different kinds for shipbuilding, in which the inhabitants are very expert. There are important mines both of iron and tin the former being used in the island and the latter exported to the Netherlands. The quantity of tin obtained in 1871 was 49,850 picols, or 60,532 cwts. The chief imports are rice, cotton goods, pottery, and cocoa-nuts. The population in 1871 amounted to 19.837, of whom only 59 were Europeans. The natives are of middle height and strongly built, and have expressive features. The island was formerly under the sultan of Palembang, by whom it was ceded to the English in 1812. As no mention was made of it in the treaty between the English and Dutch in 1814, the former at first refused to renounce their possession, and only recognized the Dutch claim in 1824. Till 1852 it was dependent on Banka, but at that date was raised to a sub-residency.

See *Tijdschrift v. Nederl. Indië*, vols. xii. and xv.; Court's *Relations of Brit. Gov. with the State of Palembang*, 1821; Croockewit, *Banka, Malakka, en Billiton*, 1852; Veth, *Woordenboek van Nederl. Indië*, 1869.

BILMA, or KAWAR, a town in the heart of the African desert, and the capital of the wandering tribe called the Tibboos. The place is mean and poor, surrounded with a mud wall. In its vicinity are a number of lakes, the waters of which, on evaporation by the heat of the sun, yield a quantity of very pure and fine salt, which is the object of an extensive and important trade with the countries in Central Africa. The largest of these lakes is at Agram, situated about four miles to the westward. Near Bilma is a small circular spot, kept green by a fine spring, but immediately to the south begins the most dreary part of the African desert, over which the caravans travel for fifteen days without discovering the slightest trace of vegetable life. During Nachtigal's visit in 1870 the temperature during the day rarely sank below 113° Fahr.

BILSA, a town of Hindustán, in the territory of Gwálior or the possessions of Sindhiá, situated on the Betwá River in lat. 23° 30′ N. and long. 77° 50′ E. It is enclosed with a stone wall, and defended by square towers and a ditch. The suburbs without the walls are not very extensive, but the streets are spacious, and contain some good houses. The town and the surrounding country are celebrated all over India for the excellent quality of the tobacco, which is bought up with great eagerness and exported. Population about 3000. Distance south from Gwálior, 190 miles

BILSTON, formerly BILSRETON, a market-town of England, in the county of Stafford, 2½ miles S.E. of Wolverhampton, indebted for its importance to the iron trade, which it carries on in various departments. In the vicinity are very productive mines of coal and ironstone, as well as sand of the finest quality for casting, and grinding-stones for cutlers. Bilston contains numerous furnaces, forges, rolling and slitting mills for the preparation of iron, and a great variety of factories for japanned and painted goods, brass-work, bells, and similar articles. The town itself is very irregularly built; but it has some handsome buildings, as St Leonard's and St Mary's chapels, and the Roman Catholic chapel. The population of township, which is under an improvements commission, and forms part of the parliamentary borough of Wolverhampton, was, in 1871, 24,188.

BINGEN, the ancient *Bingium*, a town of the grand-duchy of Hesse-Darmstadt, in the province of Rhenish Hesse, 15 miles W. of Mentz. It is situated almost opposite Rüdesheim, on the left bank of the Rhine, at the confluence of the Nahe (or *Nava*), which is crossed near its mouth by an iron railway bridge resting on old Roman foundations. A considerable trade is carried on in wine, grain, and cattle; and tobacco, starch, and leather are manufactured. A short way down the Rhine is the Bingerloch, a famous whirlpool, the dangers of which were almost removed by blastings undertaken by the Prussian Government in 1834; while about half-way between it and the town rises on a rock, in the middle of the stream, the tower of Bishop Hatto. On a height immediately to the south-east is the ruined castle of Klopp, originally founded by Drusus, and higher still on the Rochusberg the celebrated chapel of St Roch. Population in 1871, 5938.

