and other monographers substantially concurred, the application of the microscope led to the view suggested by James Clark, and still stoutly supported by Saville Kent, that the Sponge is a city of amœboid or infusorian individuals. Carter looked upon the separate ampullaceous sacs as the true individuals, while Schmidt, defining the individual by the possession of a single exhalent aperture, distinguishes Sponges into solitary and social. Later, however, he terms them *Zoa impersonalia*.

For the higher animals the problem, though perhaps really even more difficult, is less prominent. As Haeckel points out, the earlier discussions and even the comparatively late essay of Johannes Müller take an almost purely psychological or at least a physiological point of view; and the morphological aspect of the inquiry only came forward when the study of much lower forms, such as Cestoid Worms (see PLATYHELMINTHES) or Siphonophores (see HYDROZOA), had raised the difficulties with which botanists had so long been familiar. With the rapid progress of embryology, too, arose new problems; and in 1842 Steenstrup introduced the conception of an "alternation of generations" as a mode of origin of distinct individuals by two methods, for him fundamentally similar, the sexual from impregnated females and the asexual from unimpregnated "nurses,"—a view adopted by Edward Forbes and many other naturalists, but keenly criticized by Carpenter and Huxley. In Leuckart's remarkable essay on polymorphism (1853) the Siphonophora were analysed into colonies, and their varied organs shown to be morphologically equivalent, while the alternate generations of Steenstrup were reduced to a case of polymorphism in development. Leuckart further partly distinguished individuals of different orders, as well as between morphological and physiological individuals.

In 1852 Huxley proposed the view which he still substantially maintains (see BIOLOGY). Starting from such an undoubted homology as that of the egg-producing process of Hydra with a free-swimming Medusoid, he points out that the title of individual, if applied to the latter, must logically be due to the former also, and avoids this confusion between organ and individual by defining the individual animal, as Gallesio had done the plant, as the entire product of an impregnated ovum,—the swarm of Aphides or free Medusæ which in this way might belong to a single individual being termed *Zooids*.

In Carus's *System of Animal Morphology* (1853) another theory was propounded, but the problem then seems to have fallen into abeyance until 1865, when it formed the subject of a prolonged and fruitful discussion in the *Principles of Biology*. Adopting the cell (defined as an aggregate of the lowest order, itself formed of physiological units) as the morphological unit, Spencer points out that these may either exist independently, or gradually exhibit unions into aggregates of the second order, like the lower Algæ, of which the individuality may be more or less pronounced. The union of such secondary aggregates or compound units into individuals of a yet higher order is then traced through such intermediate forms as are represented by the higher seaweeds or the Liverworts, from the thallus of which the axes and appendages of Monocotyledons and Dicotyledons are ingeniously derived. The shoot of a flowering-plant is thus an aggregate of the third order; it branches into an aggregate of the fourth or higher order, and finally as a tree "acquires a degree of composition too complex to be any longer defined." Proceeding to animals, the same method is applied. The Protozoa are aggregates of the first order. These, like plants, exhibit transitions, of which Radiolarians, Foraminifera, and Sponges are taken as examples, to such definite compound wholes as Hydra; and such secondary aggregates multiply by gemmation into permanent aggregates of the third order, which may exhibit all degrees of integration up to that of the Siphonophora, where the individualities of the Polyps are almost lost in that of the aggregate form. The whole series of articulated animals are next interpreted as more or less integrated aggregates of the third order, of which the lower Annelids are the less developed forms, the Arthropods the more highly integrated and individualized. Molluscs and Vertebrates are regarded as aggregates of the second order.

In 1866 appeared the latest morphological classic, the *Generelle Morphologie* of Haeckel. Here pure morphology is distinguished into two sub-sciences,—the first purely structural, *tectology*, which regards the organism as composed of organic individuals of different orders; the second essentially stereometric, *promorphology*. To tectology, defined as the science of organic individuality, a large section of the work is devoted. Dismissing the theory of absolute individuality as a metaphysical figment, and starting from the view of Schleiden, De Candolle, and Nageli of several successive categories of relative individuals, he distinguishes more clearly than heretofore the physiological individual (or *bion*), characterized by definiteness and independence of function, from the morphological individual (or *morphon*), characterized similarly by definiteness of form; of the latter he establishes six categories, as follows:—

1. *Plastides* (cytodes and cells), or elementary organisms.
2. *Organs* (cell-stocks or cell-fusions), simple or homoplastic organs (tissues), or heteroplastic organs. Organ-systems, organ-apparatuses.
3. *Antimeres* (opposite or symmetrical or homotypic parts), *e.g.*, rays of radiate animals, "halves of bilaterally symmetrical animals."
4. *Metameres* (successive or homodynamous parts), *e.g.*, stem-segments of Phanerogams, segments or zoonites of Annelids or Vertebrates.
5. *Personæ*, shoots or buds of plants, polyps of Cœlenterates, &c., "individuals" in the narrowest sense among the higher animals.
6. *Corms* (stocks or colonies), *e.g.*, trees, chains of Salpæ, polyp-stocks, &c.

