CHAPTER XI.

Nature of the Reproductive Function—Various Forms of the Process—"Sexual" and "Asexual" Modes—"Sexual" Reproduction—"Asexual" Methods—"Gemmation" or "Budding," and Fission—Examples of Fissiparous Reproduction—Illustrations of "Gemmation"—Internal and External Gemmation—"Alternation of Generations," or "Metagenesis"—Illustrations of "Parthenogenesis"—Antagonistic Nature of Reproduction and Nutrition.

THE function of "Reproduction," and its concomitant phenomena, constitute one of the most important phases of which the cycle of existence in a living being is composed. And the present function differs materially in its mode and period of operation, and in its effects upon the organism, from those other vital processes which minister respectively to the nutrition and innervation of the living form. The process of "Nutrition" provides for the due repair and sustenance of the being. It is manifested throughout its entire existence, and is more or less constantly in operation and activity. The function of "Innervation" partakes in nature much of that of the nutritive process. It is similarly exerted and exercised from the earliest period of existence to the close and cessation of life; and, conjointly with the previous function, acts and operates in the preservative and nutritive interests of the organism. Very different, however, are the aspects in which the function of "Reproduction" must be viewed. So far from being exercised throughout the whole life of the organism, we find it in operation during a very limited portion of that existence; and in most cases, only when the mature and adult stage of life has been attained. In its duration and period of activity it is similarly inconstant; and

finally, instead of contributing to the nutrition of the organism, or aiding in the regulation of its body, we find that the reproductive function tends essentially to detract from, or even impair, the energies of the form; so much so, indeed, that in some cases the existence of the being terminates with the due performance of the process. And hence the act of Reproduction is maintained by Spencer and others to be habitually and normally opposed to that of nutrition. The conservation of the *individual* being, in this way, antagonistic to the conservation of the *species* or *race*.

Nor can these somewhat unusual phenomena appear strange or inexplicable when we reflect on the ulterior purpose of this important process. Its energies are concentrated not solely on the individual exercising them, but on the production and perpetuation in time of new individuals; a function and duty this latter of the highest import, in the face of constant extermination and death. And therefore we find the whole life and energies of the being, its present and ulterior existence, devoted to the perfect development of those phases in its constitution which have for their aim the extension of the form through space, and its perpetuation through time.

The function of "reproduction" or "generation" we thus understand to be that process in the physiological existence of every individual which provides for the production of new individuals, ordinarily resembling their progenitors; or at anyrate exhibiting, after a series of primary developments, a more or less general likeness to the type from which they are produced. Although we thus find the function itself to be universal in its occurrence throughout living beings, the modes in which it may be effected or performed exhibit a very great degree of variation, both as to means on the one hand, and manner on the other. The various forms of the reproductive process thus admit of division, primarily, into two great groups.

The first mode or form of the process is known as "Sexual reproduction," which may be defined as

that in which the two essential elements, those of the male and those of the female, come in contact with each other; the "germ-cell," "ovum," or "egg" of the female, being brought in contact or relation with the "sperm-cell" or "spermatozöon" of the male. We thus observe that the essential feature in this form of the reproductive process is the union of the two distinct sexual elements. Whether these be furnished by the same individual or not, is a fact of immaterial consequence in the recognition of this merely formal definition. The presence of the distinct elements of "sex" is therefore the great characteristic of "sexual reproduction."

The second primary form of the reproductive process is termed "Asexual" or "Agamic" generation; and this division of the process includes a variety of modes or forms, after, or according to which, the reproductive act may be effected. The distinctive and essential feature of all the various modes of "Asexual" reproduction is simply the negative one, as applied to the "sexual" form of the process. In other words, all the forms of the "asexual" reproductive process agree in the fact that no union of male and female elements takes place in this latter variety of the function; and hence we find that the condition is essentially one of growth and development from one primary "individual." We shall, however, have occasion to observe the occurrence, in certain "individuals" or groups, of both of these primary modes of the reproductive process.

Before proceeding to notice in detail the various forms of the function, we may conveniently call attention to the significance of the term "individual," used in a zoological or physiological sense. The zoological "individual" is generally defined as being invariably "equal to the total result of the development of a single ovum;" or, as "the sum of all the successive stages of development, through which the product of a single fecundated ovum passes, whether these stages have an independent existence or not." The essential of each definition lies in the fact that whatever arises or is developed from a single

egg is to be regarded as the zoological "individual;" or conversely, that the result of such development, whatever its form or relations, constitutes a single and "individual" form. Thus in the higher forms of animal life the single "individual" alone, is repeated in the course of reproduction and development. Each ovum or egg, in other words, gives rise to one and a single form known zoologically as an "individual." But we have already had occasion to notice certain organisms (such as the Sea-mat, Fig. 6, or the Hydroid Zoophytes, Fig. 4), which are of compound nature, and which, accordingly, consist of an aggregation or united colony of forms. Are such forms "individuals?" and if not, what relation do they bear to the form so designated? Bearing in mind the essential feature in the definition of the term given above, we may trace the development of such forms, with the result of proving that in most cases the compound organism of the Sea-mat, or *Hydrozoön*, has sprung by a process of budding from a single "ovum" or "egg," or from the primitive being which resulted from the direct development of an "ovum." Hence the entire compound organism must, consistently with our definition, be termed the "individual;" and to each of the separate little beings of which this compound "individual" is composed, the term "zoöid" is applied. The true "individual," in short, is the product, directly or indirectly, of the "sexual" or true reproductive act; whilst the "zoöid" is the product of "asexual" modes of generation. Lastly, it is to be remembered that, firstly, "zoöids" may be perfectly free and independent of the organism from which they are produced; their *mode of origin* being therefore the sole criterion of their true nature. And secondly, the "zoöid" itself may give rise, through a true sexual process, to "individuals," which are truly such, in virtue of the fact that they exemplify each the "total result of the development of a single ovum." Bearing these broad generalisations in mind, we shall be the better able to fully appreciate the various phenomena in which "individuals" and "zoöids" respectively take part.