BINGHAM, JOSEPH, a learned scholar and divine, was born at Wakefield in Yorkshire, in September 1668. He was educated at University College, Oxford, of which he was made fellow in 1689, and college tutor in 1691. A sermon preached by him from the university pulpit, St Mary's, on the meaning of the word "Person" in the Fathers, brought upon him a most unjust accusation of heresy. He was compelled to give up his fellowship and leave the university; but he was immediately presented by Dr John Radcliffe to the rectory of Headbournworthy, near Winchester. In this country retirement be began his laborious and valuable work entitled *Origines Ecclesiasticæ*, or Antiquities of the Christian Church, the first volume of which appeared in 1708 and the tenth in 1722. Notwithstanding his learning and merit, Bingham received no higher preferment than that of Headbournworthy till the year 1712, when he was collated to the rectory of Havant, near Portsmouth, by Sir Jonathan Trelawney, bishop of Winchester. Nearly all his little property was lost in the great South Sea bubble of 1720. He died August 17, 1723

BINGLEY, a thriving market-town in the West Riding of Yorkshire, on the River Aire, 5¼ miles from Bradford, on the Midland Railway. The inhabitants are principally engaged in manufactures of worsted, cotton, paper, and iron. The town is well built, and has a neat church, a grammar school, and several charities. The population of the Local Board District, which includes a part of Micklethwaite, was 9062 in 1871.

BINNEY, THOMAS, an English Nonconformist divine, was born at Newcastle-on-Tyne in 1798, and died February 24, 1874. After spending seven years in the employment of a bookseller he entered the theological college of Wymondley, Herts, with the view of studying for the ministry. His first pastoral charge was that of the Congregational church at Newport, Isle of Wight, to which he was inducted in 1824. Five years later—in 1829—he accepted a call to the historic Weigh House chapel, London. Here he at once established what proved to be a lasting popularity, and it was found necessary to build a much larger place of worship on Fish Street Hill, to which the congregation removed in 1834. An address delivered on the occasion of the laying of the foundation stone of the new building was afterwards published, with an appendix containing a strongly worded opinion as to the baneful influence of the Church of England, which naturally gave rise to much angry comment and a prolonged and bitter controversy. Throughout his whole career Binney was a vigorous and intelligent opponent of the state church principle, but those who inferred from one, perhaps unguarded, statement that he was a narrow-minded political dissenter did him injustice. His liberality of view and breadth of ecclesiastical sympathy entitle him to rank on questions of Nonconformity among the most distinguished of the school of Richard Baxter. Accordingly, in his later years he was not only recognized by general consent as the foremost name among all sections of English Nonconformists, but maintained friendly relations with many of the leading dignitaries of the Established Church. He continued in the active discharge of the duties of the ministry, though latterly with the help of a colleague, until 1871, when he resigned. In 1845 he paid a visit to Canada and the United States, and in 1857 he set out on a tour to the Australian colonies, which extended over a period of two years. Though he not infrequently fell markedly below his own standard of excellence, Binney exercised an influence as a preacher, especially with young men, such as few have wielded for so long a period. A manly, vigorous intellect, fearless independence of judgment, a lively imagination, showing itself chiefly in frequent flashes of happy illustration, a keen, sarcastic humour chastened but of deliberate purpose not altogether repressed, a direct forcible style, a commanding presence, and a pleasant musical voice sufficiently account for his popularity. He was the pioneer in a much needed improvement of the forms of service in Nonconformist churches, and gave a special impulse to congregational psalmody by the publication of a book entitled *The Service of Song in the House of the Lord*. Of numerous other works the best known is his *Is it Possible to Make the Best of Both Worlds?* an expansion of a lecture delivered to young men in Exeter Hall, which attained a circulation of 30,000 copies within a year of its publication. A very happy specimen of his peculiar powers as an author is his *Money, a Popular Exposition in Rough Notes* (1864), which also had a large circulation.

BINTANG, one of the islands which mark the south side of the Strait of Singapore. The latter is the exit towards China and Siam of the great channel which we call the Straits of Malacca. Bintang lies between 104° 13′ and 104° 40′ E. long., with a central latitude of 0° 52′ N. It has an area of about 440 square miles, and is surrounded by many rocks and small islands, making navigation dangerous. The soil is not fertile, and much of it is swampy. The chief product is *gambir*, of which upwards of 4000 tons are annually exported, with pepper and some other spices and fruits. The island is a good deal visited by Malay and Chinese traders. The highest hill in it is 1385 feet high, and there are five rivers, but these navigable only by small boats.

Bintang is mentioned by Marco Polo under the name of *Pentam*, which is not far from the genuine Malay name *Bentăn*, said to mean a half-moon, and to apply properly to the mountain just mentioned. The name appears on a mediæval Javanese inscription, as that of one of the numerous kingdoms conquered by the sovereigns reigning at Majapahit, in Java.

After the Portuguese conquest of Malacca (1511), the expelled Mahometan dynasty took up its residence on Bintang, where it long cherished pirates. The island still belongs nominally to the representative of these kings of Malacca, whom we usually style the sultan of Johór, the Dutch the sultan of Lingen. Supremacy is, however, claimed and exercised by the Dutch, whose port of *Rhio* or *Riouw*, founded as a rival to Singapore, stands on a small island off the western coast of Bintang.

