat.* (English ed.), p. 57. 'I have been led to place somewhat more value on the definite and direct action of external conditions.' Letter to Carus, May 1869, *Darwin's Life and Letters*, iii. 109; and cf. letter to Moritz Wagner, October 1876, *ibid.* p. 159.

forms, and, among the higher animals, in the gradual specialisation of lines of communication—the nervous system and sense organs—with the outer world from infoldings of the skin. The diffused sensitiveness to smell, light, and sound became localised, the sense of touch remaining general over the body-surface, except where horny skin is secreted. Obviously, therefore, the tendency to vary which inheres in living things being stimulated by interaction between them and their surroundings, the degree in which variations are useful to living things—*i.e.* in enabling them to win in the universal struggle for food and place—determines, under the action of natural selection, their survival.

The slow but ceaseless changes in things without have involved adaptive changes in all organisms except the lowest. Seemingly, all things remain as they were from the beginning. The range of our experience is too narrow, the time since scientific observation of nature began is comparatively so recent, the changes in living things often so beyond direct detection, that we cannot wonder at people's reluctance to accept the theory that the countless species of plants and animals which have succeeded one another have a common descent, through infinite modification, from structureless germs. And, in fact, not only is life vastly older than any record of it, but the fossil-yielding rocks supply no key to the origin of the leading groups, whose representative types of to-day are so little altered that every fossil as yet found can be put into existing classes. Huxley remarks that 'the whole lapse of geological time has thus far yielded not a single new ordinal type of vegetable structure;' and although 'the positive change in passing from the recent to the ancient animal world is greater, it is still singularly small.'[1] The variation in ordinal type of animal structure is only about ten per cent. of the whole.

Yet we know that nothing is rigid; the earth records the gradual ascent of life-forms in structure, and the changes in its crust, in a scripture that cannot be broken. The agencies within, and the far more potent agencies without, that have wrought those changes, pursue without pause their slow and sometimes sudden working. The earth itself speeds through space, heedless of the freight of life that throbs and struggles on its surface, and that at last is laid to sleep in its bosom; careens and brings the seasons in their sureness; spins and gives, unfailing, the glory of the sunrise and the sunset; and, in periodic changes of its orbit, crowns at one epoch its northern pole with vines and oaks and water-lilies, and at another epoch covers it with impassable ice.

Changes of climate and level, with the alterations in soil which they bring about, profoundly affect food and the power to obtain it. And the necessity for food being a strong—perhaps the strongest—stimulus to motion, the organism which the more readily adapts itself to the changed conditions, or is better equipped to resist them, wins in the struggle. The new functions to be discharged involve changes in structure, because the organs exist for the work which they have to do, not the work for the organs. Moreover, changes which arise in the structure are not limited to one part, the whole organisation being, in Darwin's words, 'so tied together during its growth and development, that when slight variations in any one part occur, and are accumulated through natural selection, other parts become modified.' Take, for example, the growth of the deer's antlers, which in some species attain a weight of seventy pounds in a few weeks. The

[1] *Lay Sermons*, p. 216.

increased supply of blood which this involves necessitates readjustment of circulation, and the increased weight which the skull has to bear necessitates more powerful muscles and ligaments, with increased strength of the bones to which they are attached. More food is needed to supply the energy thus expended, involving more active digestion, and therefore modification of the digestive organs. Again, in man the slow acquirement of an erect position led to flattening of the feet, and to projection of the heel as support; to altered position of the head with its added weight of brain, so as to be nicely balanced on the spine, which became peculiarly curved; and to the readjustment of a large number of muscles. Then there are the changes wrought after long lapses of time by use and disuse, in the one case leading to the development of organs, in the other case to their decline.[1] 'Thus I find,' Darwin remarks, 'in the domestic duck that the bones of the wing weigh less and the bones of the leg more in proportion to the whole skeleton than do the same bones in the wild duck; and this change may be safely attributed to the domestic duck flying much less and walking much more than its wild parents,'[2] or, more correctly, its wild ancestors. But there are many changes induced in organs by their use or disuse on the part of the animal which are not transmitted; they die with the individual in which they occur. Like mutilations of parts of the body, which are practised

[1] The question how far use and disuse are true causes of change of organic type has long exercised the attention of biologists, some among whom, notably Professor Weismann, contend that changes acquired by the individual are never transmitted. But the arguments as yet adduced by him leave his case not proven. The subject is, however, too technical for enlargement here. See article by the author in *Knowledge*, August, 1890.

[2] *Origin of Species*, p. 8, and cf. pp. 131, 401, 410; *Animals and Plants*, ii. 313, 345.

through successive generations of individuals, they are powerless to affect the type.

It is to natural selection that we must more often refer modifications which, appearing as relics of structure common to large groups, have a specious look of being due to individual use or disuse. Take the familiar example of the true whale. The epitome of its ancestry which the embryo presents reveals its descent from land mammals having short fore and hind limbs, scanty covering of hair, broad beaver-like tails, teeth of different shape, and well-developed sense-organs, especially of smell. These forefathers of the whale probably lived in marshy districts, and, being omnivorous, sought their food in both swamp and shallow water; but as conditions more and more adverse to life on land supervened, they were gradually modified under the action of natural selection into dolphin-like creatures, living in fresh water, and at last finding their way into the ocean, from which the huge sea-lizards of earlier epochs had disappeared, leaving these leviathans scope 'to play therein.' Hence are explained the adaptive changes of structure: the fore limbs were modified into flippers enclosed in a fin-like sac, but retaining the bones corresponding to like structures in other mammals, as in the arm of man, the wing of the bat, and the fore leg of the horse. Traces of the hind legs may be detected in a few species; the tail, which acted as a powerful swimming organ, became divided into two lobes; the head became fish-like in shape; the seven bones of the neck, common to most mammals, grew together; the skin became hairless; and the teeth, which appear in the young of the true whale but are never cut, gave place to hanging fringes of whalebone, in the meshes of which the animal entangles the minute organisms it feeds upon. In the seal, which is the modified descendant of land flesh-feeders, the hind legs have been developed, while the tail remains rudimentary.

The explanation is that both whales and seals are the gradually modified descendants of ancestors who, in virtue of their favourable adaptation to altered conditions, survived under the agency of natural selection, while the majority, being unfit or less adapted, perished.

Variety of readjustment to altered surroundings, through like causes, resulting in progress in some directions and in stagnation in other directions, is further evidenced in existing modifications of the common mammalian type. We find one large group—the plant-feeders—developing organs suited to their functions, as teeth for grinding instead of for tearing, large stomachs, and horny or bony structures for combat, the evolution of which in the deer's ancestry is recapitulated year by year in the individual from the boss to the noble branching antlers. In the flesh-feeders we find that higher intelligence which the stealthy or open pursuit of other animals required, economy of bulk, great muscular strength united to quickness of action, and teeth and claws adapted for attacking and readily seizing prey.

In both groups we find progression of parts which in the Primates, the group including man, are well-nigh stationary. Among this group, limbs, teeth, and organs of digestion have all been slightly modified, and no organs of defence or attack developed. The explanation is that these animals, being unable to compete with the larger mammals, took to an arboreal life, which induced few variations of bodily structure, the most important being opposable thumbs and great toes for grasping. But the need for alertness against foes sharpened their wits, and the need of combination quickened the social instincts, so that the energy which in the flesh-feeders and the plant-feeders was stored in limb and muscle was diverted in the Primates to development of brain. They thus escaped the limitations of one condition, which determined the development of lions and rhinoceroses in a given direction, and they preserved the power to adapt themselves to very diverse conditions. Whichever among the arboreal creatures possessed any favourable variation, however slight, in structure of brain and sense-organs, would secure an advantage over less favoured rivals in the struggle for food and mates and elbow-room. The qualities which gave them success would be transmitted to their offspring, the distance gained in one generation would be increased in the next, brain-power conquering brute force, and skill outwitting strength.

FIG. 73.—Gorilla walking.

(From Huxley's *Man's Place in Nature*, p. 49.)

And while some of them remained arboreal in habits, never moving easily on the ground, although making some approach to bipedal motion, as seen in the shambling gait of the man-like apes, others developed a mode of walking on the hind limbs which entirely set free the fore limbs as organs of support, and enabled them to be used as organs of handling and throwing. Whatever were the conditions which permitted this, the enormous advantage which it gave is obvious. It was the *making of man.* His bipedal and erect position involved exchange of tree-life for life on the ground, bringing him into new relations with his surroundings, and ultimately giving him the mastery over them.

We see in lower animals, as the elephant, the monkey, the opossum, and the parrot, that their power to grasp an object by reason of their prehensile organs, and thus to learn something about its nature, raises them in the scale of intelligence[1]; and when we find in man a yet more perfect instrument to carry out the behests of his brain, we may see in the interaction of brain and hand a main factor in his development. The structural differences between him and the man-like apes are insignificant; the impassable chasm lies in his larger and more complex thinking apparatus. The action of natural selection became restricted, except in minor changes, as of the jaw, to his mental faculties. Yet even in brain-structure the differences between him and the chimpanzee are slight when compared with the differences between the brain of the chimpanzee and the lemur. It is in the deeper furrows and the more intricate convolutions that the distinction lies; but even here the gap between civilised and savage man is greater than that between the savage and the man-like apes.[2] Therefore, in following evolution to its highest operations and results, the comparison lies between the several races of mankind. Darwin says that he does not believe it possible to describe the difference between savage and civilised man. 'It is the difference between a wild and tame animal; and part of the interest in beholding a savage is the same which would lead every one to desire to see the lion in his desert, the tiger tearing his prey in the jungle, and the rhinoceros wandering over the wide

[1] Cf. Spencer's *Principles of Psychology*, i. pp. 368–72.

[2] Cf. Huxley's *Man's Place in Nature*, p. 78; and his Note to chap. vii. of *Descent of Man*.