Turning our attention to the "sexual" mode of reproduction in the first instance, as exemplifying the process in its most usual and highest form, we observe this variety of the function in greatest perfection among the higher animals. We are generally aware, from external peculiarities of form in the higher animals, of the distinction of the "sexes." The peculiarity and essential feature in the nature of "sex," being the power of producing one of two distinctive elements necessary for the due performance of the reproductive process. We thus know that the "male sex" is characterised by the power of producing "spermatozoa;" whilst the function of the "female sex" is devoted to the production of "ova," or "eggs." The "sexes" in the higher forms are accordingly found situated in different individuals, known respectively as "males" and "females;" but in many forms, of even high rank in the scale of creation, we find the two sexes to be contained within one and the same individual. Where the sexes are distinct, and situated in different individuals, we term such forms "dicœcious;" and where male and female organs of reproduction are contained within one and the same form, the individual is said to be "moncœcious," "hermaphrodite," or "androgynous." In "moncœcious" forms, however, although the power of producing ova and spermatozoa resides in *one* individual, we often observe that the sexual union of *two* such "hermaphrodite" individuals appears necessary for the due impregnation of the ova. The opposite sexes in each "moncœcious" form being brought into contact in this way.

The essential feature in the "sexual" form of reproduction, therefore, consists in the contact of the "spermatozoa" of the male with the "ova" of the female. A consideration of the modes in which this process is effected throughout the animal series belongs to the province of the systematic naturalist; whilst the tracing of the subsequent development of the ovum through its various stages to the final appearance of the perfect form, falls to be more appropriately considered when treating of "Development" at large.

The essential organs of the "male" consist of "spermaria," or receptacles in which the "spermatozoa" are formed and developed. These "spermatozoa" or spermatozoöids consist of variously-shaped, hair-like, or filamentary bodies (Fig. 21, A), usually of very minute size,

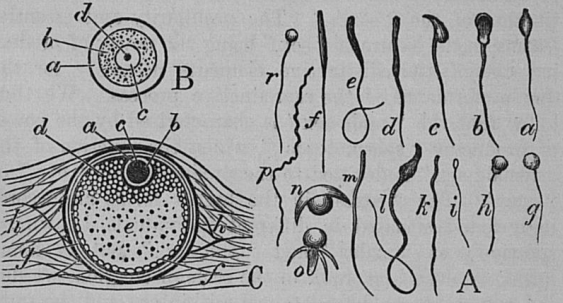

Fig. 21. Ova and Spermatozoa.

A, Spermatozoöids of various animals: *a*, Man; *b*, Squirrel; *c*, Rat; *d*, Cock; *e*, Lizard; *f*, Frog; *g*, Perch; *h*, *Cobitis* (Fish); *i*, Limpet; *k*, Sea-Lemon (Mollusc); *l*, Snail; *m*, Insect; *n*, Crab; *o*, Hermit-Crab; *p*, Earthworm; *r*, Sea-cucumber. B, Diagrammatic section of an ovum: *a*, "vitelline membrane" or "zona pellucida;" *b*, yolk or "vitellus;" *c*, "germinal vesicle;" *d*, "germinal spot." C, Semi-diagrammatic section of *Mammalian* ovum *in situ*, surrounded by its coverings and "ovisac:" *a*, "zona pellucida;" *b*, vitellus; *c*, germ-vesicle and germinal spot; *d*, "discus proligerus," or layer of cells investing the ovum; *e*, cavity of "Graäfian vesicle" or "ovisac," usually containing fluid; *f*, "membrana granulosa" or "granular membrane," lining the walls (*g*) of the ovisac; *h*, "stroma," or tissue of the "ovarium" or ovary, in which the "ovisacs" or "Graäfian vesicles" lie imbedded.

and generally possessing a more or less rounded "head," to which is attached a vibratile "tail." Under the microscope these bodies are seen to exhibit active movements, resembling those of animalcular forms, and from this resemblance the common name of "seminal animalcules" has been applied to the "spermatozoöids." The nature or source of such movements is completely unknown to us. The "spermatozoöids" appear to be developed within characteristic cells of the "spermaria,"

to which the names of "sperm-cells" or "vesicles of evolution" have been applied.

The analogous organs of the female economy are termed "ovaria;" their characteristic productions being known as "ova" or "eggs." The "ovaries" or "ovaria," in the higher animals at least, are composed of loose tissue or "stroma" (Fig. 21, C *h*); the "ova" being produced within sacs or capsules imbedded in this "stroma," and termed "ovisacs" (*g*), or in the mammalia, "Graäfian vesicles," after De Graäf, their discoverer. The term "ovisac" is, however, of more general application, and therefore to be preferred. The "ova" are generally of minute or microscopic size, and exhibit each the characters of a typical nucleated cell. The "cell-wall" of the ovum is known as the "zona pellucida" or "vitelline membrane" (Fig. 21, B *a*). The "nucleus" of the cell corresponds to the "germinal vesicle" (*c*). The "nucleolus" or inner nucleus is represented by the "germinal spot" (*d*); whilst the cell-contents are represented by the "vitellus" or "yolk" (*b*). These three parts are found present in greater or less detail in all ova; and the structure thus described is essentially that of the ovum of all animals prior to impregnation. In the higher animals the relations of the ovum to its coverings are better seen than in the lower forms; and it is in the arrangement and relative position of these coverings, that the essential difference between the ova of the various classes of the *Vertebrata* especially consists. In the lower forms, the "ovisac" is generally closely applied to the "ovum," thus leaving little or no interval between them; but in the *Mammalia*, in which the relations of the ovum and its coverings have been principally studied, we find several cellular structures interposed. As seen in the diagrammatic section of the Mammalian ovum in Fig. 21, C, the walls (*g*) of the ovisac are represented; and situated within the inner wall, so as to form an inner lining to the ovisac, we find the layer of nucleated cells known as the "membrana granulosa" (*f*). This same cellular layer also closely invests the

ovum itself, and forms an ovular covering, known as the "discus proligerus," or "granular zone" (*d*); whilst within this "discus proligerus" lies the ovum itself, constituted by the "vitelline membrane" (*a*), the "vitellus" or "yolk" (*b*), the "germinal vesicle," and "germinal spot" (*c*). These four last-mentioned parts, as already remarked, are common to the ova of all animal forms.