Bintang, regarded as the residence of the expelled sultans of Malacca, is the Bintão whereof Camoens speaks as the persistent foe of Portuguese Malacca:—

> "*No reino de* Bintão, *que tantos danos*
> *Terá a Malaca muito tempo feitos.*"

BIOLOGY

THE Biological sciences are those which deal with the phenomena manifested by living matter; and though it is customary and convenient to group apart such of these phenomena as are termed mental, and such of them as are exhibited by men in society, under the heads of Psychology and Sociology, yet it must be allowed that no natural boundary separates the subject matter of the latter sciences from that of Biology. Psychology is inseparably linked with Physiology; and the phases of social life exhibited by animals other than man, which sometimes curiously foreshadow human policy, fall strictly within the province of the biologist.

On the other hand, the biological sciences are sharply marked off from the abiological, or those which treat of the phenomena manifested by not-living matter, in so far as the properties of living matter distinguish it absolutely from all other kinds of things, and as the present state of knowledge furnishes us with no link between the living and the not-living.

These distinctive properties of living matter are—

1. Its *chemical composition*—containing, as it invariably does, one or more forms of a complex compound of carbon, hydrogen, oxygen, and nitrogen, the so-called protein (which has never yet been obtained except as a product of living bodies) united with a large proportion of water, and forming the chief constituent of a substance which, in its primary unmodified state, is known as *protoplasm*.

2. Its *universal disintegration and waste by oxidation; and its concomitant reintegration by the intus-susception of new matter.*

A process of waste resulting from the decomposition of the molecules of the protoplasm, in virtue of which they break up into more highly oxidated products, which cease to form any part of the living body, is a constant concomitant of life. There is reason to believe that carbonic acid is always one of these waste products, while the others contain the remainder of the carbon, the nitrogen, the hydrogen, and the other elements which may enter into the composition of the protoplasm.

The new matter taken in to make good this constant loss is either a ready-formed protoplasmic material, supplied by some other living being, or it consists of the elements of protoplasm, united together in simpler combinations, which consequently have to be built up into protoplasm by the agency of the living matter itself. In either case, the addition of molecules to those which already existed takes place, not at the surface of the living mass, but by interposition between the existing molecules of the latter. If the processes of disintegration and of reconstruction which characterize life balance one another, the size of the mass of living matter remains stationary, while, if the reconstructive process is the more rapid, the living body *grows*. But the increase of size which constitutes growth is the result of a process of molecular intus-susception, and therefore differs altogether from the process of growth by accretion, which may be observed in crystals and is effected purely by the external addition of new matter—so that, in the well-known aphorism of Linnæus, the word "grow," as applied to stones, signifies a totally different process from what is called "growth" in plants and animals.

3. Its *tendency to undergo cyclical changes.*

In the ordinary course of nature, all living matter proceeds from pre-existing living matter, a portion of the latter being detached and acquiring an independent existence. The new form takes on the characters of that from which it arose; exhibits the same power of propagating itself by means of an offshoot; and, sooner or later, like its predecessor, ceases to live, and is resolved into more highly oxidated compounds of its elements.

Thus an individual living body is not only constantly changing its substance, but its size and form are undergoing continual modifications, the end of which is the death and decay of that individual; the continuation of the kind being secured by the detachment of portions which tend to run through the same cycle of forms as the parent. No forms of matter which are either not living, or have not been derived from living matter, exhibit these three properties, nor any approach to the remarkable phenomena defined under the second and third heads. But in addition to these distinctive characters, living matter has some other peculiarities, the chief of which are the dependence of all its activities upon moisture and upon heat, within a limited range of temperature, and the fact that it usually possesses a certain structure, or organization.

As has been said, a large proportion of water enters into the composition of all living matter; a certain amount of drying arrests vital activity, and the complete abstraction of this water is absolutely incompatible with either actual or potential life. But many of the simpler forms of life may undergo desiccation to such an extent as to arrest their vital manifestations and convert them into the semblance of not-living matter, and yet remain potentially alive. That is to say, on being duly moistened they return to life again. And this revivification may take place after months, or even years, of arrested life.

The properties of living matter are intimately related to temperature. Not only does exposure to heat sufficient to decompose protein matter destroy life, by demolishing the molecular structure upon which life depends; but all vital activity, all phenomena of nutritive growth, movement, and reproduction are possible only between certain limits of temperature. As the temperature approaches these limits the manifestations of life vanish, though they may be recovered by return to the normal conditions; but if it pass far beyond these limits, death takes place.