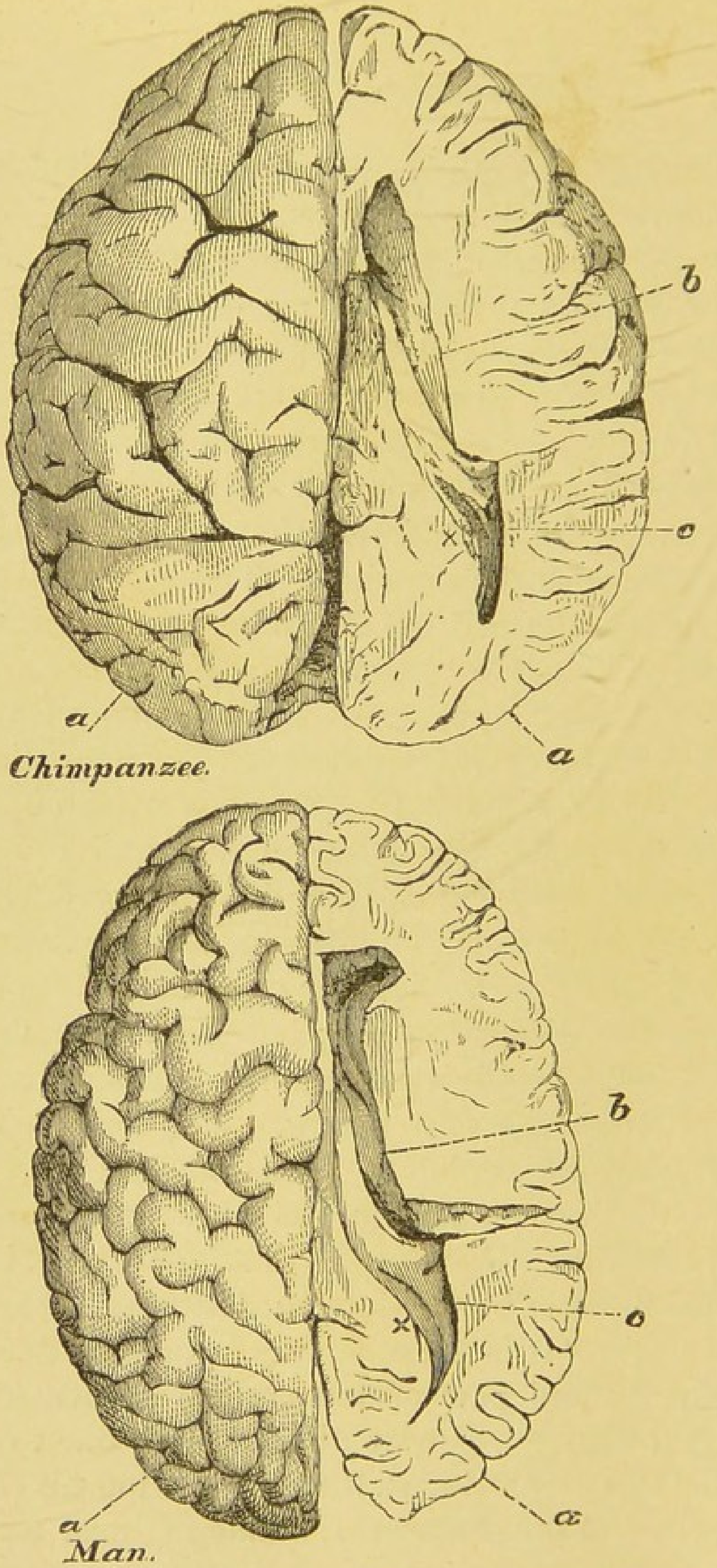


FIG. 74.—Hemispheres of Brain of Chimpanzee and of Man, showing relative proportions of the parts.

(From Huxley's *Man's Place in Nature*, p. 101.)

a, posterior lobe ; *b*, lateral ventricle ; *c*, posterior cornu ; *x*, hippocampus minor.

plains of Africa.' He describes the Fuegians, who rank amongst the lowest savages, as men 'whose very signs and expressions are less intelligible to us than those of the domesticated animals—men who do not possess the instinct of those animals, nor yet appear to boast of human reason, or at least of arts consequent on that reason.'[1] Such races are somewhat nearer to the ape than to the European, and it is from like accounts of existing savages[2] that we may form a rough picture of 'primitive' man.

Doubtless he was lower than the lowest of these—a powerful, cunning biped, with keen sense-organs (always sharper, in virtue of constant exercise, in the savage than in the civilised man, who supplements them by science), strong instincts, uncontrolled and fitful emotions, small faculty of wonder, and nascent reasoning power; unable to forecast to-morrow or to comprehend yesterday, living from hand to mouth on the wild products of nature, clothed in skin or bark, or daubed with clay, and finding shelter in trees and caves; ignorant of the simplest arts, save to chip a stone missile, and perhaps to produce fire; strong in his need of life and vague sense of right to it and to what he could get, but slowly impelled by common perils and passions to form ties, loose and haphazard at the outset, with his kind, the power of combination with them depending on sounds, signs, and gestures.

To quote the striking description from Lucretius, 'during the revolution of many lustres of the sun through heaven they led a life after the roving fashion of wild beasts. No one then was a sturdy guider of the bent plough, or knew how to labour in the fields with iron or plant in the ground young saplings. What the

[1] *Naturalist's Voyage round the World*, p. 504, ed. 1879.

[2] Cf. Lumholtz's *Among Cannibals* (1889), pp. 101, 179, 254, 271.

sun and rain had given, what the earth itself brought forth, was guerdon enough to content their hearts.'[1]

Such, in broad outline, was probably the general condition of the earliest known wanderers, the rude relics of whose presence are found associated with the bones of huge extinct mammals in old river beds and limestone caverns. As the successive deposits and their contents show, not till long ages had passed, bringing new and settled conditions, with knowledge of agriculture, metals, and other useful arts, do we find any marked progress among mankind. Even that progress, often checked in its zigzag course, and never an unmixed good, neither synonymous, as the many think, with a nation's imports and exports, has been confined to a minority of the species and to a narrow zone, while, compared to the antiquity of man, it is but as yesterday. The enterprise of the higher races has explored and utilised large tracts, and the pressure of population at the centres of civilisation has within quite recent periods vastly extended their periphery ; but whole empires, like China, advancing to a certain stage, have, through isolation and the tyranny of custom or dread of change, stagnated, whilst the lowest races have remained unmodified, like the lowest organisms, and have more or less succumbed before the imported vices and the weapons of the white man. But the causes of arrest and of advance are alike complex : man, like every other living thing, is the creature of outward and inward circumstances, and many influences have worked in the shaping of his destiny. Certainly, extremes of climate have been fatal to advance beyond a given stage ; it is in the temperate zones that the incentives exist to continuous and indefinite progress.

In reviewing the several operations by which species

[1] *De Rerum Naturâ*, v. 933–938 ; and cf. *Odyssey*, ix. 106–115.

have arisen, it is essential to bear in mind that natural selection is not causal, but only directive. It is powerless to bring about the slightest variation in organisms; it is all-powerful to preserve variations 'beneficial to the being under its conditions of life; . . . it can do nothing until favourable individual differences occur, and until a place in the natural polity of the country can be better filled by some modification of some one or more of its inhabitants.'[1] Moreover, since it tends to establish balance between life and its surroundings, it does not imply all-round development of the higher from the lower. Its keynote is adaptation. To quote Herbert Spencer's remarks on the erroneous conception of evolution as implying that everything has an *intrinsic* tendency to become something higher, 'if in the case of the living aggregates forming a species the environing actions remain constant from generation to generation, the species remains constant. If those actions change, the species changes until it is in adjustment with them. But it by no means follows that this change in the species constitutes a step in evolution. Usually neither advance nor recession results; and often, certain previously acquired structures being rendered superfluous, there results a simpler form. Only now and then does the environing change initiate in the organism a new complication, and so produce a somewhat higher type.'[2]

The parasites notably, the sea-squirts, lancelets, and the marvellous rotifers, are examples of recession. Nor these alone; the history of mankind, with its degenerate races, Bushmen, Fuegians, and, perhaps, Australians;

[1] *Origin of Species*, pp. 63, 132, 137; *An. and Pl.*, i. 6–8, chap. xxiv.–xxvi.; *Heilprin*, pp. 125, 212.

[2] *Principles of Sociology*, p. 107; Huxley's *Amer. Add.*, p. 38; and in Letter to Lyell, Darwin's *Life and Letters*, ii. 210.

with its relics of ancient civilisations, whose art we can only feebly imitate, and whose types of manliness we cannot hope to excel; furnishes its monitions of the lethargy and love of ease which precede the downfall of peoples.

Examples of persistence of type are supplied in the unaltered condition of the simplest forms since the appearance of their earliest known representatives. Their simplicity has been their salvation. A high organisation brings with it many disadvantages, for the more complex the structure the more liable is it to get out of gear. We cannot have highly convoluted brains, and at the same time digestive organs simple and renewable like those of the sea-cucumber. Death is the price paid for complexity.

Of the propositions expounded in the present chapter this is the sum:—No two living things are exactly alike. Their inherent tendency to vary is excited by their surroundings, on which all life depends, and to changes in which they must adapt themselves or perish. Every living thing transmits its qualities, and therefore, among them, its variations, to its offspring; the more useful the variation, the better is the plant or animal equipped in the struggle for life. For as all living things tend to multiply so rapidly that the earth would be too small in a very short time for a single species, a fierce and ceaseless struggle is waged, chiefly between the same species, for food and place. The result is that by far the larger number never reach maturity, or are killed and eaten. In the long result variations give rise to new species.

The only assumption at the base of Darwin's theory is that sufficient time has elapsed since the beginning of life for the development of all past and present species of plants and animals from a common ancestry. As to the age of the earth, more especially as a fit and possible abode of life, geologists and physicists are not agreed. The geological estimate rests chiefly upon the rates at which the deposit of sediment, or the wearing away of soil by rain and rivers, is going on ; but that estimate is based upon the assumption that present changes are the measure of past changes, whereas uniform action does not exclude the possibility of great and sudden revolutions. On the whole, the argument from geological evidence is strongly in favour of the lapse of not much less than one hundred million years since the earliest life-forms appeared and the oldest stratified rocks began to be laid down. This is much longer than the physicists, reasoning from the origin and age of the sun's heat, the rate of the earth's cooling, and other data, are willing to allow. But, however the question may be finally settled, the result cannot affect the evidence in support of the theory of descent.

CHAPTER X.

PROOFS OF DERIVATION OF SPECIES

THE evidence supplied by living things in support of their common descent is fivefold: viz. 1, by embryology, or likeness in their beginnings and development; 2, by morphology, or structural likenesses; 3, by their classification; 4, by their succession in time; and 5, by their distribution in space.