The term "impregnation" or "fecundation," is applied to the process by which the "spermatozoöids" are brought in contact with the "ova," and as a result of this contact the "ova" are accordingly said to be "impregnated" or "fecundated;" that is, the essential conditions for the production of a new being have been fulfilled. The exact nature of the contact between the male and female elements is not known. In what the essential principle or *materies* necessary for fecundation consists we do not know; and the reason or cause why the "spermatozoöids" should possess in themselves so peculiar a power, is a matter regarding which we can only speculate and theorise. In most cases, it would appear that the "spermatozoöids" enter the ovum, and come in contact with the "yolk" and "germinal vesicle;" this contact being provided for, sometimes by the rupture of the envelopes of the ovum, or in other cases, by the existence in the ovum of a special aperture.

The consequent changes which it is the province of Development to chronicle, are thus induced; and as a final observation, we may remark, that the act of "impregnation" is thus dependent upon the "fusion," as it were, of the properties of the male and female elements. We can safely assert thus much, although, as above stated, the exact nature of these properties, or of the fecundative process, is wholly unknown. It may only be further noticed in the present instance, that whilst in the higher forms of animal life the process of impregnation is generally effected within the body of the female, in the lower forms impregnation usually takes place external to the body. And similarly with the subsequent development of the fecundated ovum; this latter process, in the higher

forms, taking place within the body of the parent-organism, and in the lower forms, being generally, though not universally, carried on without the body, and often independently of parental care.

The consideration of the "asexual" processes of reproduction leads us to notice very different phases from those observed in the "sexual" method. We now approach to the observation of modes of reproduction, which simulate, in a manner equally strange and wonderful, the processes of ordinary "growth" and nutritive addition. The process of "sexual" reproduction, in its earlier stages at least, and viewed analogously, is merely a process of growth: since we have to consider, in a generalised aspect, the "ovaria" and "spermaria" especially of lower forms, as simply specialised "buds" or processes of the body-surface, subject to the same laws of growth and formation as the other parts of the organism. But the various modes of "asexual" reproduction exemplify this latter observation in a far greater degree than the most generalised view of the "sexual" form of the process. As we shall presently observe, several modes of "agamic" reproduction mimic, in the most extraordinary manner and in closest detail, the phenomena of vegetable generation and growth.

Two chief forms of the "non-sexual" or "agamic" modes of reproduction await our consideration. The first of these modes is that in which an organism reproduces itself by the production of "buds," springing either from its external or its internal surfaces, and which finally develop into new beings. Such a process is known as that of "Gemmation" or "Budding," and, according to the surface of origin of the buds, the process is termed "external gemmation" or "internal gemmation." This process of "gemmation" is further termed "continuous" or "discontinuous," according as the buds remain continuously and permanently connected to the producing surface or organ; or as they are detached from the parent-organism at an earlier or later stage in their life-history.

The second mode in which the "asexual" repro

ductive process may be effected, is that of "fission," or simple division of the body-substance of an organism; which original material becomes thus simply divided into new beings; and these new beings may either remain attached to and "continuous" with the parent-form, or become free, detached, and "discontinuous" organisms, just as in the case of the "gemmative" or "gemmiparous" products.

In the case of these latter modes of reproduction, we see many illustrations of the "vegetative repetition of similar parts," especially in "continuous gemmation;" but when the produced "gemmæ" or buds separate from or become "discontinuous" with the parent organism, it may be difficult or even impossible to say whether the process of "fission" or "gemmation" has been at work. A comparison of "fission" and "gemmation," will, however, readily bring to light the essential difference between these two modes of reproduction, relatively to the forms produced by either. Thus, in most cases of "fission," the detached portions simply require the ordinary process of "growth" to develop them into organisms, like those from which they were detached. Whilst, in "gemmation," the process is more purely and truly reproductive, in that a more or less defined process of "development" has to be gone through ere the primary form of the bud becomes transformed into a being, resembling that which gave it origin.

The terms "produced" and "producing" zoöid, so frequently occur in considering the "asexual" reproductive processes, that it may be well to explain the meaning of these expressions. Thus, when, as in the case of the Hydra (Fig. 7, 1), we find an organism or "zoöid" giving origin to other "zoöids," which become detached or "discontinuous," we term the first or parent "zoöid," the "producing," and the others the "produced" zoöids. Then, where we have successive series or generations of "zoöids," we term each zoöid of the first series a "protozoöid;" those of the second are "deuterozoöids;" those of the third, "tritozoöids," and so on.

Lastly, it is to be borne in mind that the parent or "producing zoöid" may possess true sexual or reproductive organs, that is ovaria and spermaria; and the "produced zoöids" may also develop generative organs—although it will be understood that both the "produced" and "producing zoöids" may as frequently be destitute of "sexual" reproductive powers, and be able in this latter instance to produce new forms only by a process of gemmation similar to that by which they themselves were produced.

We shall now consider in order the processes of "fission" and "gemmation," together with several phenomena, in which analogous reproductive phases may be said to take part.

"Fission," or simple division of the body-substance of an animal to form new, separate, and generally independent organisms, is seen typically in the case of the *Actinozoa* and Coral-polypes, in *Infusoria*, *Rhizopoda* (such as *Amœba*), and in many other forms. The Coral-polypes and their allies exemplify for us the "continuous" form of "fission." In these organisms we find the polypes frequently dividing spontaneously, and in various ways, but usually by the vertical division of the animal through its mouth, and downwards through its body; the primary form being thus divided or separated into two distinct, yet connected and "continuous" organisms, which may in turn divide in like manner. The common *Actinia* or Sea-Anemone, and allied species, occasionally divide spontaneously, and exhibit a result similar to that seen in their neighbours the Coral-polypes. And the process of "fission" has been also observed in various members of the *Hydrozoa*, of which class the *Hydra* (Fig. 7) is the type.