This much is clear; but it is not easy to say exactly what the limits of temperature are, as they appear to vary in part with the kind of living matter, and in part with the conditions of moisture which obtain along with the temperature. The conditions of life are so complex in the higher organisms, that the experimental investigation of this question can be satisfactorily attempted only in the lowest and simplest forms. It appears that, in the dry state, these are able to bear far greater extremes both of heat and cold than in the moist condition. Thus Pasteur found that the spores of fungi, when dry, could be exposed without destruction to a temperature of 120°–125° C. (248°–257° Fahr.), while the same spores, when moist, were all killed by exposure to 100° C. (212° Fahr.) On the other hand, Cagniard de la Tour found that dry yeast might be exposed to the extremely low temperature of solid carbonic acid (−60° C. or −76° Fahr.) without being killed. In the moist state he found that it might be frozen and cooled to −5° C. (23° Fahr.), but that it was killed by lower temperatures. However, it is very desirable that these experiments should be repeated, for Cohn's careful observations on *Bacteria* show that, though they fall into a state of torpidity, and, like yeast, lose all their powers of exciting fermentation at, or near, the freezing point of water, they are not killed by exposure for five hours to a temperature below −10° C. (14° Fahr.), and, for some time, sinking to 18° C. (−0°·4 Fahr.) Specimens of *Spirillum volutans*, which had been cooled to this extent, began to move about some little time after the ice containing them thawed. But Cohn remarks that *Euglenæ*, which were frozen along with them, were all killed and disorganised, and that the same fate had befallen the higher *Infusoria* and *Rotifera*, with the exception of some encysted *Vorticellæ*, in which the rhythmical movements of the contractile vesicle showed that life was preserved.

Thus it would appear that the resistance of living matter to cold depends greatly on the special form of that matter, and that the limit of the *Euglena*, simple organism as it is, is much higher than that of the *Bacterium*.

Considerations of this kind throw some light upon the apparently anomalous conditions under which many of the lower plants, such as *Protococcus* and the *Diatomaceæ*, and some of the lower animals, such as the *Radiolaria*, are observed to flourish. *Protococcus* has been found, not only on the snows of great heights in temperate latitudes, but covering extensive areas of ice and snow in the Arctic regions, where it must be exposed to extremely low temperatures,—in the latter case for many months together; while the Arctic and Antarctic seas swarm with *Diatomaceæ* and *Radiolaria*. It is on the *Diatomaceæ*, as Hooker has well shown, that all surface life in these regions ultimately depends; and their enormous multitudes prove that their rate of multiplication is adequate to meet the demands made upon them, and is not seriously impeded by the low temperature of the waters, never much above the freezing point, in which they habitually live.

The maximum limit of heat which living matter can resist is no less variable than its minimum limit. Kühne found that marine *Amœbæ* were killed when the temperature reached 35° C. (95° Fahr.), while this was not the case with fresh-water *Amœbæ*, which survived a heat of 5°, or even 10°, C. higher. And *Actinophrys Eichornii* was not killed until the temperature rose to 44° or 45° C. *Didymium serpula* is killed at 35° C.; while another *Myxomycete*, *Æthalium septicum*, succumbs only at 40° C.

Cohn ("Untersuchungen über Bacterien," *Beiträge zur Biologie der Pflanzen, Heft* 2, 1872) has given the results of a series of experiments conducted with the view of ascertaining the temperature at which *Bacteria* are destroyed, when living in a fluid of definite chemical composition, and free from all such complications as must arise from the inequalities of physical condition when solid particles other than the *Bacteria* co-exist with them. The fluid employed contained 0·1 gramme potassium phosphate, 0·1 gr. crystallised magnesium sulphate, 0·1 gr. tribasic calcium phosphate, and 0·2 gr. ammonium tartrate, dissolved in 20 cubic centimetres of distilled water. If to a certain quantity of this "normal fluid" a small proportion of water containing *Bacteria* was added, the multiplication of the *Bacteria* went on with rapidity, whether the mouth of the containing flask was open or hermetically closed. Hermetically-sealed flasks, containing portions of the normal fluid infected with *Bacteria*, were submerged in water heated to various temperatures, the flask being carefully shaken, without being raised out of the water, during its submergence.