In his subsequent monograph on calcareous Sponges, and in a final paper, he somewhat modifies these categories by substituting one category of extreme comprehensiveness, that of the *idorgan*, in place of the three separate orders of organs, antimeres, and metameres. The idorgan (of course clearly distinguished from the physiological organ or biorgan) is finally defined as a morphological unit consisting of two or more plastids, which does not possess the positive character of the person or stock. These are distinguished into *homoplasts* or *homo-organs* and *alloplasts* or *alloe-organs*, the former including, as subdivisions, plastid-aggregates and plastid-fusions, the latter idomeres, antimeres, and metameres. The former definition of the term antimere, as denoting at once each separate ray of a radiate, or the right and left halves of a bilaterally symmetrical animal, is corrected by termining each ray a *paramere*, and its symmetrical halves the antimeres. Thus an ordinary Medusoid has four parameres and eight antimeres, a Star-fish five and ten. The conception of the persona is largely modified, not only by withdrawing the comparison of the animal with the vegetable shoot and by omitting the antimere and metamere as necessary constituents, but by taking the central embryonic form of all the Metazoa—the gastrula (fig. 1) and its assumed ancestral representative, the gastræa—as the simplest and oldest form of persona. The different morphological stages to which it may attain are classified into three series: (1) Monaxonial[1] inarticulate persons, *i.e.*, uni-axial and unsegmented without antimeres or metameres, as in Sponges, or lowest Hydroids; (2) Stauraxonial[1] inarticulate persons with antimeres, but without metameres, *e.g.*, Coral, Medusa, Turbellarian, Trematode, Bryozoon; (3) Stauraxonial articulate persons with antimeres and metameres, *e.g.*, Annelids, Arthropods, Vertebrates. The colonies of Protozoa are mere idorgans. True corms, composed of united personæ, occur only among Sponges, Hydroids, Siphonophores, Corals, Bryozoa, Tunicates, and Echinoderms, of which the apparent parameres are regarded as highly centralized persons of a radially-budded worm colony; and these can be classified according to the morphological rank of their constituent personæ. They usually arise by gemmation from a single persona, yet in Sponges and Corals occasionally by fusion of several originally distinct persons or corms. The theory of successive subordinate orders of individuality being thus not only derived from historical criticism of previous theories but brought into conformity with the actual facts of development and descent,—various groups of organisms being referred to their several categories,—the remaining problem of tectology, that of the relation of the morphological to the physiological individuality, is finally discussed. Of the latter, three categories are proposed:—(1) the "actual bion or complete physiological individual," this being the completely developed organic form which has reached the highest grade of morphological individuality proper to it as a representative of, *e.g.*, its species; (2) the "virtual bion or potential physiological individual," including any incompletely developed form of the former from the ovum upwards; and (3) the "partial bion or apparent physiological individual," such fragments of the actual or virtual bion as may possess temporary independence without reproducing the species—this latter category having, however, inferior importance.[2]

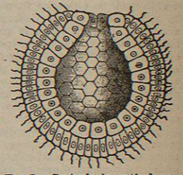

FIG. 1.—Gastrula in optical section, showing primitive opening and digestive cavity (blastopore and arch-enteron), as also outer and inner layers, ectoderm and endoderm. (After Haeckel.)

Haeckel's theory, indeed in its earlier form, has been adopted by Gegenbaur and other morphologists, also in its later form by Jäger, who, however, rejects the category of idorgan on the ground of the general morphological principle that every natural body which carries on any chemical changes with its environment becomes differentiated into more or less concentric layers; but the subject, especially as far as animals are concerned, is again recently discussed in a large work by Perrier. Starting from the cell or plastid, he terms a permanent colony a *méride*, and these may remain isolated like Sagitta or Rotifer, or may multiply by gemmation to form higher aggregates which he terms *zoides*. Such zoides may be irregular, radiate, or linear aggregates, of which the two former classes especially are termed *dèmes*. The organ—Haeckel's idorgan—is excluded, since tissues and organs result from division of labour in the anatomical elements of the mérides, and so have only a secondary individuality, "carefully to be distinguished from the individuality of those parts whose direct grouping has formed the organism, and which live still, or have lived, isolated from one another." Perrier further points out that undifferentiated colonies are sessile, as Sponges and Corals, while a free state of existence is associated with the concentration and integration of the colony into an individual of a higher order.

1 For explanation of these terms see § 5, Promorphology, p. 844.

2 For criticism of this theory on the ground of its making physiological depend on morphological individuality, see Fisch, *Aufzählung und Kritik der verschiedenen Ansichten über das pflanzliche Individuum*, p. 11.

So far the various theories of the subject; detailed criticism is impossible, but some synthesis and reconciliation must be attempted. Starting from the cell as the morphological unit, we find these forming homogeneous aggregates in some Protozoa and in the early development of the ovum. But integration into a whole, not merely aggregation into a mass, is essential to the idea of individuality; the earliest secondary unit, therefore, is the gastrula or méride. This stage is permanently represented by an unbranched Hydra or Sponge or by a Planarian. These secondary units may, however, form aggregates either irregular as in most Sponges, indefinitely branched as in the Hydroids and Actinozoa, or linear as in such Planarians as Catenula. Such aggregations, colonies, or demes, not being aggregated, do not fully reach individuality of the third order. This is attained, however, for the branched series by such forms as Siphonophores among Hydrozoa, or Renilla or Pennatula among Actinozoa; for linear aggregates again by the higher Worms, and still more fully by Arthropods and Vertebrates. Aggregates of a yet higher order may occur, though rarely. A longitudinally dividing Nais or laterally branched Syllis are obviously aggregates of these tertiary units, which, on Haeckel's view, become integrated in the Echinoderm, which would thus reach a complete individuality of the fourth order. A chain of Salpæ or a colony of Pyrosoma exhibits an approximation to the same rank, which is more nearly obtained by a radiate group of Botryllus around their central cloaca, while the entire colony of such an Ascidian would represent the individual of the fifth order in its incipient and unintegrated state,—these and the preceding intermediate forms being, of course, readily intelligible, and indeed, as Spencer has shown, inevitable on the theory of evolution.