In *Infusoria* (Figs. 5, 22, 23), we find many and most typical examples of "discontinuous fission," and also of the various modes in which it may be effected. Thus we may, as in *Vorticella* (Fig. 22, B), find it to be longitudinal; the flower-like head (*a*) of this form exhibiting a longitudinal cleavage (*b*), and finally, one half of this

cleft head falling off the stem (*c d*), and thereafter developing a new stalk, and assuming the perfect likeness of the parent-form (*a*). Transverse fission may also occur in *Infusoria*, as in *Stentor*, *Nassula*, etc. (Fig. 23, I); whilst other species (*Paramœcium*, Fig. 23, F, etc.), exemplify either or both of these modes of accomplishing fissiparous reproduction (Fig. 23, G, H, I). The idea that the reproductive organs of these animalcules—that is to say, the "nucleus and nucleolus" (Figs. 22, A, *n*, and 23, F, *a b*),—take part in the process of "fission,"

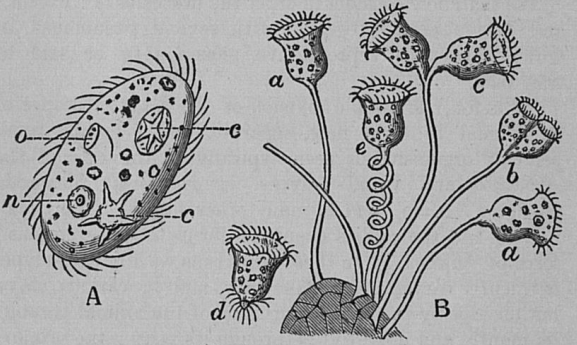

Fig. 22. INFUSORIA.

A, Diagram of *Paramœcium*, a familiar *Infusorian* form: *c c*, contractile vesicles; *n*, nucleus and nucleolus; *o*, mouth and rudimentary gullet. B, Group of *Vorticellæ*; *a a*, adult *Vorticellæ*; *b*, an animalcule beginning to divide fissiparously; *c*, further stage of *b*, two heads being borne on the one stalk; *d*, detached head, furnished with cilia, and which for a time leads a locomotive existence; *e*, *Vorticella*, contracted on its stalk.

does not appear to be borne out or confirmed by recent investigations. Since, as remarked by Greene, in some cases the division of the nucleus "into two parts is not effected until that of the body is nearly complete, or it may happen that fissure of the nucleus is not participated in by the body as a whole." The *Rhizopoda* represented by *Amœba* (Figs. 1, and 23, E), also exemplify the fissiparous mode of reproduction; a "pseudopodium" or

finger-like process of the body being, as seen in Fig. 23, E, frequently cast off to assume all the functions of a new being.

The process of "gemmation" or "budding" involves the consideration of more complicated phenomena than those witnessed in the process of "fission." Gemmation may be "external" or "internal;" "continuous" or "discontinuous." The reproduction of lost and injured members, so well exemplified in the case of Crustacea, Starfishes, etc., appears to be effected by a process analogous to that of budding. But there is no further connection or analogy than this mere identity in kind, to be drawn between this reproduction of lost parts and the reproduction of true organisms or "zoöids." We find many and excellent examples of "gemmation" amongst nearly all classes or groups of *Invertebrate* forms. The *Protozoa* exemplify the process in many interesting examples, and the *Foraminifera* may be held as illustrating the process very completely. These forms (Figs. 2 and 23) consist each of a little mass of "sarcode" or "protoplasm," which possesses the power of building up around its primitive body a similarly minute, calcareous, or limy "shell;" and through holes or "foramina" in this shell the little "pseudopodia" or "false feet," so well seen in the *Amœba* (Fig. 1, *a b*), are protruded. A *Foraminifer* simply consists of an Amœba-body within a perforated calcareous envelope or shell.

The *Foraminifera* are divisible into two great groups, according as the shell is single or many-chambered. And the study of the morphology of *Foraminiferal* forms has shown us that the "Multilocular" or many-chambered shells were originally single-chambered (Fig. 23, A), and were produced each from a single-chambered form by a process of "continuous gemmation;" that is, by the addition of new chambers budded out from the primitive apartment. Thus we have various typical forms developed. If "gemmation" proceed in a straight line, we have the single-chambered shell converted into a multilocular and linear structure (Fig. 23, B). Or if the new segments be successively larger than the older ones,

the shell will tend to become conical in shape (Fig. 23, C). And between all the different chambers of a multilocular shell, whatever its shape or size, there exist apertures of communication, so that the primitive "sarcode" is con-

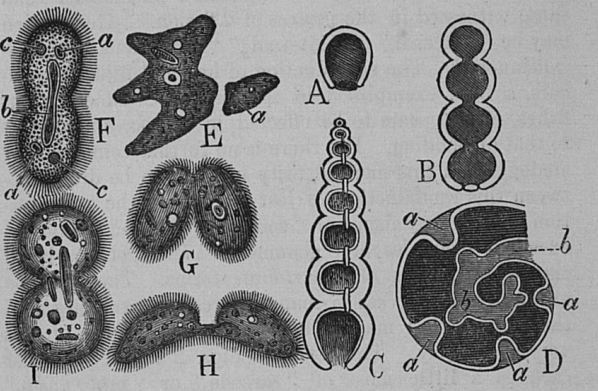

Fig. 23. Illustrations of Fission and Gemmation.

A, Section of Monothalamous or "single-chambered" *Foraminifer*. B, Section of Polythalamous or "many-chambered" *Foraminifer*, showing the production of a linear series of equal chambers by gemmation. C, Section of many-chambered *Foraminifer* (*Marginulina raphanus*), showing the increase in size of the successive chambers, producing by gemmation a spiral or conical shell. D, Helicoid or Snail-like shell of *Foraminifer* (after Huxley), formed by the coiling of the segments or chambers to form a flat, close spire, the coils of which lie in one plane: *a a*, additional material thrown out to fill up the spaces between the septa or partitions; *b b*, material filling up the gaps between the whorls of the shell (*a*, interseptal, and *b*, intergyral spaces). E, *Amœba*, undergoing process of fission: *a*, one of the finger-like processes or "pseudopodia" detached to form an independent animalcule. F, *Paramœcium bursaria* (Stein) dividing transversely: *a a*, nucleoli; *b*, nucleus; *c c*, contractile vesicles. G, *Glaucoma scintillans* (Ehrenberg) dividing vertically. H, *Glaucoma* undergoing a second process of fission. I, *Nassula ornata* (Ehrenberg) dividing itself by transverse fission.

tinuous and organically connected throughout the chambers of this curious domicile. Then similarly we can conceive of spiral shells being formed by the spiral arrangement of the budding segments (Fig. 23, D); and

other forms of symmetry may be developed after analogous fashions. The process is thus truly one of "continuous gemmation;" nor do I think that the recognition of the "vegetative repetition of parts" can be so strongly insisted upon here, inasmuch as the repeated parts are not in most cases so thoroughly alike the original segments as is implied by the use of this term. The budded segments are not perhaps to be regarded in the light of distinct zoöids; but in spite of these considerations the process of reproduction known as "continuous gemmation" is exceedingly well exemplified in these forms.