The result was, that in those flasks which were thus subjected, for an hour, to a heat of 60°–62° C. (140°–143° Fahr.), the *Bacteria* underwent no development, and the fluid remained perfectly clear. On the other hand, in similar experiments in which the flasks were heated only to 40° or 50° C. (104°–122° Fahr.), the fluid became turbid, in consequence of the multiplication of the *Bacteria*, in the course of from two to three days.

Both in Kühne's and in Cohn's experiments, which last have lately been confirmed and extended by Dr Roberts of Manchester, it was noted that long exposure to a lower temperature than that which brings about immediate destruction of life, produces the same effect as short exposure to the latter temperature. Thus, though all the *Bacteria* were killed, with certainty, in the normal fluid, by short exposure to temperatures at or above 60° C. (140° Fahr.), Cohn observed that, when a flask containing infected normal fluid was heated to 50°–52° C. (122°–125° Fahr.) for only an hour, the consequent multiplication of the *Bacteria* was manifested much earlier, than in one which had been exposed for two hours to the same temperature.

It appears to be very generally held that the simpler vegetable organisms are deprived of life at temperatures as high as 60° C. (140° Fahr.); but *Algæ* have been found living in hot springs at much higher temperatures, namely, from 168° to 208° Fahr., for which latter surprising fact we have the high authority of Descloiseaux. It is no ex-

planation of these phenomena, but only another mode of stating them, to say that these organisms have become "accustomed" to such temperatures. If this degree of heat were absolutely incompatible with the activity of living matter, the plants could no more resist it than they could become "accustomed" to being made red hot. Habit may modify subsidiary, but cannot affect fundamental, conditions.

Recent investigations point to the conclusion that the immediate cause of the arrest of vitality, in the first place, and of its destruction, in the second, is the coagulation of certain substances in the protoplasm, and that the latter contains various coagulable matters, which solidify at different temperatures. And it remains to be seen, how far the death of any form of living matter, at a given temperature, depends on the destruction of its fundamental substance at that heat, and how far death is brought about by the coagulation of merely accessory compounds.

Life and organization.

It may be safely said of all those living things which are large enough to enable us to trust the evidence of microscopes, that they are heterogeneous optically, and that their different parts, and especially the surface layer, as contrasted with the interior, differ physically and chemically; while, in most living things, mere heterogeneity is exchanged for a definite structure, whereby the body is distinguished into visibly different parts, which possess different powers or functions. Living things which present this visible structure are said to be *organized*; and so widely does organization obtain among living beings, that *organized* and *living* are not unfrequently used as if they were terms of co-extensive applicability. This, however, is not exactly accurate, if it be thereby implied that all living things have a visible organization, as there are numerous forms of living matter of which it cannot properly be said that they possess either a definite structure or permanently specialized organs: though, doubtless, the simplest particle of living matter must possess a highly complex molecular structure, which is far beyond the reach of vision.

The broad distinctions which, as a matter of fact, exist between every known form of living substance and every other component of the material world, justify the separation of the biological sciences from all others. But it must not be supposed that the differences between living and not-living matter are such as to justify the assumption that the forces at work in the one are different from those which are to be met with in the other. Considered apart from the phenomena of consciousness, the phenomena of life are all dependent upon the working of the same physical and chemical forces as those which are active in the rest of the world. It may be convenient to use the terms "vitality" and "vital force" to denote the causes of certain great groups of natural operations, as we employ the names of "electricity" and "electrical force" to denote others; but it ceases to be proper to do so, if such a name implies the absurd assumption that "electricity" and "vitality" are entities playing the part of efficient causes of electrical or vital phenomena. A mass of living protoplasm is simply a molecular machine of great complexity, the total results of the working of which, or its vital phenomena, depend,—on the one hand, upon its construction, and, on the other, upon the energy supplied to it; and to speak of "vitality" as anything but the name of a series of operations is as if one should talk of the "horologity" of a clock.

Classification of the phenomena of life.

Living matter, or protoplasm and the products of its metamorphosis, may be regarded under four aspects:—

(1.) It has a certain external and internal form, the latter being more usually called structure;

(2.) It occupies a certain position in space and in time;

(3.) It is the subject of the operation of certain forces in virtue of which it undergoes internal changes, modifies external objects, and is modified by them; and

(4.) Its form, place, and powers are the effects of certain causes.

In correspondence with these four aspects of its subject, biology is divisible into four chief subdivisions—I. Morphology; II. Distribution; III. Physiology; IV. Ætiology.

I. Morphology.

So far as living beings have a form and structure, they fall within the province of *Anatomy* and *Histology*, the latter being merely a name for that ultimate optical analysis of living structure which can be carried out only by the aid of the microscope.