The exclusion of tissues and organs from rank in this series is thus seen to necessarily follow. Ectoderm and endoderm cannot exist alone; they and the organs into which they differentiate arise merely, as Jäger expresses it, from that concentric lamination, or, with Perrier, from that polymorphism of the members of the colony, which is associated with organic and social existence. The idea of the antimere is omitted, as being essentially a promorphological conception (for a Medusoid or a Star-fish, though of widely distinct order of individuality, are equally so divisible); that of the metamere is convenient to denote the secondary units of a linear tertiary individual; the term persona, however, seems unlikely to survive, not only on account of its inseparable psychological connotations, but because it has been somewhat vaguely applied alike to aggregates of the second and third order; and the term colony, corm, or deme may indifferently be applied to those aggregates of primary, secondary, tertiary, or quaternary order which are not, however, integrated into a whole, and do not reach the full individuality of the next higher order. The term zooid is also objectionable as involving the idea of individualized organs, a view natural while the medusoid gonophores of a Hydrozoon were looked at as evolved of its homologue in Hydra, whereas the latter is really a degenerate form of the former. Passing to the vegetable world, here as before the cell is the unit of the first order, while aggregates representing almost every stage in the insensible evolution of a secondary unit are far more abundant than among animals. Complete unity of the second order can hardly be allowed to the thallus, which Spencer proposes to compound and integrate into tertiary aggregates—the higher plants; as in animals the embryological method is preferable, both as avoiding gratuitous hypothesis and as leading to direct results. Such a unit is clearly presented by the embryo of higher plants in which the cell-aggregate is at once differentiated into parts and integrated into a whole. Such an embryo possesses axis and appendages as when fully developed (fig. 2). The latter, however, being as organs mere lateral expansions of the concentric layers into which the plant embryo, like the animal, is differentiated, and so neither stages of evolution nor capable of separate existence, are not entitled to individual rank. The embryo, the bud, shoot, or uni-axial plant, all thus belong to the second order of individuality, like the Hydroid they resemble. Like the lower Cœlenterates, too, aggregates of such axes are formed by branching out from their low degree of integration. Such colonies can hardly be termed individuals of the third, much less of higher order, at least without somewhat abandoning that unity of treatment of plants and animals without which philosophical biology disappears. Individuality of the second order is most fully reached by the flower,—the most highly differentiated and integrated form of axes and appendages. Such a simple inflorescence as a raceme or umbel approximates to unity of the third order to which a composite flower-head must be admitted to have attained, while a compound inflorescence is on the way to a yet higher stage.

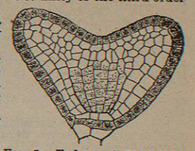

FIG. 2.—Embryo of Dicotyledon (after Sachs), showing incipient axis and appendages, as also the three concentric embryonic layers.

If, as seems probable, a nomenclature be indispensable for clear expression, it may be simply arranged in conformity with this view. Starting from the unit of the first order, the plastid or *monad*, and terming any undifferentiated aggregate a *deme*, we have a *monad-deme* integrating into a secondary unit or *dyad*, this rising through *dyad-demes* into a *triad*, this forming *triad-demes*, and these when differentiated becoming *tetrads*, the Botryllus-colony with which the evolution of compound individuality terminates being a *tetrad-deme*. The separate living form, whether monad, dyad, triad, or tetrad, requires also some distinguishing name, for which *persona* will probably ultimately be found most appropriate, since such usage is most in harmony with its inevitable physiological and psychological connotations; while the geneal-ogical individual of Gallesio and Huxley, common also to all the categories, may be designated with Haeckel the *ovum-product* or *ovum-cycle*, the complete series of forms needed to represent the species being the *species-cycle* (though this coincides with the former save in cases where the sexes are separate, or polymorphism occurs). For such a peculiar case as *Diplozoon paradoxum*, where two separate forms of the same species coalesce, and still more for such heterogeneous individuality as that of a Lichen, where a composite unit arises from the union of two altogether distinct forms—Fungus and Alga,—yet additional categories and terms are required.[1]

§ 5. *Promorphology.*—Just as the physiologist constantly seeks to interpret the phenomena of function in terms of mechanical, physical, and chemical laws, so the morphologist is tempted to inquire whether organic as well as mineral forms are not alike reducible to simple mathematical law. And just as the crystallographer constructs an ideally perfect mathematical form from an imperfect or fragmentary crystal, so the morphologist has frequently attempted to reduce the complex-curved surfaces of organic beings to definite mathematical expression.[2] Canon Moseley (*Phil. Trans.*, 1838) succeeded in showing, by a combination of measurement and mathematical analysis, that the curved surface of any turbinated or discoid shell might be considered as generated by the revolution, about the axis of the shell, of a curve, which continually varied its dimensions according to the law of the logarithmic spiral. For Goodsir this logarithmic spiral, now carved on his tomb, seemed a fundamental expression of organic curvature and the dawn of a new epoch in natural science—that of the mathematical investigation of organic form—and his own elaborate measurements of the body, its organs, and even its component cells seemed to yield, now the triangle, and again the tetrahedron, as the fundamental form. But such supposed results, savouring more of the Naturphilosophie than of sober mathematics, could only serve to discourage further inquiry and interest in that direction. Thus we find that even the best treatises on botany and zoology abandon the subject, satisfied with merely contrasting the simple geometrical ground-forms of crystals with the highly curved and hopelessly complicated lines and surfaces of the organism.

But there are other considerations which lead up to a mathematical conception of organic form, those namely of symmetry and regularity. These, however, are usually but little developed, botanists since Schleiden contenting themselves with throwing organisms into three groups—first, absolute or regular; second, regular and radiate; third, symmetrical bilaterally or zygomorphic—the last being capable of division into two halves only in a single plane, the second in two or more planes, the first in none at all. Burmeister, and more fully Bronn, introduced the fundamental improvement of defining the mathematical forms they sought not by the surfaces but by axes and their poles; and Haeckel has developed the subject with an elaborateness of detail and nomenclature which seems unfortunately to have impeded its study and acceptance, but of which the main results may, with slight variations chiefly due to Jäger (*Lehrb. d. Zool.*, i. 233), be briefly outlined.

A. *ANAXONIA*—forms destitute of axes, and consequently wholly irregular in form, *e.g.*, Amœbæ and many Sponges.

B. *AXONIA*—forms with definite axes.

1 See Haeckel, *Gen. Morph.* i., *Kalkschwämme* i., and *Jena. Zeitschr.* x.; also Sachs, *Geschichte d. Bot.*; Fisch, *Aufzählung u. Kritik*, &c., Rostock, 1880; Perrier, *Les Colonies Animales*, 1882, as from these all other references can be obtained.

2 The sciences of organic and mineral form would thus (as Haeckel points out) become thoroughly analogous, for, as promorphology develops the crystallography of organic form, so mineralogy, in the study of such phenomena as those of pseudomorphism or of mineral development, becomes parallel to morphology.

I. Homaxonia—all axes equal.

(*a*) Spheres, where an indefinite number of equal axes can be drawn through the middle point, *e.g.*, Sphærozoum.

(*b*) Polyhedra, with a definite number of like axes.