Among the *Cœlenterata* the "continuous" and "discontinuous" forms of gemmation are well exemplified. The *Hydra*, or common Fresh-Water Polype (Fig. 7, 1), in one phase of its reproductive process exemplifies "discontinuous gemmation." During the warmer months of the year we find the *Hydra* to exhibit little bud-like projections on the sides of its body. As development advances, a mouth and tentacles are developed at the free or "distal" extremity of this little bud, and in due course we are presented with a little *Hydra* budding from the sides of its parent (Fig. 7, 1), to which in every respect, save perhaps in size, it bears a close resemblance. The parent *Hydra* in such a case would be termed the "producing," and the young budded organism the "produced" zoöid; for the parent *Hydra* is merely a "zoöid" similar to its "gemmiparous" offspring. If we suppose the parent *Hydra* to have been produced from an ovum, that is by "sexual" reproduction, the parent would, in this latter case, be simply a "zoöid;" since the zoological "individual" would be constituted by the parent Hydra, together with all the "zoöids" which might be produced by "gemmation" from it. The "total result of the development of a single ovum," including not the parent *Hydra* alone, but all the "zoöids" which spring by "gemmation" or otherwise from it. In the *Hydra* the zoöids may remain connected to the parent organism for a period of greater or less duration; but they invariably drop off from the "producing zoöid," and seek a new

and independent existence. The primary buds to which the parent or "producing zoöid" gives origin, may in turn, and whilst still connected to the parent organism, produce by budding a second generation or series of zoöids; and we may thus have three generations of *Hydræ* connected together for a longer or shorter period, but eventually becoming detached organisms. Such a combination illustrates the terminology applied to the successive series of "zoöids; the parent zoöid being the "protozoöid," the primary buds the "deuterozoöids," and the secondary series of buds the "tritozoöids."

In other members of the class *Hydrozoa*, exemplified by the Sea-firs and their allies (Fig. 4, *a b c d*), and in the *Mollusca*, represented by the Sea-mats (Fig. 6), we find typical examples of "continuous gemmation," and of the "compound individual" and its component "zoöids" also. In most *Hydrozoa* we find the branching tree-like organism to consist generally of a main stem and branches (Figs. 4 and 24, A), bearing numerous little "zoöids" (*a a*), produced from a primitive being by a process of "gemmation;" but which, unlike the "zoöids" of the *Hydra*, remain permanently attached together, to form the compound organism we know as the "individual."

The Flustra or Sea-mat (Fig. 6, *a*) exemplifies a similar condition of parts. In this organism we find the little "zoöids" enclosed in tiny cells (Fig. 6, *b*), the aggregation of such "zoöids"—or "polypides," as they are termed in the case of the "Sea-mats"—making up the zoological "individual." Like many of the *Hydrozoal* "individuals," the compound organism of the "Sea-mat" springs by "gemmation" from a single primitive "polypide." And in each of the preceding cases every "zoöid" may, roughly speaking, produce true "ova" by "sexual" reproduction, and from these ova the compound "individuals" will in turn be produced.

These examples may be deemed sufficiently illustrative of "external gemmation" in its two chief aspects. We may next, and very briefly, observe the phenomena incidental to the "internal" form of the same process. Such

a process is exemplified typically in the case of forms allied in nature to the "Sea-mats," or *Polyzoa*, as they are collectively designated. These organisms ordinarily reproduce their species by means of true ova, from which by "gemmation" the compound organisms are developed. In connection with these forms, and chiefly by aid of the researches of Professor Allman, a second set of so-called "ova" has been detected; these latter being developed, not in the "ovaria," but by budding from a cord-like structure, the "funiculus," which is attached to the lower and posterior extremity of the stomach. Such "ova" have been termed "winter ova" or "statoblasts." These "statoblasts" are enclosed in a curious envelope of corneous or horny texture, and appear to be contained for a longer or shorter period within the body-cavity of the organism. The "winter ova" are liberated during the colder season of the year—and hence their name—by the death of the organism in which they were produced, or by other means of escape; and from the free "statoblast" there issues in due course "a young *Polyzoön*, already in an advanced stage of development, and in all essential respects resembling the adult individual in whose cell the statoblasts were produced" (Allman). Such a form, when thus liberated from its statoblast, gives rise, by "continuous gemmation," to the "compound individual;" the separate "zoöids" of which will in turn develop these "statoblastic" germs.

At first sight, therefore, this would appear to be a case of "discontinuous gemmation," since we have the "compound individual" giving rise through its "zoöids" to single "individuals," from which, again, the compound form is produced by budding. But Dr. Allman has shown that these "statoblasts" are not to be accounted true ova, from the fact, that an "ovarium" exists in each "zoöid," and produces true ova independently of these "statoblasts;" and also from the fact that these "winter ova" do not exhibit or pass through the characteristic phases which invariably accompany the development of true "ova." Dr. Allman is therefore of opinion that

these peculiar bodies are to be regarded as internal buds or "gemmæ" in a state of encystation, and which thus remain for a certain period in a "quiescent or pupa-like state." The value of such researches in aiding us to draw the very necessary, but not always patent distinctions between (*a*) true ova, (*b*) separated or detached "gemmæ" or "buds," and (*c*) attached buds, cannot be too highly or over-estimated.