And, in so far as the form and structure of any living being are not constant during the whole of its existence, but undergo a series of changes from the commencement of that existence to its end, living beings have a *Development*. The history of development is an account of the anatomy of a living being at the successive periods of its existence, and of the manner in which one anatomical stage passes into the next.

Finally, the systematic statement and generalization of the facts of Morphology, in such a manner as to arrange living beings in groups according to their degrees of likeness, is *Taxonomy*.

The study of Anatomy and Development has brought to light certain generalizations of wide applicability and great importance.

Most plants and animals are aggregates of cells.

1. It has been said that the great majority of living beings present a very definite structure. Unassisted vision and ordinary dissection suffice to separate the body of any of the higher animals, or plants, into fabrics of different sorts, which always present the same general arrangement in the same organism, but are combined in different ways in different organisms. The discrimination of these comparatively few fabrics, or *tissues*, of which organisms are composed, was the first step towards that ultimate analysis of visible structure which has become possible only by the recent perfection of microscopes and of methods of preparation.

Histology, which embodies the results of this analysis, shows that every tissue of a plant is composed of more or less modified structural elements, each of which is termed a *cell*; which cell, in its simplest condition, is merely a spheroidal mass of protoplasm, surrounded by a coat or sac—the *cell-wall*—which contains cellulose. In the various tissues, these cells may undergo innumerable modifications of form—the protoplasm may become differentiated into a nucleus with its nucleolus, a primordial utricle, and a cavity filled with a watery fluid, and the cell-wall may be variously altered in composition or in structure, or may coalesce with others. But, however extensive these changes may be, the fact that the tissues are made up of morphologically distinct units—the cells—remains patent. And, if any doubt could exist on the subject, it would be removed by the study of development, which proves that every plant commences its existence as a simple cell, identical in its fundamental characters with the less modified of those cells of which the whole body is composed.

But it is not necessary to the morphological unit of the plant that it should be always provided with a cell-wall. Certain plants, such as *Protococcus*, spend longer or shorter periods of their existence in the condition of a mere spheroid of protoplasm, devoid of any cellulose wall, while, at other times, the protoplasmic body becomes enclosed within a cell-wall, fabricated by its superficial layer.

Therefore, just as the nucleus, the primordial utricle, and the central fluid are no essential constituents of the morphological unit of the plant, but represent results of its metamorphosis, so the cell-wall is equally unessential; and either the term "cell" must acquire a merely technical significance as the equivalent of morphological unit, or some new term must be invented to describe the latter. On the whole, it is probably least inconvenient to modify the sense of the word "cell."

The histological analysis of animal tissues has led to results and to difficulties of terminology of precisely the same character. In the higher animals, however, the modifications which the cells undergo are so extensive, that the fact that the tissues are, as in plants, resolvable into an aggregation of morphological units, could never have been established without the aid of the study of development, which proves that the animal, no less than the plant, commences its existence as a simple cell, fundamentally identical with the less modified cells which are found in the tissues of the adult.

Though the nucleus is very constant among animal cells, it is not universally present; and among the lowest forms of animal life, the protoplasmic mass which represents the morphological unit may be, as in the lowest plants, devoid of a nucleus. In the animal, the cell-wall never has the character of a shut sac containing cellulose; and it is not a little difficult, in many cases, to say how much of the so-called "cell-wall" of the animal cell answers to the "primordial utricle" and how much to the proper "cellulose cell-wall" of the vegetable cell. But it is certain that in the animal, as in the plant, neither cell-wall nor nucleus are essential constituents of the cell, inasmuch as bodies which are unquestionably the equivalents of cells—true morphological units—are mere masses of protoplasm, devoid alike of cell-wall and nucleus.

For the whole living world, then, it results:—that the morphological unit—the primary and fundamental form of life—is merely an individual mass of protoplasm, in which no further structure is discernible; that independent living forms may present but little advance on this structure; and that all the higher forms of life are aggregates of such morphological units or cells, variously modified.

Moreover, all that is at present known tends to the conclusion, that, in the complex aggregates of such units of which all the higher animals and plants consist, no cell has arisen otherwise than by becoming separated from the protoplasm of a pre-existing cell; whence the aphorism "*Omnis cellula e cellula.*"

It may further be added, as a general truth applicable to nucleated cells, that the nucleus rarely undergoes any considerable modification, the structures characteristic of the tissues being formed at the expense of the more superficial protoplasm of the cells; and that, when nucleated cells divide, the division of the nucleus, as a rule, precedes that of the whole cell.