Of these a considerable number occur in nature, for example, many Radiolarians (fig. 3), pollen-grains, &c., and they are again classifiable by the number and regularity of their faces.

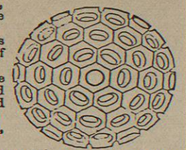

Fig. 3.—Radiolarian (Ethmosphæra), an irregular endosphæric polyhedron with equiangular faces. Type of Homaxonia.

II. Protaxonia, where all the parts are arranged round a main axis, and of these we distinguish—

1. *Monaxonia*, with not more than one definite axis. Here are distinguished (*a*) those with similar poles, spheroid (Coccodiscus) and cylinder (Pyrosoma) and (*b*) those with dissimilar poles, cone (Conulina).

2. *Stauraxonia*, where, besides the main axes, a definite number of secondary axes are placed at right angles, and the stereometric ground-form becomes a pyramid. Here, again, may be distinguished (*a*) those with poles similar, *Stauraxonia homopola*, where the stereometric form is the double pyramid (fig. 4), and (*b*) those with poles dissimilar, *Stauraxonia heteropola*, where the stereometric form is the single pyramid, and where we distinguish a basal, usually oral, pole from an apical, aboral, or anal pole. The bases of these may be either regular or irregular polygons, and thus a new classification into *Homostaura* and *Heterostaura* naturally arises.

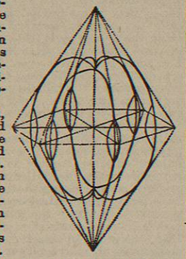

Fig. 4.—Pollen of Passion Flower, as example of Stauraxonia homopola. Ground-form a regular double pyramid of six sides.

The simpler group, the Homostaura, may have either an even or an odd number of sides, and thus among the Homostaura we have even-sided and odd-sided, single and double pyramids. In those Homostaura with an even number of sides, such as Medusæ, the radial and inter-radial axes have similar poles; but in the series with an odd number of sides, like most Echinoderms, each of the transverse axes is half radial and half semi-radial (fig. 5). Of the group of regular double pyramids the twelve-sided pollen-grain of Passiflora (fig. 4) may be taken as an example, having the ground-form of the hexagonal system, the hexagonal dodecahedron. Of the equal even-sided single pyramids (Heteropola homostaura), Alcyonium, Geryonia, Aurelia may be taken as examples of the eight-sided, six-sided, and four-sided pyramids, while those with an odd number of sides may be illustrated by Ophiura or Primula with five sides, and the flower of Lily or Rush with three sides.

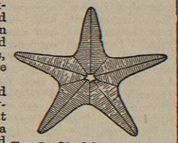

Fig. 5.—Starfish, an example of Heteropola homostaura. Ground-form a regular single pyramid of five sides.

In the highest and most complicated group, the Heterostaura, the basal polygon is no longer regular but amphithect (ἀμφίθηκτος = double-edged). Such a polygon has an even number of sides, and can be divided into symmetrical halves by each of two planes intersecting at right angles in the middle point, and thus dividing the whole figure into four congruent polygons. The longer of these axes may be termed lateral, the shorter the equatorial or dorso-ventral; and these two axes, along with the main axes, always define the three dimensions of space. Ctenophores (fig. 6) furnish examples of eight-sided amphithect pyramids, some Madrepore Corals of six-sided, Crucifers, some Medusæ, and Cestodes of four-sided amphithect pyramids.

In these forms the poles of the dorso-ventral and lateral axes are similar, and, as in the preceding Monaxonia and Stauraxonia, the centre of the body is defined by a line; and they are therefore termed *Centraxonia*, while the Protaxonia, which are defined by their central point, are called *Centrostigma*. There are, however, other forms, and these the most complicated, in which the poles of at least the dorso-ventral axis are unlike, and in which the body is thus defined not with reference to a line but to a median plane, and these have accordingly received the name of *Centropipeda*. Their ground-form is a polygon with an even number of sides, which can only be divided into two symmetrical halves by the one median plane. It can be obtained by halving an amphithect pyramid of double the number of sides, and is consequently termed a half amphithect pyramid (fig. 7). The whole amphithect pyramid may be most conveniently obtained by the reduplication of the ground-form as if in a mirror. Of half amphithect pyramids there are again two forms, termed by Haeckel *Amphipleura* and *Zygopleura*, the former including the "bilaterally symmetrical" or irregularly radiate forms of previous authors, such as Spatangus, Viola, Orchis, while the *Zygopleura* include forms bilaterally symmetrical in the strictest sense, in which not more than two radial planes, and these at right

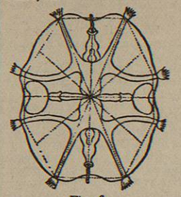

Fig 6.

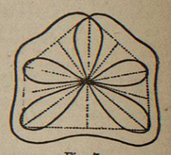

Fig. 7.

Fig. 6.—Ctenophore (Eucharis). Ground-form an eight-sided double amphithect pyramid.

Fig. 7.—Spatangus. Ground-form a five-sided half amphithect pyramid.

angles to each other, are present. The stereometric ground-form is a half rhombic pyramid. Haeckel again divides these, according to the number of antimeres, into *Tetrapleura* and *Dipleura*.

Promorphology has thus shown that the reigning dogma of the fundamental difference of organic and mineral forms is false, and that a crystallography of organic forms is possible,—the form of the cell or the cell-aggregate differing from the crystal merely by its more or less viscous state of aggregation, its inherited peculiarities, and its greater adaptability to the environment. The classification into *bilateral* and *radiate* forms which usually does duty for more precise promorphological conceptions must be abandoned as hopelessly confusing essentially different forms, or at least must be rigidly restricted,—the term radial to regular and double pyramids, the term bilateral to the Centropipeda if not indeed to dipleural forms. Similarly, the topographical and relative terms, anterior and posterior, upper and under, horizontal and vertical, must be superseded by the terms above applied to the axes and their poles, oral and aboral, dorsal and ventral, right and left.