1. *Embryology.*—The eggs or germs from which all organisms spring are, to outward seeming, exactly alike, and this likeness persists through the earlier stages of all the higher animals, even after the form is traceable in the embryo. In proof of this Darwin quotes the following from Von Baer, the discoverer of this remarkable fact:—

'In my possession are two little embryos in spirit, whose names I have omitted to attach, and at present I am quite unable to say to what class they belong. They may be lizards, or small birds, or very young mammalia, so complete is the similarity in the mode of formation of the head and trunk in these animals. The extremities, however, are still absent in these embryos. But even if they had existed in the earliest stage of their development we should learn nothing, for the feet of lizards and mammals, the wings and feet of birds, no less than the hands and feet of man, all arise from the same funda-

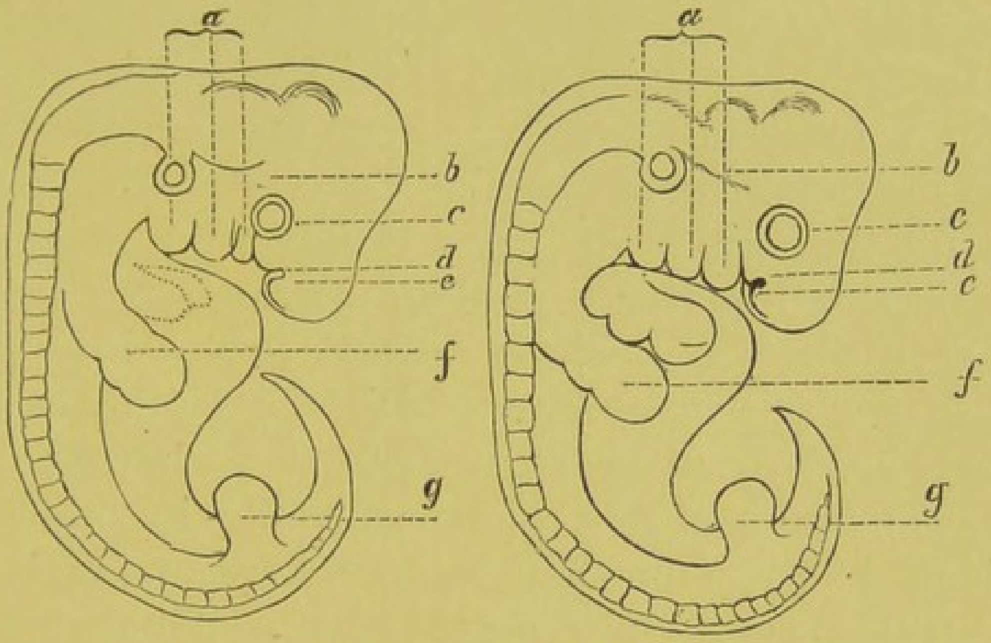


FIG. 75.—Dog (4 weeks). Man (4 weeks).
Magnified about 7 diameters. (After Hæckel.)

a, gill-arches; *b*, mid-brain; *c*, eye; *d*, nose; *e*, fore-brain; *f*, fore-leg; *g*, hind-leg.

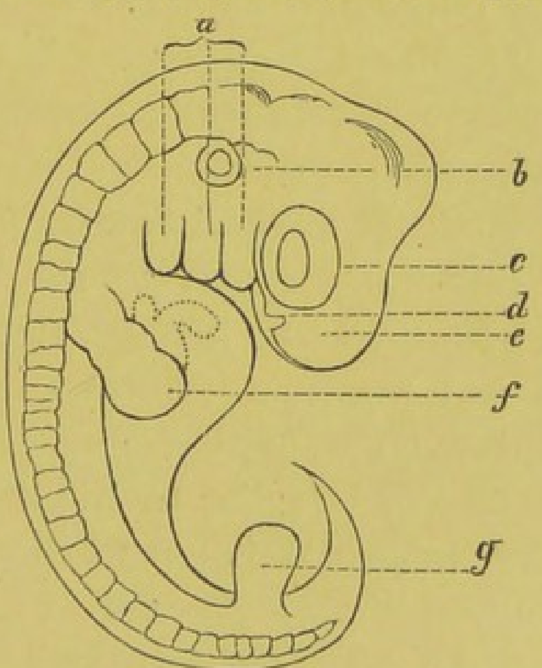


FIG. 76.—Tortoise. (4 weeks).

a, gill-arches; *b*, ear; *c*, eye; *d*, nose; *e*, fore-brain; *f*, fore-leg; *g*, hind-leg.

mental form.'[1] In further evidence of this interrelation of living things, their embryos, as we have seen, epito-

[1] *Origin of Species*, p. 388.

mise during development the series of changes through which the ancestral forms passed in their ascent from the simple to the complex ; the higher structures passing through the same stages as the lower structures up to the point when they are marked off from them, yet never becoming in detail the form which they represent for the time being. For example, the embryo of man has at the outset gill-like slits on each side of the neck like a fish ; these give place to a membrane like that which supersedes gills in the development of birds and reptiles ; the heart is at first a simple pulsating chamber like that in worms ; the back-bone is prolonged into a movable tail ; the great toe is extended or opposable, like our thumbs and like the toes of apes ; the body three months before birth is covered all over with hair except on the palms and soles. At birth the head is relatively larger and the arms relatively longer than in the adult ; the nose is bridgeless ; both features, with others which need not be detailed, being distinctly apelike. Thus does the egg from which man springs, a structure only one hundred and twenty-fifth of an inch in size, compress into a few weeks the results of millions of years, and set before us the history of his development from fish-like and reptilian forms, and of his more immediate descent from a hairy, tailed quadruped. That which is individual or peculiar to him, the physical and mental character inherited, is left to the slower development which follows birth.

Besides the past history which the embryo recapitulates, there are the rudimentary structures of which relics remain as witnesses to the former close connection of organisms. Among these are teeth in fœtal whales, remnants of hind limbs in certain snakes, wings under the wing-cases of insects that do not fly, rudiments of pointed ears and of a third eyelid in man, abortive stamens in plants, as in the snapdragon, and so forth. Except as evidence of the modification of life-forms in which they occur from other life-forms, and of persistency of type, these vestiges of organs are meaningless; the functions they once discharged have long ceased, being exercised only in other and allied living things where they are found fully developed.

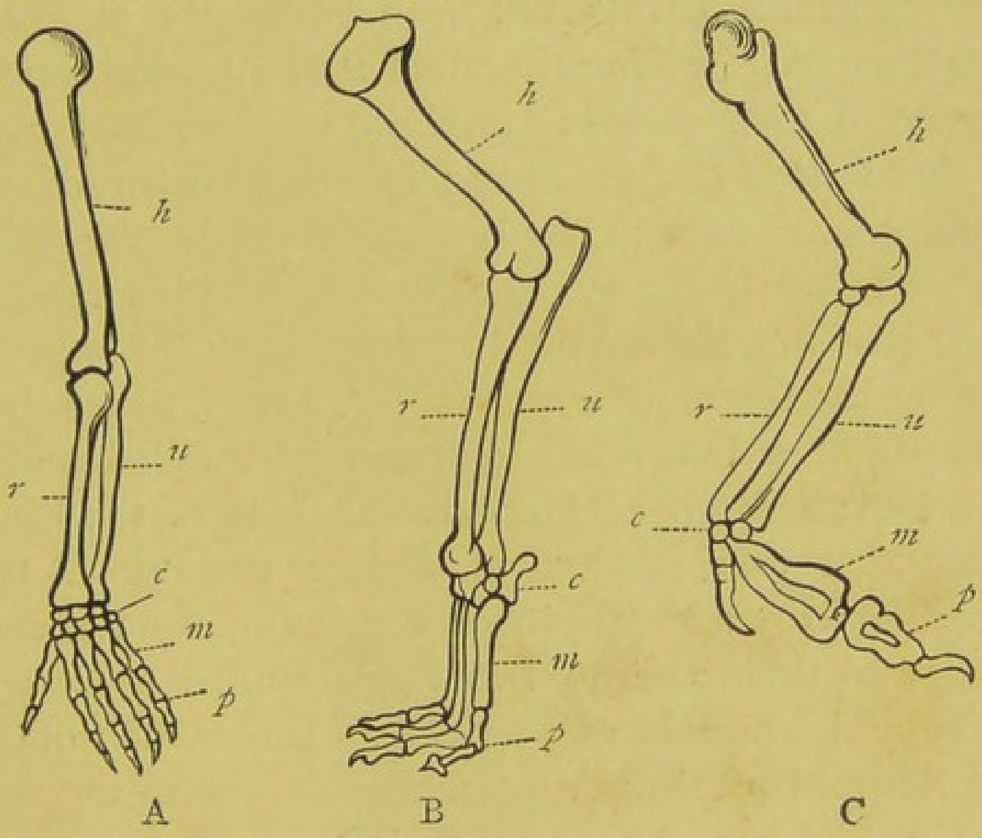


FIG. 77.—A, Arm of Man. B, Fore-leg of Dog. C, Wing of Bird.
h, humerus; *r*, radius; *u*, ulna; *c*, carpus; *m*, metacarpus; *p*, phalanges.

2. *Morphology.*—Large groups of species, whose habits are widely different, present certain fundamental likenesses of structure. The arms of men and apes, the fore-legs of quadrupeds, the paddles of whales, the wings of birds, the breast-fins of fishes, are constructed on the same pattern, but altered to suit their several functions. Nearly all mammals, from the long-necked giraffe to the short-necked elephant, have seven neck-bones; the eyes

of the lamprey are moved by six muscles which correspond exactly to the six which work the human eye; all insects and crustacea—moth and lobster, beetle and cray-fish—are alike composed of twenty segments; the sepals, petals, stamens, and pistils of a flower are all modified leaves arranged in a spire. Such facts need no comment.

3. *Classification.*—It has been shown somewhat in detail that all plants fall into two main groups, the flowerless and the flowering, and that all animals may be reduced to three types: (1) those without body cavity; (2) those with body cavity; (3) those with digestive cavity separate from body cavity. And the general likenesses of structure upon which division into sub-kingdoms is based having been given in the chapters on existing life-forms, it here suffices to repeat that the old attempts at a linear arrangement have failed, and that the only true mode of presentment, both of the life that is and that was, is that of a tree with short trunk, indicating common origin of the living from the non-living, and divided into two large trunks representing plants and animals respectively. From each of these start large branches representing classes, the larger branches giving off smaller branches representing families, and so on with smaller and smaller branches representing orders and genera, until we come to leaves as representing species, the height of the branch from which they are hanging indicating their place in the growth of the great life-tree.

4. *Succession.*—Each formation has its peculiar groups of fossil remains representing the life-forms of the period; the older the rock, the simpler are its organic contents; and, what is of no mean importance, although transitional forms are from their nature fewer and less

permanent than forms which have arrived at balance with their surroundings, the fossil-yielding rocks have disclosed the existence of several hitherto missing links between species. Reference has been made to the proofs of descent of the one-toed horse of to-day, with his knee corresponding to our wrist or ankle, from the five-toed primitive horse found in the Eocene beds of North America, and to the connecting link between birds and reptiles supplied by the archæopteryx. To these may be added, among others, the compsognathus, with its swan-like neck, its toothed jaws, and hind limbs on which it walked. Then there are the links between pigs and hippopotamuses in the anoplotherium; between tapirs, horses, and rhinoceroses in the palæotherium; between seals and whales; between sloths and beavers; between lemurs and man-like apes; and in the Devonian strata forms occur which are considered intermediate between ganoids and mud-fishes. Thus one by one the blanks are being filled up; the faith of the biologist is justified by his works.