Having thus investigated the nature of the typical forms of the reproductive process, we may next in order turn to the consideration of certain more complicated phenomena connected with the successive cycles or reproductive phases through which many forms pass in the course of their reproductive and developmental history. It is needless to remark that the significance and relation of the terms "individual" and "zoöid" must be clearly borne in mind in such investigations; since the explanation of these and allied phenomena amounts simply to the tracing out of these two forms, in which an entire organism may at once, or interruptedly, make its appearance.

Such cycles of the reproductive process may be typically witnessed in the case of most *Hydrozoa*, in certain of the lower *Mollusca*, in the *Tæniada* or tape-worms, and in allied forms. The first-mentioned group will exemplify the phenomena we are about to describe in the simplest, and at the same time most typical, manner. With many forms of *Hydrozoa* every seaside visitor will be familiar, and we have already had occasion to notice the general morphology of the group. The illustrations at Figs. 4 and 24 will serve to impress the essential features of a *Hydroid* Zoophyte on the mind; and we thus observe that the organism presents us with a branching tree-like structure (Figs. 4, *a c*, and 24, A) growing from a fixed rooted point, and in every way resembling a vegetable production. If we magnify a portion of such an organism (Figs. 4, *b d*, and 24, B), we find the branches bearing small cells, of varying form and size, in place of leaves or flowers. Each cell contains a tiny inhabitant

or "polypite" as it is technically called (Fig. 24, B, *a*); and with the knowledge that each "polypite" consists of a soft tubular body, terminating superiorly in a mouth and crown of tentacles (*a*), and communicating internally with the general cavity or interior of the branch on which it is borne, we shall possess a sufficiently clear idea of the essential features of each little member of this strange commonwealth. For each "polypite" is exactly the counterpart of all its neighbours, and although, in a manner, every member of the colony is independent of its fellow-beings, it yet contributes its share to the nutrition and support of the colony at large. Through the hollow connecting medium or "cœnosarc" (Fig. 24, A, *c c*), which binds the members of this commonwealth together, a constant circulation of fluid is kept up. And to the current of this nutritive stream each "polypite" contributes its quota of elaborated matter, and in turn derives its nutriment from this common source. The entire organism is therefore nourished by the united efforts of its semi-independent members; just as the leaves of the tree at once contribute to and draw upon the general fund of nutriment, in the formation and elaboration of which they all aid.

A very brief consideration of such an organism will show us its morphological and physiological composition. The entire Zoophyte is simply an "individual" of compound nature; whilst its component members or "polypites" are "zoöids," produced by a process of "continuous gemmation" from a single and primitive embryonic form.

A further and more detailed examination of the zoophyte, however, would reveal the fact that, to all appearance, it could increase and extend its growth simply by the power of "gemmation" by which it was primarily developed. As the leaves of the tree fall and wither, so, in a manner, do the little "polypites" of the *Hydrozoön;* but the power of "gemmation" amply suffices for the renewal of these disintegrated portions, and thus new growths of these little buds are continually taking place from the common medium or "cœnosarc," and fresh members are thus added

to the commonwealth to fill the place of those which have died or fallen away.

We have thus ascertained that the "individual" in this case consists of numerous connected "zoöids," which perfectly nourish the organism, and which are produced and renewed by "gemmation."

If we now return to our present comparison of the zoophyte and the tree, we shall at once detect a gap or break in the parallelism. We have provided for the growth and nutrition of the one "individual," but not for the production of *new* "individuals." The zoophyte, as we have seen it, exhibits in its life the simple phenomena of growth, and nothing more—nutritive growth on the one hand, and a reproductive growth by gemmation on the other. But this latter form of the reproductive process is incompetent to perpetuate the species. It is simply sufficient to add to and extend the "individual," just as the leaves, root, stem, and branches, extend the growth of the single tree. The tree, however, possesses true reproductive, as well as merely nutritive organs, and these reproductive organs we know as the flowers. From these flower-buds will in time arise the true sexual elements from which a new being or tree will spring. If the parallelism between the zoophyte and the tree be perfect, we will require to show that the former possesses buds or organs which will correspond in function to the flower-buds of the latter.

In our previous and general examination, therefore, we detected only one set of "zoöids" or buds; but our more minute examination reveals a second set or series (Fig. 4, *d;* and 24, A B, *b b*),—these latter zoöids devoted not to the nutrition but to the reproduction of the organism. Hence, in reality, our miniature commonwealth is composed of two sets of members: the hydroid "individual" is constituted by a double set of zoöids. Collectively we designate all the nutritive zoöids of the "individual" the "trophosome" (Fig. 24, A, *a a*); whilst the reproductive zoöids similarly make up the "gonosome" (Fig. 24, A, *b b*; and B, *b*).

The "individual" so formed is primarily, therefore, of a double nature; the two series of zoöids are essentially

different in form, and different in function also ; although morphologically the two series are constructed on the same

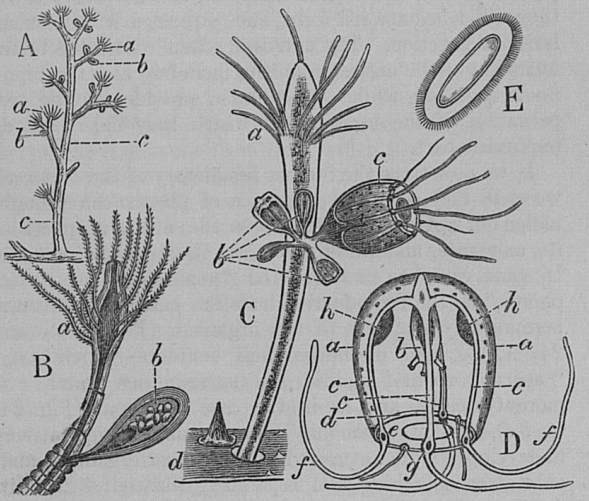

Fig. 24. Reproduction of Hydrozoa.