§ 6. *Nature of Morphological Changes.*—The main forms of organic structure being analysed and classified and their stage of individuality being ascertained, the question next arises, by what morphological changes have they arisen, and into what categories can these modes of differentiation be grouped? They at first sight seem innumerable, yet in reality are few. Goethe somewhat vaguely generalized them for the flower as ascending and descending metamorphosis, expansion and contraction of organs, &c.; but the first attempt at careful enumeration seems to be that of Auguste de St-Hilaire, who recognized defects of development, adherences, excesses of production or "dédoublements," metamorphosis and displacement of organs. Subsequent authors have variously treated the subject; thus Asa Gray enumerates as modifications of the flower—coalescence, adnation, irregularity, abortion, non-alternation or anteposition, multiplication, enation, unusual development of the axis, and other morphological modifications connected with fertilization. These are obviously too numerous, as may best be shown by a single comparison with the view of an animal morphologist. Thus Huxley, in discussing the arrangement of the Vertebrata, recognizes only three processes of modification, not only in the ancestral evolution of the Equidæ, but in the individual development of animals generally; these are "(1) excess of development of some parts in relation to others, (2) partial or complete suppression of certain parts, (3) coalescence of parts originally distinct." It is probable that this "threefold law of evolution" may include all observed cases of change, even in the flower; thus Chorisis and Peloria may be regarded as peculiar forms of excess, while displacement is probably in all cases only apparent, and really due to adhesion or coalescence (see Biology, vol. iii. p. 681 *sq.*).[1]

§ 7. *Nature of Morphological Correspondence—Categories of Homology.*—To indicate all the steps by which the idea of morphological has been distinguished from that of physiological resemblance would be to examine the whole history of morphology; it must suffice to discuss the terminology of the subject which has, as ever, served not only as an index but as an engine of progress. For these two distinct forms of resemblance the terms *homology* and *analogy* gradually became specialized, and were finally established and clearly defined by Owen in 1843,—"the former as the same organ in different animals under every variety of form and function (*e.g.*, fore-limbs of *Draco volans* and wings of Bird); the second as a part or organ in one animal which has the same function

[1] Compare A. de St-Hilaire, *Morphologie*; Gray, *Manual*, p. 179 (1868); Huxley, *Proc. Zool. Society*, p. 619, Lond., 1880.

as another part or organ in a different animal (*e.g.*, parachute of Draco and wings of Bird)." He further distinguishes three kinds of homology:—(1) *special*, being "that above defined, namely, the correspondence of a part or organ determined by its relative position and connexions with a part or organ in a different animal, the determination of which homology indicates that such animals are constituted on a common type," *e.g.*, basilar process of human occipital with basi-occipital of fish; (2) *general*, that "higher relation in which a part or series of parts stands to the fundamental group in question is constituted," *e.g.*, the same human bone and centrum of the last cranial vertebra; (3) *serial* homology, "representative or repetitive relation in the segments of the same skeleton" (demonstrated when general and special homologies have been determined); thus usually the basi-occipital and basi-sphenoid are "homotypes." These terms were henceforth accepted by naturalists; but the criterion of analogy and homology became for Agassiz and other embryologists developmental as well as comparative, reference to the ideal archetype becoming less and less frequent. Passing over the discussions of Agassiz and Bronn, of which the latter is criticized and partly incorporated by Haeckel, we find the last-named (1) placing serial under general homology; (2) erecting categories of homology partially corresponding to those of individuality,—(*a*) *homotypy* (of antimeres), hence distinct from that of Owen, (*b*) *homodynamy* (of metameres), (*c*) *homonomy* (of parts arranged on transverse axes); (3) defining special homology in terms of identity of embryonic origin. In 1870 this latter point was more fully insisted upon by Ray Lankester, who, decomposing it into two others, proposed to supersede the term homology by *homogeny*, being the correspondence of common descent, and *homoplasy*, denoting any superinduced correspondence of position and structure in parts embryonically distinct. Thus, the fore-limb of a mammal is *homogenous* with that of a bird, but the right and left ventricles of the heart in both are only *homoplastic*, these having arisen independently since the divergence of both groups from a uni-ventriculate ancestor in relation to similarity of physiological needs. Mivart next proposed to retain homology as a generic term, with homogeny and homoplasy as two species under it, and carried the analysis into great detail, distinguishing at first twenty-five, but later fifteen, kinds of correspondence:—(1) parts similar in function only, *e.g.*, legs of Lizard and Lobster; (2) parts similar both in function and relative position, wings of Bat and Bird; (3) parts of common descent, fore-limb of Horse and Rhinoceros; (4) parts of similar embryonic origin, whatever be their racial genetic relations, *e.g.*, occipitals of Panther and Perch; (5) parts of dissimilar embryonic origin, whatever be their racial genetic relations, *e.g.*, legs of Diptera; (6, 7, 8, 9, 10) laterally, vertically, serially, antero-posteriorly, and radially homologous parts; (11) subordinate serial homologues, *e.g.*, joints of antenna; (12 and 13) secondary and tertiary subordinate serial homologues; (14 and 15) special and general homologies (in Owen's sense). In his *Kaltschwämme* Haeckel proposed to term *homophyly* the truly phylogenetic homology in opposition to *homomorphy*, to which genealogic basis is wanting; and finally Von Jhering has published a repetition of Lankester's view.

In this discussion, as in that of individuality, it is evident that we are dealing with numerous logical cross-divisions largely corresponding, no doubt, to the complex web of inter-relations presented by nature, yet remaining in need of disentanglement. Though we must set aside analogies of functional activity, the resemblances in external shape or geometric ground-form which correspond to these, *e.g.*, Hydrozoa and Bryozoa, Fishes and Cetaceans, mimetic organisms, are nevertheless, as our historic survey showed, the first which attract attention; and these homoplastic or homomorphic forms, as Haeckel has shown, come as fairly within the province of the promorphologist as do isomorphic crystals within that of his an-organological colleague the crystallographer. Here, too, would be considered "radial," "vertical," "lateral" homology, "homotypy of antimeres," and all questions of symmetry, for which Haeckel's nomenclature of *homaxonial, homogolic*, &c., is distinctly preferable. Entering the field of tectology or morphology in the ordinary sense, we may next consider whether two organisms compared are of the same category of individuality—are *homocategoric*; and under this serial homology, for instance, would come as a minor division, the correspondence between the units or parts of units of a linear dyad-deme or triad. From a third point of view, that of the embryologist, we trace the development of each multicellular organism (1) from the embryonic layers and systems into which the secondary unit (gastrula or plant embryo) differentiates, (2) from a unit-deme or unit of the inferior order or orders of individuality. The parts and units thus recognized by ontogenetic research, respectively or successively *homodermic, homosystemic*, and *homodemic*, may then conveniently be termed (indifferently save for considerations of priority) either "specially homologous," "homogenous," "homophylic," or "homogenetic," in the language of phylogenetic theory. These three great classes of morphological correspondence—promorphological, tectological, and embryological—may or may not coincide. But the completest homology, in which all forms of resemblance unite and from which they differentiate, is that expressed in the cell theory, or rather in that ovum theory which underlies it, and which Agassiz therefore not unjustly regarded as "the greatest discovery in the natural sciences of modern times."[1]