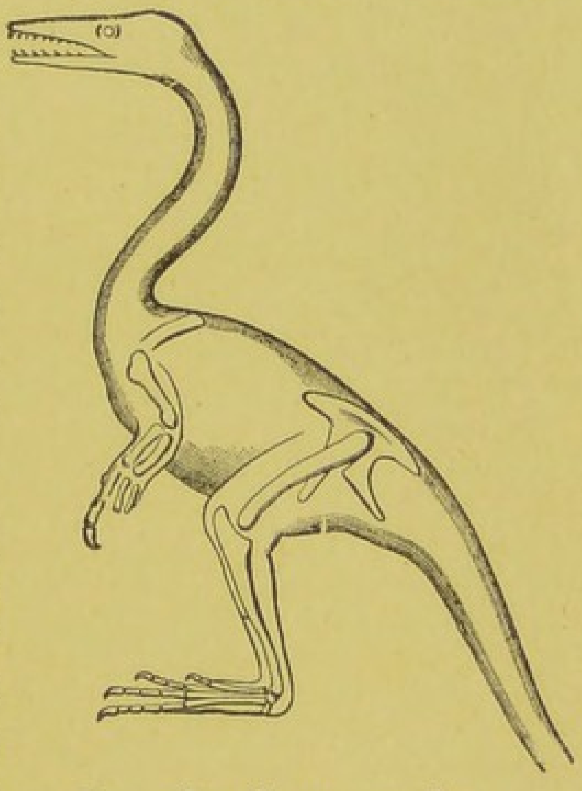


FIG. 78.—Compsognathus.

5. *Distribution.*—Emerson says that 'the man of this age must be matriculated in the university of sciences and tendencies flowing from all past periods;' and certainly if we would know something of the complicated subject of the geographical distribution of plants and animals we must study the past as well as the present,

and learn both from geologist and astronomer, the one telling us of the shiftings of land and water, and the other accounting for the great climatal changes that have swept over the globe.

Every living thing has its definite area of range: the sloth is peculiar to America; the hippopotamus to Africa; the chamois to the Alps. The higher we climb, the hardier and more stunted is all vegetation; tropical plants perish in cold or even temperate zones; Arctic plants wither under the equator; while a vast number of plants flourish only in water, their primeval life-home. Among animals a few, notably man and the cat genus, have spread themselves well-nigh everywhere, but as a rule certain life-forms—and this holds good of their fossil representatives also—are restricted to certain regions. Hence the land has been divided into life-regions corresponding to that distribution, and the water into life-regions measured by the limits of depth at which marine forms are found. Speaking broadly, the plants and animals of countries in unbroken connection resemble one another, while those of countries remote or cut off are unlike. But although, at first sight, climate and separation would appear to account for this, there are likenesses and unlikenesses which are not to be thus explained. In fine, exceptions meet us at every turn. Great Britain and New Zealand are much alike in general conditions, yet the life-forms of New Zealand, now being fast supplanted by aliens, are the little-altered survivors of plants and animals once dominant over the globe. On the other hand, as Mr. Wallace tells us, the Englishman visiting Japan finds its woods and fields tenanted by the singing birds familiar to him at home. Tapirs, whose origin in the north-western parts of the Old World is indicated by their fossil remains in Miocene beds, are now separated by nearly half the globe's circumference, being found only in South America and Malacca, while the man-like apes are found only in West Africa and Borneo.

But puzzling and seemingly capricious as is the distribution of life, the general causes are not far to seek.

Distribution is due to the slow but ceaseless migration and transport of living things rendered necessary by their rate of increase. While climate has much to do with it in compelling organisms, in proportion to their power of dispersion, to shift their quarters, the struggle for life between them has had more influence still, so that the past and present habitats of plants and animals throw welcome light not only on changes in the relations of land and water, but also on the origin of species.

Where unallied forms are found on the same continent we may infer that the physical barriers between them have been permanent through long periods; where allied forms which are unable to cross the seas are found in lands now separated, as in Britain and Japan, in South Europe and North Africa, we have evidence of former union. The degree in which life-forms have been modified gives some key to the remoteness of that union; as, for example, when we find more ancient types in New Zealand than in Australia, and more ancient types in Australia than in Madagascar.

Islands afford important aid in the study of the intricate problem of distribution. They are of two kinds, continental and oceanic. The continental, as the British Isles, Japan, ancient Madagascar with its lemurs, and New Zealand with its wingless birds and Hatteria lizard, have been broken off from the mainland. The oceanic, as the Azores and Sandwich Islands, are of volcanic or coralline formation, and depend for their life-forms upon their relative position to the mainland, and also to the winds and ocean currents that prevail. Exclusive of animals introduced by man, they are found destitute of frogs and other batrachians; also of mammals, bats excepted; the explanation being that sea water kills frogs and toads and their spawn, and that only flying animals can cross the ocean. For this reason bats, at least the insect-eating species, are found everywhere, except at the poles; and the range of birds, although defined, is much wider than that of all the larger and wingless land animals.[1]

Isolated islands like St. Helena are peopled with waifs and strays from all quarters, while in continental islands like our own the life-forms are, for the most part, identical with those of the nearest mainland. But here, again, exceptions exist. The islands of Bali and Lombok in the Malay Archipelago, although only fifteen miles apart, differ far more from each other in their birds and quadrupeds than do England and Japan, the birds being extremely *unlike*.[2] As shown by the deep soundings, Bali belongs to the Indian region, and Lombok to that zone of 'living fossils,' the Australian region. Australia contains only the lowest mammals, as duckbills and kangaroos—for there is little doubt that the dingo or wild dog was introduced by man—witnessing to its severance from Asia millions of years ago during the

[1] Although the dispersal of the larger animals is instanced in this summary of facts of distribution, it should be added that far more striking, if less obvious, evidence could be cited from the dispersal of insects. Their great powers of flight, and their extreme lightness, cause them to be transported enormous distances by the wind; their eggs and larvæ, deposited in the bark or crevices of logs, are carried with these as they float to far-off shores, while their immense antiquity largely explains the wide areas over which they range. Cf. Wallace's *Island Life*, p. 75.

[2] *Ibid.*, p. 4.

Secondary epoch. It is an ancient and little altered fragment, preserving as in a museum the types of plants and animals which were then dominant on the

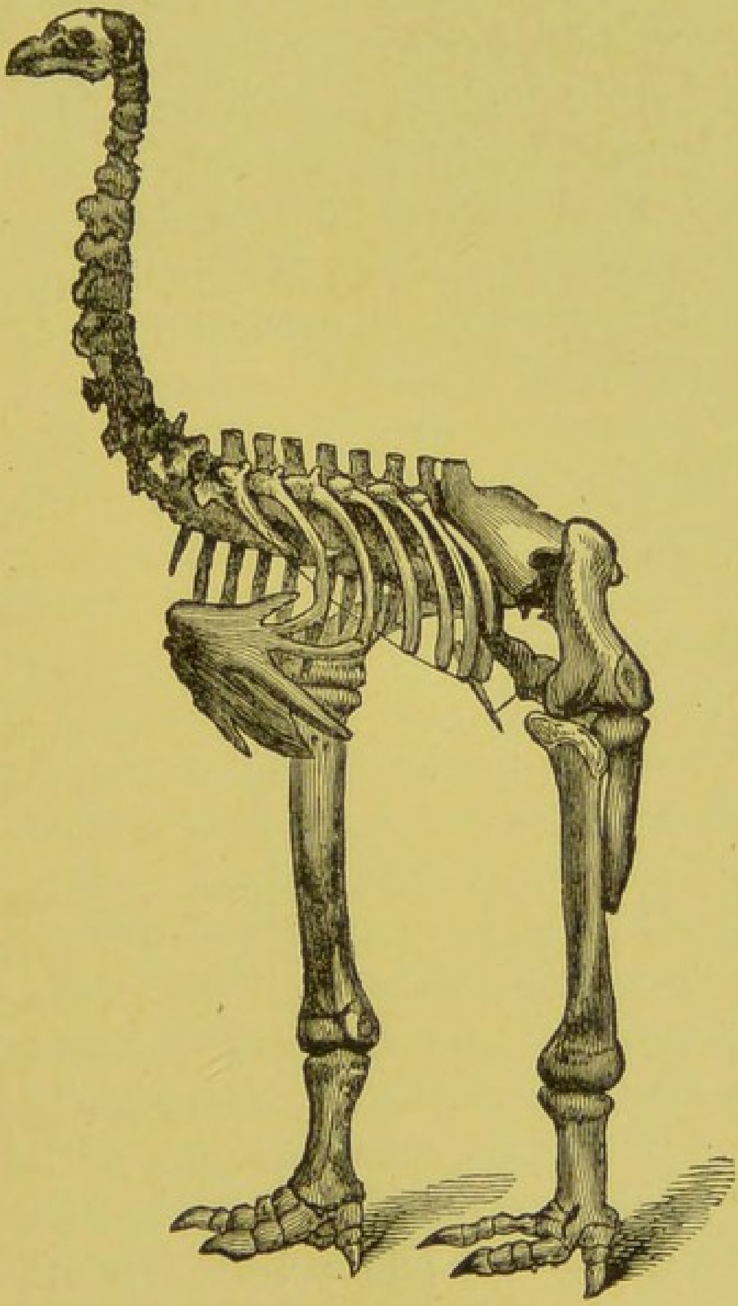


FIG. 79.—*Dinornis elephantopus*, New Zealand.

great shifting land areas, and from which the higher forms have been developed.

Oceanic islands, with their population of birds, flying insects, and a few creeping things, are the refuge spots of castaways. Strange are the ways and means of dispersal. Winds waft the light seeds of plants to great distances ; currents drift to far-off shores icebergs laden with earth and seeds, or masses of floating vegetation, sometimes so matted with soil as to form island rafts, with trees upstanding, and carrying with them not only numbers of grubs and eggs of insects, but even large animals. Darwin found beetles swimming in the open ocean seventeen miles from land ; and one evening when ten miles from the Bay of San Blas, in the Pacific, the air was thick with butterflies—it snowed them, as the sailors said. But the most remarkable instance cited in his Journal is the arrival of a grasshopper when the ship was three hundred and seventy miles from the coast of Africa. Birds are important agents in plant distribution, transporting seeds embedded in dirt sticking to their feet or beaks, or the barbed seeds of certain plants, as the hook-like spikes of the curious *Uncinia*, which cling to their feathers, or the undigested seeds and stones of fruits which are passed through their bodies. A swift-winged bird may drop cherry-stones a thousand miles from the tree they grow on ; a hawk, in tearing a pigeon, may scatter from its crop the still fresh rice it had swallowed at a distance of ten degrees of latitude. Among the many suggestive experiments which Darwin made in this matter, he cites the case of the leg of a wounded partridge to which a ball of hard earth weighing six and a half ounces adhered. The earth had been kept for three years, but when broken, watered, and placed under a bell-glass, no less than eighty-two separate plants of about five distinct species sprang from it.