A, Portion of the "hydrosoma" or entire organism of *Cordylophora lacustris* (Allman), natural size: *a a*, nutritive polypites or zoöids; *b b*, reproductive zoöids or "gonophores;" *c c*, connecting medium or "cœnosarc." B, Branch of *Cordylophora*, greatly magnified, showing a nutritive zoöid or polypite (*a*), and a reproductive zoöid or "gonophore" (*b*) containing ova. C, Portion of *Podocoryne carnea*, greatly magnified (after Hincks: *a*, an ordinary "polypite" with tentacles; *b*, "gonozoöids," or reproductive zoöids, in various stages of development; *c*, a gonozoöid fully developed, and on the point of detaching itself; *d*, connecting crust or medium of the polypites. D, The free gonozoöid or "Medusoid" embryo of *Podocoryne carnea* (C), having detached itself from the plant-like organism; *a a*, swimming-bell or "umbrella;" *b*, manubrium; *c c c*, "radiating" canals terminating in, and connected by, the "circular" canal (*d*); *e*, "veil" with central aperture; *f f*, tentacles; *g*, ocelli; *h h*, reproductive organs. E, "Planula," or general form of the "embryo" of *Hydrozoa*.

fundamental plan. Just as the flower and leaf-buds of the tree differ in function, but are morphologically, and so far

as their fundamental type is concerned, the same, so are the nutritive and reproductive "zoöids" of the *Hydrozoön* primarily identical in structure, but, as we observe them, they differ in outward form, and present a wide dissimilarity of function. The nutritive zoöids contribute to the nutrition of the entire organism, including also the reproductive zoöids, whilst these latter provide for the perpetuation of the organism, of which they thus form an important part.

If we now trace the further life-history of the zoophyte, we shall find a curious sequence of phenomena brought under our notice. We have seen the nutritive phase of its existence, and we next observe its reproductive cycle. In some cases we find that the "gonozoöids" or "gonophores," as the reproductive buds are called, may remain permanently attached to the organism (Figs. 4, *d;* and 24, A, B), and discharge their contents—"ova" and "spermatozoöids"—into the surrounding water; or more typically, and as in the case before us (Fig. 24, C, *b c*), the "gonozoöids" may remain comparatively undeveloped whilst attached to the parent organism, and, only after detaching and separating themselves from it, do they mature the reproductive elements which it is their function to elaborate and develop.

We thus find that, in the latter case, the "gonozoöid," (Fig. 24, C *b*), having attained a certain development, liberates itself (*c*) from the "ectotheca" or envelope in which it is contained whilst attached to the parent organism, and floats freely away in the surrounding water, thus entering upon a completely new phase of existence. We now find the free and independent gonozoöid (Fig. 24, D), exhibiting a form singularly unlike that of the being which gave it birth. Nor can we feel surprised, as we contemplate this beauteous form, that the older naturalists should imagine it to be an organism *specifically* distinct from the zoophyte, and that they assigned to it the rank and place of a true "individual." We now behold a delicate fragile form, consisting of a bell-shaped body, (Fig. 24, D, *a*), composed of a clear crystalline jelly, which

is tinted, as it moves gracefully through the water, with all the most beautiful of cerulean hues: a clear crystalline dome, swimming through the sea by the alternate expansion and contraction of its bell-shaped body, or "umbrella" (*a*), as it is technically called. And such a form, in all its many varieties, will be familiar to every seaside visitor as the *Medusa*, "jelly-fish," or "sea-blubber"—a being popularly accounted of distinct "individual" identity, and as unlike the form from which it was derived as we could conceive any form to be.

This "medusoid" form, or free "gonozoöid"—for we must not, in spite of its altered form, lose sight or recollection of its original relation with the zoophyte—possesses a structure also peculiar to itself. If we compare its body to a bell, we find a hollow central organ, known as the "manubrium," depending, like the "clapper" from the roof of the bell, into its interior (*b*). At the free extremity of the "manubrium" we find a mouth, whilst from its attached or upper end we observe a series of tubes or canals (*c c c*) to radiate from this central point to the edges of the bell or "umbrella," where they open into a "circular vessel" (*d*) which runs round the margin of the disc, and thus connects the "radiating canals" together. The "manubrium" is simply a modified "polypite" or nutritive "zoöid," and the radiating system of canals subserves the function of a digestive or circulatory system, to distribute throughout this strange economy the products of the digestive or nutritive function.

The margin of the "bell" is provided with a variable number of tentacles (*f f*), at the bases of which, peculiar little bodies of the nature of pigment-cells (*g*), with brightly coloured and contained particles, are situated. And along the margin, and between the insertions of the tentacles, we also find a number of small saccular organs, containing little calcareous or mineral particles, suspended in a clear fluid. To the former bodies, the function of sight has been assigned, whilst the latter are generally believed to be auditory or hearing organs; but there appear to be reasonable grounds for doubting the correct-

ness of these ideas. Then, finally, we observe the open mouth of the bell below to be more or less completely closed by a delicate membrane termed the "veil" (*e*); this membrane possessing a central aperture of variable size.

So far the "medusoid" zoöid provides for its nutrition, and its further and still more characteristic development is marked by the appearance of the reproductive organs (*h*). These latter organs are developed at various stages of its existence; this free *Medusa* in some cases possessing a generative apparatus before its detachment from the zoophyte, and in other cases producing them only after a lengthened period has passed in its free state of existence. But generally, and in either case, with the maturity of the generative organs, the nutritive energies of the "gonozoöid" seem to disappear; and its existence usually terminates with the full development of its reproductive system, and with the fulfilment of its peculiar and characteristic function.

And a no less curious series of phenomena than those we have just traced, may yet be perceived in the latter history of the *Medusa*. The true reproductive organs destined for the exercise of the "sexual" form of the process are developed between the walls of the "manubrium," or in special sac-like structures (*h h*) situated on the radiating canals. They consist either of the typical "ovaria" or of "spermaria," destined for, and capable of, reproducing a new being by true "sexual" generation. But in addition to these reproductive organs destined for the performance of the sexual process, we find that the "gonozoöid" may apparently emulate the "gemmative" or "budding" tendencies of its progenitor; and, accordingly, we may observe it to produce "medusoid buds," which resemble their parent in every particular, and which soon detach themselves from the parent form, and propel themselves in like manner through the water. And thus we may find that these secondary *Medusæ* will also develop true reproductive organs, and repeat the same cycle of existence through which their parent is destined to pass.