§ 8. *Results to Taxonomy.*—The advance and modification of classifications which follow each morphological advance have been pointed out above, and taxonomy thus never quite reaches a level with morphological knowledge. That it requires much reform at present is obvious. Although the dogma of the constancy of species is no longer maintained, its results survive, and perhaps a majority of groups have still to be remonographed in the generalizing spirit with which Haeckel has treated the calcareous Sponges, or Carpenter, Parker, and Brady the Foraminifera. The union of the Protophyta and Protozoa into the Protista (a generalization which research is constantly confirming) involves a final abandonment of the mediæval figment of three kingdoms of nature, and a revival of the Organisata of Linnæus. Physiological prejudices, too, are not completely expelled; hence, for instance, the constant attempts to separate Animalia and Vegetabilia by physiological characteristics, which would be irrelevant even if in themselves valid. A strictly morphological standard must be applied to the construction of classifications and the pruning of genealogical trees; organisms are "higher" or "lower" not according to their stage of evolution in beauty or intelligence but (as Huxley has most clearly pointed out in the essay referred to under § 6) to the degree of morphological differentiation by excess, suppression, or coalescence which they exhibit. Thus the supreme position of Man in classification must be abandoned, since the Primates are simply one of the less specialized, *i.e.*, lower orders of Mammals, and the Mammals themselves are on the whole distinctly less specialized than the Birds, or perhaps even some of the higher Reptiles. The morphological importance of the "vegetable kingdom" sinks when tested by such a standard. The Cormophytes are all nothing more than an axis with appendages, and as such may fairly be compared, not with the entire animal assemblage, but merely to that group which is homomorphic (or rather isomorphic) with them as reducible to axis and appendages too. Such a group we find in the Hydromedusæ, which we can easily model in imagination into all the specializations of the floral world, a single genus like Clava or Tubularia affording a starting-point for countless "natural orders."

§ 9. *Relation of Morphology to Physiology.*—Although the pure morphologist investigates laws of structure only, and rightly eliminates the conceptions of life, environment, and function, yet if kept permanently apart from physiological considerations his labours would be incomplete and his results inexplicable, if not indeed almost illusory. For, however deeply one penetrates through superficial and adaptive characters to an apparently permanent and fundamental morphological type, this is itself but an earlier adaptation, showing the fading traces of an earlier adaptation still. And, conversely, the most superficial of adaptive characters, if transmitted to numerous varying descendants, may attain high morphological importance. The morphological aspect of an organism is merely statical, and, like that of an eddy or a vortex-ring, becomes only truly intelligible when viewed in its dynamic aspect; and thus, though the demonstration of the structural unity of the organic world is in itself a great result, yet the desire of a deeper explanation of form as determined by function and environment is thereby rendered all the more pressing. An example may be taken from botany. Thus Airy beautifully explains the phenomena of phyllotaxis as adaptations to bud-life. Or again, in a common flower, say the Dead-nettle, all the details of form are indeed described by the systematist with equal minuteness (a proceeding which, except in so far as serving for specific identification, is of no further scientific value), but receive separate interpretation from the two distinct standpoints of the morphologist and physiologist. The latter, to whom form is important merely so far as explanatory of function, shows how the tough persistent calyx is protective against various dangers, how the corolla serves to lure the fertilizing bees, which find in its lip a landing stage and in each lateral process a hold-fast, while its hood at once protects the pollen against rain and determines the curvature of the stamens,—this curvature, as well as their didynamous arrangement, median position, and linearly arranged anther-lobes being all adaptations through the medium of the bee's hairy back to meet the similarly placed stigma of another flower,—and so on. The morphologist, on the other hand, analyses the calyx into its five constituent sepals, reduces the corolla to a regular pentamerous type, ascertains the position of the four stamens, and asserts the loss of a fifth posterior one, finds the ovary to be primitively two-celled, and thus reaches a schematic conception of a not archetypal but ancestral form. This ground-form itself, however, suggests a new train of considerations both morphological and physiological respecting the origin of

[1] For bibliography see Lankester, *Ann. Mag. Nat. Hist.*, 1870, or Geddes, *Jena. Zeitschr.*, 1882.

this primeval flower from a somewhat fern-like Cryptogam, of which the foliage-leaves, the envelopes of the spore-bearing leaves, the micro- and macrosporangiosphores had become permanently differentiated in ascending order; of which the microspores, doubtless through the intervention of a spore-eating insect, had come to germinate upon the macrosporangium instead of upon the ground; and in which this variation (evidently advantageous, since making fertilization at once more certain and more economical) was aided to perpetuate itself by the contemporaneous evolution of those floral colours which are nascent even among the Thallophytes. And thus the morphologist, though excluding teleological and functional considerations from his anatomical researches, has yet a physiological ideal, and enters sooner or later upon a new series of inquiries—those of the interdependence of structure and function. Milne-Edwards's law of the physiological division of labour, Dohrn's principle of functional change, the speculations of Claude Bernard, Spencer, and Haeckel, experimental inquiries such as those of Semper, where organisms are subjected to special modifications of their environment, and the like, are all contributions to this newest and evolutionary department of morphology. Such ideas are even applied to the study of cellular morphology. Thus, Spencer points out the relation of the shapes of cells to their environments; James ingeniously explains the occurrence of cell-division by the rapid increase of bulk over surface which the growth of a solid involves, and the corresponding increase of difficulty of nutrition; and the writer has attempted to explain the forms of free and united cells as specializations of a (protomyxoid) cycle in which variations of functional activity are accompanied by the assumption of corresponding forms, the whole series of changes depending upon the properties of protoplasm under the variations in the supply of energy from the environment. Rauber, His, and others have even attempted to explain embryological phenomena in terms of the simplest cellular mechanics, but as yet such speculations are somewhat crude.[1]