Very important also, although more remote in its ultimate results, is the agency of man, especially of civilised races, in the distribution of life. Both with and without intent he distributes and destroys, as his needs or caprices demand. Clearing forest, draining lake and bog, reclaiming land from sea, or uniting ocean with ocean, he disturbs, or mingles, or kills their life-forms. He imports strange plants and noxious insects in his merchandise; the sheep-walks of the antipodes are cursed with the fecund rabbit, and their river beds choked with our water-cress; while the European rat has left our shores as a stowaway to oust the native rat wherever it goes, as the white man ousts the coloured man. But man blesses as well as curses; he transports the healing cinchona plant from Peru to India, or the salmon ova from our native streams to the rivers of Australia; and to him is due the reintroduction of the horse into America, which had been extinct there long before the arrival of Columbus. 'The *hortus siccus* of a botanist may accidentally sow seed from the foot of the Himalayas on the plains that skirt the Alps; and it is a fact of very familiar observation, that exotics, transplanted to foreign climates suited to their growth, often escape from the flower-garden and naturalise themselves among the spontaneous vegetation of the pastures. When the cases containing the artistic treasures of Thorwaldsen were opened in the court of the museum at Copenhagen where they are deposited, the straw and grass employed in packing them were scattered upon the ground, and the next season there sprang up from the seeds no less than twenty-five species of plants belonging to the Roman Campagna, some of which were preserved and cultivated as a new tribute to the memory of the great Scandinavian sculptor, and at least four are said to have spontaneously naturalised themselves about Copenhagen.'[1]

It surprises one to learn how many of our familiar flowers are foreigners, which happy chance or wise intent

[1] Marsh's *Man and Nature*, p. 67.

have acclimatised. The daisy and the violet are natives, but not the laburnum and jasmine, nor

> Sweet William with his homely cottage smell,
> And stocks in fragrant blow.

While needless destruction has often followed in the wake of man, as he kills out of sheer wantonness, or seeks profit by gratifying the cruel freaks of fashion, his enterprise and needs have, on the other hand, rid the earth of harmful and baneful plants and animals, produced food and clothing from wild species, luscious fruit from sour and dwarfed varieties, and developed domestic animals, the dog probably earliest of all, from the fierce beasts of the forest and the field.

Enough has been cited to show that no preordained scheme of fitness for their several habitats has placed plants and animals where they are found. Remembering what has been said about the probable polar origin of life, we are prepared to find that, so far as most of the higher forms are concerned, our best authorities, with Mr. Wallace at their head, incline to the theory of their development in the Euro-Asiatic continent when the temperature was comparatively warm from the pole to the antipodes. The wave of migration rolled over the Old World far south by routes now long submerged, and into the New World, where other life-forms appear to have been developed, by a northerly route. One among several proofs of the existence of an old land connection between North America and Europe is supplied by the musk-sheep (or musk-ox), which flourished ages ago in Eurasia, and is now confined to Greenland. And it is interesting to note that the path taken by some birds in their migrations gives further clue to other ancient land connections.[1] Incapable as they are of crossing the wide oceans, we find them migrating between Europe and Africa by way of Greece, Malta, and Gibraltar, the three points at which the two continents were formerly united. They follow instinctively the route which their ancestors have taken for countless seasons.

Widespread as is the distribution of the races of mankind, they are probably of common origin. All of them being fertile with one another, they are to be classed as varieties of one species, whose physical and mental differentiations from their nearest congeners, the highest apes, had been acquired before their dispersion. The modifications which exist have been developed through the potent agency of natural and sexual selection acting upon variations induced by diverse conditions—conditions which have surrounded man in virtue of his migrations from pole to pole, and which have called his industry and resource into full play. Perhaps the most striking illustration throughout history of the rapid rise of a variety is supplied by the Anglo-American race, the vigour of which may be primarily due to the blending of many bloods, pre-Celtic, Celtic, Saxon, Norman, and Dane, in its British ancestry.

[1] 'A bird may travel from England to the equator without launching out and exposing itself to boundless seas, and that by crossing the water at Dover, and again at Gibraltar. . . . When arrived there the birds do not—

> "Ranged in figure wedge their way,
> . . . . and set forth
> Their airy caravan high over seas
> Flying, and over lands with mutual wing
> Easing their flight" (*Milton*),

but scout and hurry along in little detached parties of six or seven, and sweeping low, just over the surface of the land and water, direct their course to the opposite continent at the narrowest passage they can find.'—White's *Selborne*, letter ix., to the Hon. Daines Barrington.

'That many and serious objections may be advanced against the theory of descent with modification through variation and natural selection I do not deny. I have endeavoured to give them their full force.'[1] The sixth, seventh, and tenth chapters of the 'Origin of Species' are proof of this. Darwin shirked no difficulty, and in laying stress upon whatever told against his theory he made its foundations more sure. One great, but unduly overrated, stumbling-block—the absence of intermediate forms in the fossil-yielding rocks—has been removed by the discovery of many more connecting links in the long chain of life than could be expected when we take into account the small minority of ancient forms which have escaped the havoc of the past, and when we remember how much smaller are the chances in favour of the preservation of the more fragile, rare, and unstable transitional forms than of the species which they connect.

Another leading objection, drawn from the barrenness of hybrids[2]—as, *e.g.*, of the mule—loses much of its force in view of the numerous examples to the contrary, both in plants and animals, as amongst genera of the thistle and of the laburnum, and as in the cases of fruitful hybrids of sheep and goats in Chili.[3] But, as against natural selection, the real difficulty lies in the interbreeding of species developed by selective breeding from a common stock. For example, the different species of pigeons have been developed from the wild rock-pigeon, and these are fertile with one another, which would seem to tell in favour of the fixity of species, unless the carrier, pouter, and tumbler are, after all, to be regarded only as varieties or sub-

[1] *Origin of Species*, p. 404.
[2] *Animals and Plants*, ii. 130-156, and ch. xix. *passim*.
[3] Hæckel's *Hist. of Creation*, i. 145-149.

divisions of species. The matter, however, is too abstruse for these pages, and, moreover, it has no weight as against the theory of derivation. We know very little as to the complex conditions ruling fertility and barrenness; we know that the reproductive organs are peculiarly sensitive to altered habits and surroundings; and we know, further, that it is through changes in those organs that the barriers to interbreeding have arisen, and the consequent multiplication of countless intermediate varieties been arrested. Happily, the Darwinian theory has no fatal element of rigidness in it, and those who would mould it into a dogma know not what spirit they are of. It admits of alterations in detail at the behest of fresh facts, and of such correction of proportion as time alone gives to things new and near. But the truth of the theory of which it is a subordinate part will thereby stand out the clearer, and the full accord of past and present to the oneness of things appear more manifest.

CHAPTER XI.

SOCIAL EVOLUTION.

1. *Evolution of Mind.*—If the theory of evolution be not universal, the germs of decay are in it. And here we pass from what is interesting to what is of serious import for us, because if the phenomena of mind are not capable of the like mechanical explanation as the phenomena of stars and planets, and of vegetable and animal life, evolution remains only a speculation to fascinate the curious. It can, in that case, furnish no rule of life or motive to conduct, and man, 'the roof and crown of things,' would be the sole witness against their unity and totality. If there be in him any faculty which is no part of the contents of the universe, if there be anything done by him which lies outside the range of causation, then the doctrine of the Conservation of Energy falls to pieces, for man has the power to add to that which the physicist demonstrates can neither be increased nor lessened.

The ground already covered need not be retrodden to show that man is one in ultimate beginnings, and in the stuff of which he is made, with the meanest flower that blows, and that in mode of development from the egg to the adult state there is exact likeness between him and other mammals. But some repetition of the process of mental development from the lowest life-forms to the highest is needful.

'Structure for structure,' remarks Professor Huxley, 'down to the minutest microscopical details, the eye, the ear, the olfactory organs, the nerves, the spinal cord, the brain of an ape, or of a dog, correspond with the same organs in the human subject. Cut a nerve, and the evidence of paralysis, or of insensibility, is the same in the two cases; apply pressure to the brain, or administer a narcotic, and the signs of intelligence disappear in the one as in the other. Whatever reason we have for believing that the changes which take place in the normal cerebral substance of man give rise to states of consciousness, the same reason exists for the belief that the modes of motion of the cerebral substance of an ape, or of a dog, produce like effects.'[1]

Let us begin, however, at the bottom of the life-scale. The lowest things, being organless, or alike all over, respond to touch, 'the mother-tongue of all the senses,' in every part, simply changing their shape from moment to moment. A step higher we find forms in which unlikenesses in parts begin to show themselves—*e.g.* in the formation of a layer at the surface; and here the responses to the stimuli, as they are called, become localised, because the movements set up by the stimuli take place, like all modes of motion, along the lines of least resistance. These movements give rise to changes in the structure of the organism, driving the molecules out of their places, and, following in incredibly rapid succession, finally lay down permanent nerve-tracks, built up of the more sensitive parts of the skin. All sense-organs, whether the whiskers of a cat or the eye of a man, all the wondrous network of nerves and the brain

[1] *English Men of Letters*, Hume, p. 105.

itself, have thus originated. Practice makes perfect; and, as the result of their incessant repetition, the lowest and simplest nerve-actions, known as *reflex*, take place automatically in plants and animals Such are the contractions of an amœba or of the leaves of a mimosa, the shutting up of an oyster when the shell is touched, breathing, the action of the heart, winking of the eyes—in short, all actions which are performed unconsciously, and repeated in virtue of the tendency to do them being innate in the structure which each organism inherits from its ancestors. Besides these natural reflex actions, there is a group of artificial reflex actions which our higher intelligence enables us to acquire, as the arts of reading, playing instruments, &c.

As every one knows, it takes a soldier a long time to learn his drill—for instance, to put himself into the attitude of 'attention' at the instant the word of command is heard; but after a time the sound of the word gives rise to the act, whether the soldier be thinking of it or not. There is a story, which is credible enough though it may not be true, of a practical joker, who, seeing a discharged veteran carrying home his dinner, suddenly called out 'Attention!' whereupon the man instantly brought his hands down, and lost his mutton and potatoes in the gutter. The drill had been thorough, and its effects had become embodied in the man's nervous structure. The possibility of all education is based upon the existence of this power, which the nervous system possesses, of organising conscious actions into more or less unconscious, or reflex, operations.[2]

Instinct is a higher form of reflex action. The salmon migrates from sea to river; the bird makes its nest or migrates from one zone to another by an unvary-

[2] Huxley's *Elementary Physiology*, p. 306.

ing route, even leaving its young behind to perish; the bee builds its six-sided cell; the spider spins its web; the chick breaks its way through the shell, balances itself, and picks up grains of corn; the new-born babe sucks its mother's breast—all in virtue of like acts on the part of their ancestors, which, arising in the needs of the creature, and gradually becoming automatic, have not varied during long ages, the tendency to repeat them being transmitted within the germ from which insect, fish, bird, and man have severally sprung.[1] Touching on larger matters for a moment, even the so-called necessary truths and innate ideas of the mind, as of time and space, take their place among transmitted experiences. 'Being,' as Herbert Spencer says, 'the constant and infinitely repeated elements of thought, they must become the automatic elements of thought of which it is impossible to get rid.'