2. In the course of its development every cell proceeds from a condition in which it closely resembles every other cell, through a series of stages of gradually increasing divergence, until it reaches that condition in which it presents the characteristic features of the elements of a special tissue. The development of the cell is therefore a gradual progress from the general to the special state.

The like holds good of the development of the body as a whole. However complicated one of the higher animals or plants may be, it begins its separate existence under the form of a nucleated cell. This, by division, becomes converted into an aggregate of nucleated cells: the parts of this aggregate, following different laws of growth and multiplication, give rise to the rudiments of the organs; and the parts of these rudiments again take on those modes of growth and multiplication and metamorphosis which are needful to convert the rudiment into the perfect structure.

The development of the organism as a whole, therefore, repeats in principle the development of the cell. It is a progress from a general to a special form, resulting from the gradual differentiation of the primitively similar morphological units of which the body is composed.

Moreover, when the stages of development of two animals are compared, the number of these stages which are similar to one another is, as a general rule, proportional to the closeness of the resemblance of the adult forms; whence it follows that the more closely any two animals are allied in adult structure, the later are their embryonic conditions distinguishable. And this general rule holds for plants no less than for animals.

The broad principle, that the form in which the more complex living things commence their development is always the same, was first expressed by Harvey in his famous aphorism, "*Omne vivum ex ovo,*" which was intended simply as a morphological generalization, and in no wise implied the rejection of spontaneous generation, as it is commonly supposed to do. Moreover, Harvey's study of the development of the chick led him to promulgate that theory of "epigenesis," in which the doctrine that development is a progress from the general to the special is implicitly contained.

Caspar F. Wolff furnished further, and indeed conclusive, proof of the truth of the theory of epigenesis; but, unfortunately, the authority of Haller and the speculations of Bonnet led science astray, and it was reserved for Von Baer to put the nature of the process of development in its true light, and to formulate it in his famous law.

3. Development, then, is a process of differentiation by which the primitively similar parts of the living body become more and more unlike one another.

This process of differentiation may be effected in several ways. Modes of differentiation.

(1.) The protoplasm of the germ may not undergo division and conversion into a cell aggregate; but various parts of its outer and inner substance may be metamorphosed directly into those physically and chemically different materials which constitute the body of the adult. This occurs in such animals as the *Infusoria*, and in such plants as the unicellular *Algæ*.

(2.) The germ may undergo division, and be converted into an aggregate of cells, which cells give rise to the tissues by undergoing a metamorphosis of the same kind as that to which the whole body is subjected in the preceding case.

The body, formed in either of these ways, may, as a whole, undergo metamorphosis by differentiation of its parts, and the differentiation may take place without reference to any axis of symmetry, or it may have reference to such an axis. In the latter case, the parts of the body which become distinguishable may correspond on the two sides of the axis (bilateral symmetry), or may correspond along several lines parallel with the axis (radial symmetry).

The bilateral or radial symmetry of the body may be further complicated by its segmentation, or separation by divisions transverse to the axis, into parts, each of which corresponds with its predecessor or successor in the series.

In the segmented body, the segments may or may not give rise to symmetrically or asymmetrically disposed processes, which are *appendages*, using that word in its most general sense.

And the highest degree of complication of structure, in both animals and plants, is attained by the body when it becomes divided into segments provided with appendages; when the segments not only become very different from one another, but some coalesce and lose their primitive distinctness; and when the appendages and the segments into

which they are subdivided similarly become differentiated and coalesce.

It is in virtue of such processes that the flowers of plants, and the heads and limbs of the *Arthropoda* and of the *Vertebrata*, among animals, attain their extraordinary diversity and complication of structure. A flower-bud is a segmented body or axis, with a certain number of whorls of appendages; and the perfect flower is the result of the gradual differentiation and confluence of these primitively similar segments and their appendages. The head of an insect or of a crustacean is, in like manner, composed of a number of segments, each with its pair of appendages, which by differentiation and confluence are converted into the feelers and variously modified oral appendages of the adult.

In some complex organisms, the process of differentiation, by which they pass from the condition of aggregated embryo cells to the adult, can be traced back to the laws of growth of the two or more cells into which the embryo cell is divided, each of these cells giving rise to a particular portion of the adult organism. Thus the fertilized embryo cell in the archegonium of a fern divides into four cells, one of which gives rise to the rhizome of the young fern, another to its first rootlet, while the other two are converted into a placenta-like mass which remains embedded in the prothallus.