§ 10. *Orientation and Subdivisions of Morphology.*—The position of morphology in the classification of the sciences and the proper mode of subdividing it cannot be discussed within these limits, although the latter is especially the subject of much disagreement. The position above assumed, that of including under morphology the whole statical aspects of the organic world, is that of Haeckel, Spencer, Huxley, and most recent animal morphologists; botanists frequently, however, still use the term under its earlier and more limited significance.[2] (P. GE.)

MORRIS, Robert (1734-1806), American statesman, was born at Liverpool, England, on 20th January 1734. At the age of thirteen he accompanied his father to America, and after serving in a counting-house at Philadelphia he became in 1754 partner in the business. From 1776 to 1778 he was delegate to the Continental Congress, and he was one of those who signed the Declaration of Independence. During the war he served on the committee of ways and means, and freely placed his immense wealth at the disposal of his country, his personal credit being at one time pledged to the amount of $1,400,000. He also in 1780 established the Bank of North America, and until 1784 acted as superintendent of finance. In 1786 he became a member of the Pennsylvania legislature, and he was one of the convention which framed the Federal constitution in 1787. From 1786 to 1795 he was United States senator. On account of the disastrous result of some of his financial speculations Morris passed the later years of his life in a debt prison. He died at Philadelphia, 8th May 1806. Robert Morris had as his assistant-superintendent of finance Gouverneur Morris (1752-1816), with whom he engaged also in several mercantile enterprises. Gouverneur Morris, who rose to some eminence as a statesman and orator, was more fortunate in his speculations than his colleague, and latterly became celebrated for the munificence of his hospitality. He was the author of a series of essays on currency and finance, which are included in the *Life, Correspondence, and Writings of Gouverneur Morris*. 3 vols., edited by Jared Sparks, 1832.

MORRIS-DANCE, or Morrice-dance, a performance for a long time associated with certain festive seasons in England, but now wholly discontinued. The origin of the name is doubtful; and whether the dance was indigenous to England, or was introduced by John of Gaunt from Spain, or was borrowed from the French or Flemings, must be left to conjecture. That, as the name would seem to indicate, it was a development of the moriscodance or Spanish fandango is not, however, invalidated by the fact that the morisco was for one person only, for, although latterly the morris-dance was represented by various characters, uniformity in this respect was not always observed, and the elements of the dance may have been borrowed from the morisco. There are few references to it earlier than the reign of Henry VII., but it would appear that in the reign of Henry VIII. it was an almost essential part of the principal village festivities. Although allusions to it in poems are very frequent in the 16th and 17th centuries, nothing more than fragmentary descriptions have been handed down to us, so that an accurate knowledge of its characteristic features at even any particular period is impossible. In earlier times it was usually danced by five men and a boy dressed in a girl's habit, who was called Maid Marian. There were also two musicians; and, at least sometimes, one of the dancers, more gaily and richly dressed than the others, acted as "foreman of the morris." The garments of the dancers were ornamented with bells tuned to different notes so as to sound in harmony.[3] Robin Hood, Friar Tuck, and Little John were characters extraneous to the original dance, and were introduced when it came to be associated with the May-games. At Betley, in Staffordshire, there is a painted window of the time of Henry VIII., or earlier, portraying the morris,—the characters including Maid Marian, Friar Tuck, the hobby-horse, the piper, the tabourer, the fool, and five other persons apparently representing various ranks or callings. The hobby-horse, which, latterly at least, was one of the principal characters of the dance, consisted of a wooden figure attached to the person of the actor, who was covered with trappings reaching to the ground, so as to conceal his feet. The morris-dance was abolished along with the May-games and other festivities by the Puritans, and, although revived at the Restoration, the pageant gradually degenerated in character and declined in importance. Maid Marian latterly was personated by a clown who was called Malkin. Though the dance is now wholly discontinued, it is probable that some of the original elements of it still survive in a country-dance which, under the same name, is still popular in the north of England.

See Douce, "Dissertations on the Ancient Morris Dance," in his *Illustrations of Shakspeare* (1839); Strutt, *Sports and Pastimes of the People of England*; and Brand, *Popular Antiquities* (1849).

MORRISON, Robert (1782-1834), the first Protestant missionary to China, was born of Scottish parents at Morpeth, Northumberland, on 5th January 1782. After receiving an elementary education in Newcastle, he was apprenticed to a lastmaker, but his spare hours were devoted to studies connected with theology, and in 1803 he was received into the Independent academy at Hoxton. In the following year he offered his services to the London Missionary Society, by which, after he had attended the mission college of Gosport and studied Chinese under a native teacher, he was sent to Canton in 1807. He was appointed translator to the East India Company's factory

[1] See, Biology, vol. iii. p. 681 *sq.*; Spencer, *Principles of Biol.*; Haeckel, *Gen. Morph.*; C. Bernard, *Phénomènes d. l. vie communs aux an. et aux vég.*; Semper, *Animal Life* (1880); James, *Edin. Med. Journal*, 1883; Geddes, *Zool. Anzeiger*, 1883; Rauber, *Morph. Jahrb.*, vi.; Haeckel, *Kalkschwämme*, i. p. 481, &c.

[2] See Haeckel, *Gen. Morph.*, i. introduction; also Comte, *Phil Pos.*, iii. (1851-1854); Spencer, *Prin. of Biol.*, i.; Gegenbaur, *Comp. Anat.*; Asa Gray, *Manual*; and the article Biology; also Geddes, *Jena Zeitschr.*, 1883.