More than a century ago Gilbert White remarked that 'the maxim that defines instinct to be that secret influence by which every species is compelled naturally to pursue at all times the same way or track without any teaching or example, must be taken in a qualified sense, for there are instances in which instinct does vary and conform to the circumstances of place and convenience.'[2] Herein that delightful observer, perhaps without suspecting what he was conceding to the brute, indicates where instinct passes into *Reason*. For the main difference

[1] An interesting illustration of this was supplied by a St. Bernard dog belonging to a relative. The dog was born in London, and taken into the country when a puppy. After a few months a sharp fall of snow happened, and 'Ju,' who had never seen snow before, was frantic to get outdoors. When she was set free, she rolled in the snow, bit it, and dug it up with her claws as if rescuing some buried traveller. The same excitement was shown whenever snow fell.

[2] Letter lvi., to Hon. Daines Barrington.

between the two is that while the one is done because the animal cannot help doing it, and has no knowledge of the relation between the end and the means, the other is the conscious adjustment of means to ends—selection as the result of reflection. In the one there is no pause, in the other there is a measurable interval; the stimuli to action are more complex and less rapid, giving time for that perception of likenesses and unlikenesses in things which is essential to rational action. This is manifested by all animals except the lowest, which, however, form the vast majority. The latter start fully equipped for their functions: their actions are reflex and unvarying from birth to death. But in the higher animals the same mental processes are apparent as in man. There is not a faculty of the human mind which is not possessed in lesser or greater degree by them; oftenest in lesser degree, sometimes in larger degree, as in the showing forth of affection and devotion that puts man's selfishness to shame. Where some of the highest animals approach him, although *longo intervallo*, is in their passage through a period of helpless infancy, because the brain and connecting apparatus are not complete at birth; and in this lies the explanation of the capacity for receiving instruction and for profiting by experience, which reaches its fullest development in man. And it is because the knowledge that is gained, and the habits that are acquired, in early life abide with us, determining character, that the importance to ourselves and to others of learning what is true, and of cultivating what is good, is paramount. Vast, therefore, as are the differences between the highest and lowest mental actions, there is no break in the series which, starting with the reflex movements of an amœba or of a carnivorous plant, advances along the line of animal instinct and intelligence, and ends with the complex movements of the brain of civilised man, with its infinite modes of response to infinite stimuli.

2. *Evolution of Society.*—Like every other species, man multiplies beyond the means of subsistence. Civilised races are more prolific than savage races. Under prosperous conditions they double their numbers in a quarter of a century, a rate at which the present population of the United States alone would in six hundred and fifty years cover the terraqueous globe so thickly that four individuals would have to stand on each square yard of surface.[1] Consequently the mortality of the human species, though far less than that of any other animal, is still enormous. It is computed that more than seven hundred million human beings are every century pounded back to nothingness without knowing that they ever lived, to which have to be added the vast number that die before reaching manhood, and the wholesale destruction of communities by wars, pestilences, famines, and catastrophes. In various ways natural selection weeds out the least fit; and although under civilised conditions the weak and diseased are coddled and even permitted to multiply their kind, this check is too local to affect the larger result, while that which the race might gain in physique by its removal is not to be compared to the loss that would ensue from the repression of mercy and sympathy. In a barbaric society, or among the civilisations where infanticide was practised, weaklings like Newton and hunchbacks like Pope would have been left to perish: modern civilisation spares them, and humanity is enriched by their genius.

When the weeding process has done its utmost, there remains a sharp struggle for life between the survivors.

[1] *Descent of Man*, p. 44.

Man's normal state is therefore one of conflict ; further back than we can trace, it impelled the defenceless bipeds from whom he sprang to unity, and the more so because of their relative inferiority in physique to many other animals. The range of that unity continued narrow long after he had gained lordship over the brute ; outside the small combinations for securing the primal needs of life the struggle was ferocious, and, under one form or another, rages along the line to this day. 'There is no discharge in that war.' It may change its tactics and its weapons : among advanced nations the military method may be more or less superseded by the industrial, and men may be mercilessly starved instead of being mercifully slain ; but be it war of camps or markets, the ultimate appeal is to force of brain or muscle, and the hardiest or craftiest win. In some respects the struggle is waged more fiercely than in olden times, while it is unredeemed by any element of chivalry.

Moreover, the greater strength of man's emotions, and the persistent craving for excitement, acting upon his inherited savage instincts, have made that struggle more terrible in his case than any that rages between the lower animals. These fight for food and mates, not for the mere love of fighting. No brute ever tortured its kind or gloated over the agonies of its prey as man has tortured in fiendish glee the victims of his revenge, intolerance, and hate. True it is that peace has been wrung from pain ; that war is a nation-builder ; that slavery and superstition have been agents of progress, whereby the many, through the sacrifice of the few, have gained freedom, unity, and larger life ; that in the death-struggle for food, curiosity, the mother of knowledge, has been awakened, never more to sleep ; that in the fight for mates the germ of the highest and purest love of man for woman has been developed ;

that in the conflicts between tribes, patriotism, morals, and the hardy virtues have been evolved: but when we count the cost, all this would afford small content did we not have faith that the slow-footed years are bringing us nearer to the goal where might shall be subdued by right, and where injustice and selfishness shall be swallowed up by goodness, because this shall have become spontaneous to man.

The social instincts to which his progress is due are without doubt inherited from his pre-human ancestors. 'There is,' wrote Gilbert White in 1775, 'a wonderful spirit of sociality in the brute creation, independent of sexual attachment;' and Darwin remarks that 'the social animals which stand at the bottom of the scale are guided almost exclusively, and those which stand higher in the scale are largely guided by special instincts in the aid which they give to the members of the same community; but they are likewise in part impelled by mutual love and sympathy, assisted apparently by some amount of reason.'[1] In the degree that animals are social we find them higher in the scale, as ants, bees, and wasps among insects; and among domestic animals, dogs, whose wild ancestors hunted in packs, as compared with cats, which inherit the solitary and wandering habits of their wild ancestors.

We do not know what the earliest social unions among mankind were like. Probably there were no family arrangements as we understand the term, but only various kinds of relations, more or less fugitive, between groups of men and women.[2] The details, how-

[1] *Descent of Man*, p. 109.

[2] Cf., *e.g.*, Sir A. C. Lyall's account of the Bheels, an undoubted remnant of the aboriginal tribes of India. 'They may be taken to represent generally the barbarian type before the earliest civilisation had brought in

ever, do not affect the general fact of social intercourse, in which community of interest was the binding force. Impetus was given to more personal and permanent relationships by the longer period of infancy in man as compared with the same period in the man-like apes, in whom, again, it is much longer than in the lower monkeys.[1] For as the maternal instinct 'sublimes the passions, quickens the invention, and sharpens the sagacity of the brute creation,'[2] so this period of helplessness would draw parent and child closer together, evolving love and sympathy, and developing those enduring and exalting relations of the family which widened into tribal life. Struggles against common foes brought the bravest to the front as leaders, turbulent elements within involved the rule of the ablest, disputes called for the settlement of the wisest; and thus the rough foundations of law and order were laid. As the wants and capacities of the ever-increasing community multiplied, the work done by each one under rude conditions was divided among the many; hence specialisation of the people into classes, with all the complex duties of modern societies.

Carlyle says that the great man shapes the age; Herbert Spencer says that the age shapes the great man. The truth lies in the mean; the great man is the product of past tendencies and present conditions, and he is supreme in virtue of these operating in him in higher degree; hence he acts upon society for good or evil.

ideas and prejudices about food, worship, and *connubium*. So far as can be ascertained, the Bheels are all subdivided into a variety of distinct groups, a few based on a reputed common descent, but most of them apparently muddled together by simple contiguity of habitation, or the natural banding together of the number necessary for maintaining and defending themselves.' *Asiatic Studies*, p. 160.

[1] Cf. Fiske's *Outlines of Cosmic Philosophy*, ii. 342–346.

[2] White's *Selborne*, letter xiv., to Mr. Barrington.

3. *Evolution of Language, the Useful Arts, and Science.*—Man is markedly separate from the highest brute, not only by his brain-power and his erect attitude, with its free command over the hands, but also by language. Not that the 'dumb' animals, as they are called, are all voiceless, many of them having no small or inexact gamut of sounds by which to express their thoughts and emotions. But although the love-calls of birds and the danger-cries of beasts may be not more unintelligible to us than the language of savages like the Fuegians, which Captain Cook compared to a man clearing his throat, the distinction abides that language, as the plastic symbol of ideas of unlimited range and complexity, marks the impassable gulf between the mental capacity of man and every other animal. Its origin lies in his need to communicate with his fellows; and but for it all attempts after social union, except of the lowest and most fleeting kind, would have been as the weaving of a rope of sand. 'Nature,' says Lucretius (v. 1028, 9), 'impelled them to utter various sounds of the tongue, and use struck out the names of things.'

Words themselves reveal under analysis the history of their origin from a few simple root-sounds, which were instinctive cries or imitations of various natural noises very largely aided at the outset by signs and gestures. Speech is but one way of expressing thought; deaf mutes can converse only by gesture; to this day it is the sole mode of communication between certain wandering tribes of American Indians, and among the vivacious races of Southern Europe it largely supplements talk. We can never know what the first sound-signs were like, but their choice and currency obviously depended on the success with which they conveyed the meaning of those who invented them—a principle, of course, applicable to every stage of language, from the simple names of objects with which it began to the ultimate transfer of those names to abstract ideas. For all abstract terms have a concrete origin. The words just used evidence this; *abstract* meaning 'dragged away,' and *concrete* 'grown together.' Even the verb *to be* is made up of 'the relics of several verbs which once had a distinct physical significance. *Be* contained the idea of "growing"; *am, art, is,* and *are,* that of "sitting"; *was* and *were,* that of "dwelling," "abiding."'[1] Certain it is that from mimetic sounds, with their boundless variety of modulation, there have been developed not merely the scanty and shifting speech of the lower races, but the wondrously rich, copious, and ever-growing languages of civilised races, the sound-carriers not only of man's common wants, but of the lofty conceptions which are enshrined in prose and poetry, and without which, now made the common intellectual wealth of nations through the arts of writing and printing, how poor and dwarfed would human life have been! Language has, therefore, followed the common law of evolution in advance from the simple to the complex, from nouns and verbs to the elaboration of families of words and of parts of speech, with their subtile shades of meaning whereby no thought remains unexpressed. Thus does it prove itself one of the many instruments which the skill of man has perfected from raw materials as his social needs have impelled him and as his intelligence has increased.