The structure of the stem of *Chara* depends upon the different properties of the cells, which are successively derived by transverse division from the apical cell. An *inter-nodal* cell, which elongates greatly, and does not divide, is succeeded by a *nodal* cell, which elongates but little, and becomes greatly subdivided; this by another inter-nodal cell, and so on in regular alternation. In the same way the structure of the stem, in all the higher plants, depends upon the laws which govern the manner of division and of metamorphosis of the apical cells. and of their continuation in the *cambium* layer.

In all animals which consist of cell-aggregates, the cells of which the embryo is at first composed arrange themselves by the splitting, or by a process of invagination, of the blastoderm into two layers, the *epiblast* and the *hypoblast*, between which a third intermediate layer, the *mesoblast*, appears, and each layer gives rise to a definite group of organs in the adult. Thus, in the *Vertebrata*, the epiblast gives rise to the cerebro-spinal axis, and to the epidermis and its derivatives; the hypoblast, to the epithelium of the alimentary canal and its derivatives; and the mesoblast, to all the intermediate structures. The tendency of recent inquiry is to prove that the several layers of the germ evolve analogous organs in invertebrate animals, and to indicate the possibility of tracing the several germ layers back to the blastomeres of the yelk, from the subdivision of which they proceed.

It is conceivable that all the forms of life should have presented about the same differentiation of structure, and should have differed from one another by superficial characters, each form passing by insensible gradations into those most like it. In this case Taxonomy, or the classification of morphological facts, would have had to confine itself to the formation of a serial arrangement representing the serial gradation of these forms in nature.

It is conceivable, again, that living beings should have differed as widely in structure as they actually do, but that the interval between any two extreme forms should have been filled up by an unbroken series of gradations; in which case, again, classification could only effect the formation of series—the strict definition of groups would be as impossible as in the former case.

As a matter of fact, living beings differ enormously, not only in differentiation of structure, but in the modes in which that differentiation is brought about; and the intervals between extreme forms are not filled up in the existing world by complete series of gradations. Hence it arises that living beings are, to a great extent, susceptible of classification into groups, the members of each group resembling one another, and differing from all the rest, by certain definite peculiarities.

No two living beings are exactly alike, but it is a matter of observation that, among the endless diversities of living things, some constantly resemble one another so closely that it is impossible to draw any line of demarcation between them, while they differ only in such characters as are associated with sex. Such as thus closely resemble one another constitute a *morphological species;* while different morphological species are defined by constant characters which are not merely sexual.

The comparison of these lowest groups, or morphological species, with one another, shows that more or fewer of them possess some character or characters in common—some feature in which they resemble one another and differ from all other species—and the group or higher order thus formed is a *genus.* The generic groups thus constituted are susceptible of being arranged in a similar manner into groups of successively higher order, which are known as *families, orders, classes*, and the like.

The method pursued in the classification of living forms is, in fact, exactly the same as that followed by the maker of an index in working out the heads indexed. In an alphabetical arrangement, the classification may be truly termed a morphological one, the object being to put into close relation all those leading words which resemble one another in the arrangement of their letters, that is, in their form, and to keep apart those which differ in structure. Headings which begin with the same word, but differ otherwise, might be compared to genera with their species; the groups of words with the same first two syllables to families; those with identical first syllables to orders; and those with the same initial letter to classes. But there is this difference between the index and the Taxonomic arrangement of living forms, that in the former there is none but an arbitrary relation between the various classes, while in the latter the classes are similarly capable of co-ordination into larger and larger groups, until all are comprehended under the common definition of living beings.

The differences between "artificial" and "natural" classifications are differences in degree, and not in kind. In each case the classification depends upon likeness; but in an artificial classification some prominent and easily observed feature is taken as the mark of resemblance or dissemblance; while, in a natural classification, the things classified are arranged according to the totality of their morphological resemblances, and the features which are taken as the marks of groups are those which have been ascertained by observation to be the indications of many likenesses or unlikenesses. And thus a natural classification is a great deal more than a mere index. It is a statement of the marks of similarity of organization; of the kinds of structure which, as a matter of experience, are found universally associated together; and, as such, it furnishes the whole foundation for those indications by which conclusions as to the nature of the whole of an animal are drawn from a knowledge of some part of it. Artificial and natural classification.

When a palæontologist argues from the characters of a bone or of a shell to the nature of the animal to which that bone or shell belonged, he is guided by the empirical morphological laws established by wide observation, that such a kind of bone or shell is associated with such and such structural features in the rest of the body and no