[3] See Sir Walter Scott's *Fair Maid of Perth*, note on a dress preserved by the glover incorporation of Perth.

there in 1808, and, in addition to his official duties connected with this post, laboured with intense application at a *Chinese Grammar* and a translation of the New Testament, both of which were published in 1814. In 1817 he published *A View of China for Philological Purposes*, and his translation of the entire Bible was completed in the following year. His next enterprise was the establishment of an Anglo-Chinese college at Malacca for "the reciprocal cultivation of Chinese and European literature," which was opened in 1820. In 1821 his *Chinese Dictionary* was published by the East India Company at an expense of £15,000. Leaving China at the close of 1823 he spent two years in England, where he advocated Chinese missions before large and enthusiastic audiences, and was elected a Fellow of the Royal Society. Returning to China in 1826 he set himself to promote education and to prepare a Chinese commentary on the Bible and other Christian literature. He died at Canton on 1st August 1834. His *Memoirs*, compiled by his widow, were published in 1839 (2 vols. 8vo, London).

MORRISTOWN, a city of the United States, county seat of Morris county, New Jersey, lies on the Whippany river, 31 miles from New York by the Morris and Essex division of the Delaware, Lackawanna, and Western Railroad. It was twice the headquarters of the American army during the War of Independence, and Washington's residence, owned by the Washington Association, assisted by the State, is a half-mile to the east. On Whatnong mountain, 3 miles distant, stands the State insane asylum, usually called Morristown Asylum, a vast granite building 1243 feet long, erected in 1874-1875, and capable of accommodating 1000 patients. The population in 1880 was 5418.

MORSE, Samuel Finley Breese (1791-1872), artist and inventor, was born at the foot of Breed's Hill, Charlestown, Massachusetts, on 27th April 1791. His father was the Rev. Jedediah Morse, D.D., the author of Morse's *Geography*. At the age of fourteen Samuel Morse entered Yale College; under the instruction of Professors Day and Silliman he received the first impulse towards those electrical studies with which his name is mainly identified. In 1811 Morse, whose tastes during his early years led him more strongly towards art than towards science, became the pupil of Washington Allston, then the greatest of American artists, and accompanied his master to England, where he remained four years. His success at this period was considerable; but on his return to America in 1815 he failed to obtain commissions for historical paintings, and after working on portraits for two years at Charleston, S.C., he removed first to Washington and afterwards to Albany, finally settling in New York. In 1825 he laid the foundations of the National Academy of Design, and was elected its first president, an office which he filled until 1845. The year 1827 marks the revival of Morse's interest in electricity. It was at that time that he learned from Professor J. F. Dana of Columbia College the elementary facts of electromagnetism. As yet, however, he was devoted to his art, and in 1829 he again went to Europe to study the old masters.

The year of his return, 1832, may be said to close the period of his artistic, and to open that of his scientific life. On board the packet-ship "Sully," which sailed from Havre 1st October 1832, while discussing one day with his fellow-passengers the properties of the electromagnet, he was led to remark: "If the presence of electricity can be made visible in any part of the circuit, I see no reason why intelligence may not be transmitted by electricity." It was not a novel proposition, but the process of formulating it started in his mind a train of new and momentous ideas. The current of electricity, he knew, would pass instantaneously any distance along a wire; and if it were interrupted a spark would appear. It now occurred to him that the spark might represent a part of speech, either a letter or a number; the absence of the spark, another part; and the duration of its absence, or of the spark itself, a third, so that an alphabet might be easily formed, and words indicated. In a few days he had completed rough drafts of the necessary apparatus, which he displayed to his fellow-passengers.[1] During the twelve years that followed Morse was engaged in a painful struggle to perfect his invention and secure for it a proper presentation to the public. The refusal of the Government to commission him to paint one of the great historical pictures in the rotunda of the Capitol seemed to destroy all his old artistic ambition. In poverty he pursued his new enterprise, making his own models, moulds, and castings, denying himself the common necessaries of life and encountering embarrassments and delays of the most disheartening kind. It was not until 1836 that he completed any apparatus that would work, his original idea having been supplemented by his discovery in 1835 of the "relay," by means of which the electric current might be reinforced or renewed where it became weak through distance from its source. Finally, on 2d September 1837, the instrument was exhibited to a few friends at his room in the university building, New York, where a circuit of 1700 feet of copper wire had been set up, with such satisfactory results as to awaken the practical interest of the Messrs Vail, iron and brass workers in New Jersey, who thenceforth became associated with Morse in his undertaking. Morse's petition for a patent was dated 28th September 1837, and was soon followed by a petition to Congress for an appropriation to defray the expense of subjecting the telegraph to actual experiment over a length sufficient to establish its feasibility and demonstrate its value. The committee on commerce, to whom the petition was referred, reported favourably. Congress, however, adjourned without making the appropriation, and meanwhile Morse sailed for Europe to take out patents there. The trip was not a success. In England his application was refused, on the alleged ground that his invention had been already published; and, while he obtained a patent in France, it was subsequently appropriated by the French Government without compensation to himself. His negotiations also with Russia proved futile, and after a year's absence he returned to New York. On 23d February 1843 Congress passed the long-delayed appropriation, steps were at once taken to construct a telegraph from Baltimore to Washington, and on the 24th of May 1844 it was used for the first time. Morse's patents were already secured to him and his associates, and companies were soon formed for the erection of telegraph lines all over the United States. In the year 1847 Morse was compelled to defend his invention in the courts, and successfully vindicated his claim to be called the original inventor of the electromagnetic recording telegraph. Thenceforward Morse's life was spent in witnessing the growth of his enterprise and in gathering the honours which an appreciative public bestowed upon him. As years went by he received from the various foreign Governments their highest distinctions, while in 1858 the representatives of Austria, Belgium, France, the Netherlands, Piedmont, Russia, the Holy See, Sweden, Tuscany, and Turkey appropriated the sum of 400,000 francs in recognition of the use of his instruments in those countries. In the preparations for laying the first Atlantic cable he took an active part, though the attempt of 1857, in which he personally engaged, was not successful. He died 2d April

[1] Five years later the captain of the ship identified under oath Morse's completed instrument with that which Morse had explained on board the "Sully" in 1832.