And the like adaptation of means to ends applies to the development of the useful arts, as well as of those arts in which the head is more concerned than the hand. The primal needs of clothing and shelter, of weapons of

[1] Professor W. D. Whitney's *Lect. on Language*, p. 115.

war and of the chase—for the sword and bow precede the spade and hammer—the need, under more settled conditions, of implements for the household and the field, set man's wits at work to supplement and improve that which nature supplies in the rough. For if he is not the only tool-user, he is the only tool-maker among the Primates. Every instrument of his culture bears traces of its development from simpler forms: the spear and knife-blade from the sharp-edged flint flake; the saw from the jagged-edged flake; the matchlock from the crossbow; the warrior's armour from the scaly hide of beasts; the plough from the stag's antlers or the tree branch; the mill from pounding stones; the ship from the scooped-out trunk; the oar from the hands or feet as primitive paddles; the house from the sun-baked clay hut, or, as in China, from the Tatar tent; the pyramid from the earth mound or cairn: all art from imitation—the alphabet from picture-writing; sculpture and painting from rude scratchings on bone and horn; stringed instruments from the twang of the hunter's bow; wind instruments from the blast of his horn; the 'blowing into hollow stalks from the whistling of the zephyr through the hollows of reeds;' melody and dance from the rude, impassioned chant of the savage, time-marked by yell and tamtam; arithmetic from primitive perception of more or less; counting and measuring, as shown in our words cubit, ell,[1] foot, hand, digit, span, fathom, and in cognate terms of other languages, from using the fingers, toes, and other parts of the body; geometry, or *land*-measur-

[1] Some confusion of measures of length having occurred in the reign of Henry I., he commanded that the ancient ell (Lat. *ulna*), which corresponds to our yard, should be made of the exact length of his own arm. The span, which is nine inches, is the space from the end of the thumb to the end of the little finger when extended, or the eighth of a fathom (A.S. *fæthem*, the bosom), the space to which a man's arms can ordinarily be extended.

ing, from early perceptions of space; all science from crude and false guesses about the nature and causes of things, from illusions of alchemist and astrologer, which made attainment of the truth more possible to chemist and astronomer; and so on through the whole range of man's social and intellectual development.

4. *Evolution of Morals.*—Man by himself is not only unprogressive, he is also not so much immoral as unmoral. For where there is no society there is no sin. Therefore the bases of right and wrong lie in conduct towards one's fellows; the moral sense or conscience is the outcome of social relations, themselves the outcome of the need of living. The common interests which impel to combination involve praise or blame of the acts of each individual in the degree that they aid or hinder the well-being of all—in other words, add to their pleasure or their pain; and this praise and blame constitute the moral code, the collective or *tribal conscience.* Society, like the units of which it is made up, has to fight for its life, and all primitive laws are laws of self-preservation. Tribal self-preservation is based on sympathy between the several members, and it is therefore the ultimate foundation of the moral sense; whatever is helpful to it is *right*, whatever is a hindrance to it is *wrong.* Although union involves limitation and restraint, so that the units can no longer do exactly as they like, self-interest comes into play, since a man best insured respect for his own rights by respecting the rights of others. Society is not possible where a man is not true to his fellow; there is, as the phrase goes, honour among thieves, probably even among savages as low as the Jolas of the Gambia, every one of whom does as he likes, the most successful thief being the greatest man. In that model of sound and clear reasoning, so refreshing a contrast to the tedious word-mongering of most

writers on ethics, the chapter on the growth of the moral sense in the 'Descent of Man,'[1] Darwin points out how man's instinctive sympathy would lead him to value highly the approval of his fellows, and how his actions would be determined in a high degree by their expressed wishes; unfortunately, often by his own selfish desires. But while the lower instincts, as hunger, passion, and thirst for vengeance, are strong, they are not so enduring or satisfying as the higher feelings which crave for society and sympathy. And the yielding to the lower, however gratifying for the moment, would be followed by the feeling of regret that he had thus given way, and by resolve to act differently for the future. Thus at last man comes to feel, through acquired and perhaps inherited habit, that it is best for him to obey his more persistent impulses. It is this self-accusing feeling of remorse (literally *biting again*), due to power of reflection on actions and motives, that makes the difference so profound between man and the lower animals, whose moral sense does not advance beyond the stage which commits or avoids certain acts according as they are remembered as pleasurable or painful to the creature itself.

Special value would be set by the tribe upon brave and unselfish deeds as contributing to the common weal; praise and honour would reward the doer, encouraging that love of the tribe in which lay the germ of love of country. For he who is not a good citizen cannot be a true patriot, and he who holds not his fatherland dear can never become a well-wisher to mankind. The conceptions which these larger interests involve are, however, of very slow growth; for a long time the feeling of rightness and wrongness was limited to acts harmful or

[1] Chap. iv. *passim*; and cf. Clifford's *Lectures and Essays*, ii. pp. 106–176.

helpful to the tribe; in fact, that which was a crime within its borders became a virtue, and even a duty, outside them. What Cæsar says of the ancient Germans —'Robberies beyond the bounds of each community have no infamy, but are commended as a means of exercising youth and lessening sloth'[1]—still applies to barbaric peoples, and has its survival in the slowly decaying prejudices of civilised nations.

Morals are relative, not absolute; there is no fixed standard of right and wrong by which the actions of all men throughout all time are measured. The moral code advances with the progress of the race; conscience is a growth. That which society in rude stages of culture approves, it condemns at later and more refined stages, although such is the power of custom in investing the antique with sanctity, such the persistence of authority, and so deep its interest against change, that moral qualities are grafted upon acts apart from any question of their bearing upon character. Such, for example, are the prohibitions against certain foods and the commands to keep certain days sacred; such also the tyranny of caste, as among the Bhattias of India, who regard dining at an hotel as a greater sin than murder. Among the Mohammedan sect of the Wahhabees murder and adultery are venial offences compared to the smoking of tobacco. Among many savage peoples it is worse to marry a girl within the tribe than to murder one of another tribe. Among ourselves society condones a seduction, but not a *mésalliance*, and forgives an offence against etiquette less readily than an act of dishonour.

Although tending of late to unwise laxity towards offences for which death is the rightful penalty, the

[1] *Comm.*, bk. vi. cap. 23.

alterations in criminal codes witness to progress in morals and humaneness, and to the recognition of crime as more or less of the nature of disease. We need not go back to the time when laws punishing heresy and witchcraft were in force, since within the present century people were burned to death for coining false money, hanged for stealing a few shillings' worth of goods, and imprisoned for paltry debts, death being often the only bringer of release. Among the sights of London were the procession of condemned criminals to Tyburn every six weeks, and the auctions of negroes at the Poultry Compter. These and a hundred other barbarities went on without protest from the humane, whether Christians or non-Christians, for the collective conscience did not question their rightness, and their abolition was ultimately due to the efforts of individuals in whom a higher sense of human rights and duties was aroused, and through whom the general moral tone was advanced. That heightened tone, which is a yet stronger note of our time, is, in the main, due to the progress of science, using the term as including not merely knowledge of the operations of nature, but knowledge of human life as affected by divers causes, and of the community of blood in all mankind.

It is this which has broken down the barriers of prejudice between the classes of each nation and between nations themselves, bringing home the force of the Italian proverb, 'Tutto il mondo è paese'—'all the world is one country.' This larger view extends the range of human sympathy and of the service of man to his fellows, as well as to the lower animals, which that sympathy inspires. Terrible are the ills which the misuse of knowledge in the hands of the selfish and the ruffian inflicts, but these are as dust in the balance against the good which has been wrought. The conduct of a nation is no longer regulated solely by its own interests without regard to what is due to others, neither does it draw its sanction from the tribal legislation of a barbaric past, but from what, after ages of dearly bought experience, has proved itself to be best for man. In this, as in aught else which endures, nothing is rigid or final. Man's capacity can never overtake his loftiest ideals; in their conception is the spur to their pursuit. What dead weight of care do morals, thus regarded, lift from the heart of man! what new energy is given to his efforts! Thought becomes fixed on the evolution of goodness instead of on the origin of evil; time is set free from useless speculation for profitable action; evils once deemed inherent in the nature of things, and therefore irremovable, are accounted for and shown to be within our power to extirpate.

For in proving the unvarying relation between cause and effect in morals as in physics, science gives the clue to the remedy for moral ills. Moreover, that which man calls sin is shown to be more often due to his imperfect sense of the true proportion of things, and to his lack of imagination, than to his wilfulness; 'evil is wrought by want of thought as well as want of heart.' As Herbert Spencer says, 'the world is governed or overthrown by feelings to which ideas serve only as guides;'[1] and the lack of imagination, which is itself largely due to defective training of the intellect, prevents a man from putting himself in the place of others, and deprives him of that sympathy which is essential to the unselfish life. Since morals are due to the social instinct, the highest morality is that wherein each one shares to the full the life of all. The terrible mass of wrong-doing can only be lessened

[1] *Social Statics*, quoted in *Essays*, iii. 69.

and finally removed by suppression of the over-self; by the maintenance of the balance between such care of oneself as shall best fit us for the service of man, and such thought for others as shall inflict on them no suffering through our selfishness, nor loss through our gain[1] The crises of history are now rare when great principles or causes, demanding the sacrifice of the individual life, are at stake, but the world has never lacked a Curtius, and the spread of the scientific spirit has not proved fatal to the heroic.

Especially is science a preacher of righteousness in making clear the indissoluble unity between all life past, present, and to come. We are only on the threshold of knowledge as to the vast significance of the doctrine of heredity, but we know enough to deepen our sense of debt to the past and of duty to the future. We are what our forefathers made us, *plus* the action of circumstances on ourselves; and in like manner our children inherit the good and evil, both of body and mind, that is in us. Upon us, therefore, rests the duty of the cultivation of the best and of the suppression of the worst, so that the future of the race suffers not at our hands. More imperious is that duty since nothing—not omnipotence itself—can step in between us and the consequences of our acts. The 'forgiveness' of which men talk shows the charity of the injured, and may win the wrong-doer to a better life; but the thing 'forgiven'—who can undo its effects?[2] 'Our deeds are like the children born to us—

[1] Cf. the eloquent and stimulating chapter on the 'Cultivation of Human Nature,' in Mr. Cotter Morison's *Service of Man*.

[2] '"Do you know, Wilfrid, I once shot a little bird—for no good, but just to shoot at something. It wasn't that I didn't think of it—don't say that. I did think of it. I knew it was wrong. When I had levelled my gun I thought of it quite plainly, and yet I drew the trigger. It dropped, a heap of ruffled feathers. I shall never get that little bird out of my

they live and act apart from our own will. Nay, children may be strangled, but deeds never.'[1]

Self-conquest lies in obedience, obedience lies in knowledge; and if to know that it rests with man to make or to mar the lives of others be not sufficing stimulus to learning the true that we may do the right, no other motive can avail. Whatever power the threats of punishment and the promises of reward in an after life may have had in lawless and superstitious ages, they have now but the smallest effect on conduct; their remoteness exhausts their power, and, moreover, the belief in them is slowly decaying.

For the conduct of life brief maxims are enough; all the law and commandments are in the golden rule; all ethics in the teaching that if man be true to himself he cannot be false to his fellows; while in the knowledge that life's demands will always exceed its opportunities we may feel—

> How fair a lot to fill
> Is left to each man still.

5. *Evolution of Theology.*—Theology may be defined as dealing with man's relations to the god or gods in whom he believes; morals, as dealing with his relations to his fellow-men.

Unfortunately, the two have become a good deal mixed in the degree that conduct has been made to rest on supposed divine commands as to what men shall

head. And the worst of it is, that to all eternity I can never make any atonement."

'"But God will forgive you, Charley."

'"What do I care for that," he rejoined almost fiercely, "when the little bird cannot forgive me?"'—George Macdonald's *Wilfrid Cumbermede*, p. 179.

[1] *Romola*, p. 150 (one-vol. edition).

and shall not do—an assumption which serves a useful purpose as a restraint upon the brutal and ignorant, but which has been a powerful engine of terrorism in the hands of impostors and fanatics. The confusion, however, disappears when it is seen that the evolution of belief in spiritual beings is a thing apart from the evolution of morals, which, as has been shown, are based on social instincts and sympathies guided by reason and strengthened by inheritance and practice. For primitive theology is primitive science ; it is the outcome of man's first efforts to explain the nature of his surroundings, and of the divers influences which affect him for good, and still more for ill. At this stage of his mental growth the emotions have foremost play, because feeling precedes reason, and its exercise is more easy, its results more rapid, although, on that account, less trustworthy. Moreover, the phenomena on which experience, as the sole guide to true knowledge of things, is based, are too vast for a single life to compass, even were the reasoning faculty capable of dealing with them. It needed the lapse of long time ere man found out how his senses tricked him at every turn, and ere he could form any conception of orderly relation in his surroundings. So far as effort to supply his lower needs sharpened his wits, he did not go far astray ; in his struggle against material foes the weapons of his warfare were carnal, but as against spiritual powers ne was defenceless. Ignorance, always the mother of mystery, made him the slave of his fears. The vacuity of his mind gave admission to all the demons of panic and terror. The universal instinct of the savage leads him to ascribe an indwelling life to everything that moves, from the sun in heaven to the rustling leaves, and the stones that roll from the hill-side across his path. In this he acts as we see shying horses, timid pups, and young children act, until they learn from experience what things move of their own accord and what things do not. Shakespeare might have added Caliban to 'the lunatic, the lover, and the poet,' as of imagination all compact, and on whom it plays such tricks—

> That if it would but apprehend some joy,
> It comprehends some bringer of that joy.

Ever on the alert against enemies, man's fancy multiplied them on all sides; and since he naturally attributed passions like his own to the unseen beings in whom he believed, he dreaded 'some bringer of that' harm from every quarter, especially from things near at hand whose dire effects touched him closely, as the whirlpool and the breaker, the falling tree, the devouring beast, or venomous reptile. Phenomena farther off and less fitful moved him less, but although day succeeded night, both sun and moon were in turn often swallowed and disgorged by the black cloud-monsters, and in the wake of the fire- and wind-dragons of the lightning and the storm there followed destruction and death.

What man fears, but is powerless to control, he seeks to appease. Hence the prominence of devil-worship, of belief in baleful spirits amongst lower races; hence, likewise, the persistence of kindred beliefs among the ignorant in civilised countries; hence the world-wide custom of averting the wrath of gods or of buying their favour by sacrifices, smearing their images with human blood, and wreathing them with human intestines. Hence, also, the rise of a special class, 'medicine-men' and priests, into whose hands all ghastly and ghostly functions fall, and who secure dominance over their fellow-men by pretending to be the mouthpiece of the gods, to forgive sins in their name and to make known their will.

This animism, or general doctrine of spiritual agents, was largely fostered by personal experience supplied by dreams about both the dead and living, hallucinations, swoons, and by the shadows or reflections which objects cast, all which seemed to witness to the existence of a second self or soul, that came and went at pleasure during life, and haunted its old home after death. The burial-place became the spot where the living brought their gifts to the dread spirits of the departed, whose worship is a leading feature of barbaric religions. The grave was the cradle of beliefs about the departed; the tomb became the temple. Combined with the belief in life wherever power or movement was manifest, these ideas have built up all theologies, from the polytheistic to the so-called monotheistic, the common element in each being the ascription of personality to unseen powers. Given the intellectual stage which a people has reached, the character of their gods can be predicted, although the higher theologies will retain persistent traces of the barbaric conceptions of deity in which they arose. They are not, as shallow carpers have argued, the ingenious inventions of self-seeking men; they arise out of the necessity of human nature to frame an explanation of that which affects it deeply and constantly. Their roots draw nutriment from a common soil; the frenzy of the savage and the ecstasy of the saint have a common base in undisciplined imagination.

Theology is purified from gross conceptions only in proportion as it is purged of the false science with which, to its own hurt, it identified itself in the past, and to the remnants of which it still clings. The function of science is to clarify the mind, and to show how the beliefs of the past are the myths of the present; the duty of theology is to readjust itself to what science proves to be true, since science has no facts to interpret save those which man has gained from experience. Of aught else, as Omar Khayyám sings—

> Myself when young did eagerly frequent
> Doctor and saint, and heard great argument
> About it and about, but evermore
> Came out by the same door wherein I went.

Creeds may die, rites and ceremonies become matters of archæological interest, but human needs endure. Conduct is everything, because duty never lapses. Theology, uncorrected, troubles itself about the fate of a man who denies its speculative doctrines ; morals bid him remember, as the one thing needful, that what he sows he or his will reap. In the end, when it is seen that theories about gods and all other spiritual beings have nothing whatever to do with man's duty to his fellows, theology and morals will again become distinct.

In the chapters now brought to an end a vast field, the limits of which shade into the unlimited on all sides, has been roughly surveyed. We began with the primitive nebula, we end with the highest forms of consciousness ; the story of creation is shown to be the unbroken record of the evolution of gas into genius.

Let us epitomise in fewest words what, after all, is itself but a summary of a large subject :—

1. *Description.*—The universe is made up of Matter and Power, both of which are indestructible. Matter contains about seventy so-called elementary substances, which exist in a free or combined state as solid, liquid, or gaseous ; it is also present throughout space in the imponderable state known as ethereal. The motions of Matter are due to Power, which acts in a twofold and

opposite way, viz. as a pulling or combining Force, and as a pushing or separating Energy. Force inheres in matter, and acts continuously whatever the distance; Energy is both passive or stored up, and active or in a state of transfer from body to body, the sum-total being in gradual course of transfer to the ethereal medium, where its power to do work ends. Ponderable matter is distributed throughout space in bodies of various size and density, from molecules to sidereal or solar systems. Such a system is our central sun, with his company of planets and their moons, and of comets and other wandering gaseous bodies. The planet on which we live is a nearly spherical body, three-fourths of which is covered by water, and the whole surface enveloped by an atmosphere. So far as its rind or crust can be examined, it is found to consist of solid rocks, the lowest of which have been fused by fire, and the uppermost laid down by water. The water-laid rocks contain the remains of plants and animals which have escaped the general destruction of organisms in the wear and tear which the rocks undergo ceaselessly. The simplest fossils are found in the oldest deposits, the more advanced in the newer, and so on in ascending scale until we reach the newest deposits, which contain the highest forms. The existing species of plants and animals comprise the lowest and simplest, which have probably persisted throughout the entire life-period, as well as the highest and some others, the vast majority of intermediate species having died out. All plants and animals are made of the same materials, and have to do the same work. That work is threefold: to feed, to multiply their kind, and to respond to the outer world. The cells of which every part of every plant and animal is built up are variously altered and arranged according to the way in which that work is more or less divided amongst the several parts. The main difference between plant and animal is in the mode of feeding ; the plant is alone able, in virtue of its chlorophyll, to convert the inorganic into the organic, and the animal therefore depends on the plant for its food supply.

2. *Explanation.*—At the beginning of the present universe Matter was a diffused vaporous mass, unequally distributed throughout space. Force, acting on the unstableness of that mass, drew its particles together, and the resulting collision set free the stored-up Energy, which became active in two forms: the *molar*, causing the several masses into which the particles had gathered to spin round in an orbit; and the *molecular*, causing a swing-like motion among the particles, which motion was diffused as light and heat. The masses into which the primitive nebula was broken up became sidereal or solar systems, each of which, like the parent mass, threw off, as it was indrawn towards its common centre of gravity, masses which became the planets, and from these were detached, in like manner, masses which became moons. Comets and other fugitive bodies are probably due to expulsion. Both in its shape and general condition the earth gives proof of this passage from the gaseous to the solid state. As one of the smaller bodies, it long ago ceased to shine by its own light, but a vast period elapsed before it became cool enough to form a crust and to condense the vapours that swathed it into primeval oceans. The simplest compounds of its elements were formed first, the combinations becoming more and more complex until they reached that subtile form which is the physical basis of life, and which, starting in water as a structureless jelly, has reached its fullest development in man. The organic

is dependent upon the inorganic; and mind, as a special form of life, takes its place as the highest product of the action of Power upon Matter. From the action of mind on mind has arisen that social evolution to which, in a supreme degree, is owing the progress of man in knowledge, whereby he has subdued the earth.

The ultimate transference of all energy to the ethereal medium involves the end of the existing state of things. But the ceaseless redistribution of matter, force-clasped and energy-riven, involves the beginning of another state of things. So the changes are rung on evolution and dissolution, on the birth and death of stellar systems—gas to solid, solid to gas, yet never quite the same—mighty rhythmic beats of which the earth's cycles, and the cradles and graves of her children, are minor rhythms.

. . . .

Thus the keynotes of Evolution are Unity and Continuity. All things are made of the same stuff differently mixed, bound by one force, stirred by one energy in divers forms. Force inheres in matter; Energy acts through it; therefore both have neither more nor less claim to objective reality than matter. And as science tends to the conclusion that all kinds of matter are modifications of one primal element, and that all modes of motion are varied operations of one power, perchance these three—Matter, Force, and Energy—are one.

But into these and like speculative topics Evolution does not intrude. Dealing with processes, and not with the nature of things in themselves, it is silent concerning any theories that may be formulated to gratify man's insatiate curiosity about the whence and whither. Since it can throw no light on the genesis of matter, or on the origination of motion, or on the beginnings of life or of mind, it leaves great and small alike a centre of impenetrable mystery. It may correct, but it does not repress, the imagination; neither does it impose any limits on thought; it has a larger charity for superstition than for irreverence; it has no shibboleths the surrender of which can awaken dread; its temper is not aggressive; it seeks to inform life with the love of truth, and to let the facts which it reveals, and whose significance is its chief concern, win their way on their own merits; since 'a dogma learned is only a new error—the old one was perhaps as good; whereas a spirit communicated is a perpetual possession.' Our sense of the beauty of Nature is not dimmed by fuller and truer knowledge of her works and ways; the more we feel our oneness with her the more do we desire to know her as she IS; while all that it really suffices us to learn for the discharge of life's duties, and all the motive that is needed to impel us thereto, is supplied in the theory which has so profoundly and permanently affected every department of human thought.

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