Finally, however, the process of sexual reproduction takes place in our Medusa's history, that process consisting in the escape from the parent body of the ripe "ova" or "spermatozoöids," and in the subsequent impregnation and fecundation of the ova. The free "gonozoöid" or *Medusa* may then disintegrate and pass out of existence, or it may die before the ova escape; these developed germs being liberated by the death of the organism, and being subsequently fertilised. Or, lastly, we may find the "gonozoöid" to undergo a "retrograde development" or "metamorphosis" after the escape of the reproductive elements, in the course of which it loses its clear crystalline appearance and characteristic form, shrivels up, and then dissolves away, and becomes one with the water in which it so buoyantly swam, and to which, in the delicacy and transparencey of its guise, it bore so close a resemblance.

The ova, liberated by the decay of the "gonozoöid," and subsequently fertilised, pass, firstly, through the primary stages of development common to all ova, and then appear in the characteristic form of the *Hydroid* embryo—namely, as a ciliated, elongated, or ovoid body, known as the "planula" (Fig. 24, E). This embryo, at first free-swimming and independent, at last fixes itself to some marine object, and from this simple form a primitive "polypite" is developed, which gives rise by subsequent and rapid "gemmation" to the branched tree-like zoophyte with which the cycle began. This latter form will, in turn, produce its "zoöids," nutritive and reproductive; the latter destined again to repeat the curious cycle through which their indirect progenitors have passed.

Tracing in order these various stages, for the sake of impressing them clearly on the mind, we find—

(1.) The zoophytic "individual," with its nutritive zoöids (trophosome), and its reproductive zoöids (gonosome), giving rise by the functional development of its "gonosome" to

(2.) The free "gonozoöid" or *Medusa*, which may

produce other free "gonozoöids" by "gemmation," but which ultimately develops "ova" and "spermaria," through which impregnated ova are produced; and these "ova" in turn develop into

(3.) The "embryo" or "planula," which finally gives rise by "gemmation" to the (1) zoophyte or doubly-compound "individual" with which the series began.

How could we reconcile, at this further stage, the parallelism between the tree and the *Hydrozoon?* If we could suppose that the tree detached its flower-buds, which should in turn produce winged seeds, and that these latter should finally give origin to new trees, we should construct a case analogous to that of the zoophyte and its reproduction. The detached flower-bud would correspond to the locomotive "gonozoöid," and the winged seed would be the analogue of the embryonic "planula."

We need not trace any further examples of the same kind, since they would all exhibit the same order of phenomena, slightly varied in the form or mode of exhibition. Our next consideration must be that of investigating the relations of the various forms we have seen to take part in the cycle of reproduction.

The older naturalists, as already remarked, explained the above series of reproductive stages, by assigning to the zoophyte on the one hand, and to the free *Medusa* or "gonozoöid" on the other, the rank and position of true "individuals." And they further supposed that these "individuals" were capable of mutually reproducing each other; that is, that the one generation, resulting from this mutual reproduction, "alternated" with the other generation. Or, in other words, that each "individual" became alternately the parent and progeny of the other. Thus the zoophyte might, firstly, be the progenitor of the *Medusa;* then the *Medusa* became the progenitor of the zoophyte: the offspring of each individual, to use the simile of Chamisso, 'resembled not the parent but the grandparent.' To this series of phenomena, Steenstrup gave the name of "alternation of generations," and he thus expresses himself regarding the chief ideas involved in the term:—

"The fundamental idea expressed by the words 'alternation of generations' is the remarkable and till now inexplicable phenomenon of an animal producing an offspring which at no time resembles its parent; but which, on the other hand, itself brings forth a progeny which returns in its form and nature to the parent animal, so that the maternal animal does not meet with its resemblance in its own brood, but in its descendants of the second, third, or fourth degree of generation."

With extended observation and improved means of research, resulting in the more correct appreciation of the terms "individual" and "zoöid," we now have reason to altogether dispute and deny the correctness of Steenstrup's term, and of the ideas on which it is founded. There is but *one* "individual" concerned in the process, and the alternation is not one of "generations," but one of true "sexual" reproduction with "fission" and "gemmation." The "individual" resulting from the "total development of a single ovum," is embodied in the zoophyte with its double series of zoöids; whilst "gemmation" and "fission" respectively alternate with the process of sexual reproduction in the production by budding, firstly, of the tree-like zoophyte, and secondly, in the detachment by fission from this latter of the medusoid embryo or "gonozoöid." This process of alternation might be more clearly perceived if we supposed that the "gonozoöid" gave origin to its ova without leaving the parent organism. In such a case (exemplified by certain *Hydrozoa*), the alternation would take place without the separation of the reproductive element as a *Medusa;* and thus we would have the zoophytic "individual" giving origin directly to impregnated ova, from which the "individual" would again directly be reproduced.

The primary or "proto-zoöids" in this case are represented in the "gonosome" and "trophosome" of the zoophytic "individual;" the "deuterozoöids" would be constituted by the *Medusæ* or free "gonozoöids; whilst if this latter form gave origin to the Medusoid buds which we have seen it capable of producing, these last would represent the "tritozoöids."

We thus see that the former significance of the term "alternation of generations" is completely altered in the face of these considerations. The entire series of alternating phenomena merely constitute the single and highly-individualised reproductive phase of one individual, and are not, in any sense, the alternations of one generation, or of one individual, with another generation, or with another distinct and specific form. The reproductive phase especially, and the nutritive phase also, are highly-specialised in such cases; and the zoological "individual" may thus be exceedingly difficult of detection or recognition when the already complicated series of phenomena is still further and more highly specialised. We might thus, without fear of contradiction, talk of "alternation of zoöids," but not of "generations;" and the term "metagenesis" has been employed in lieu of Steenstrup's name, as expressing a more correct idea of the nature of the included phenomena.

Closely allied to the previous subject is that known as "Parthenogenesis." By this term we express the occurrence of a curious set of phenomena, typically witnessed in the case of certain insects, and which consist in the production, from the "ova" of an *unimpregnated* or "virgin" female, of new beings or individuals—the ova in such a case undergoing development into new beings, without the act and co-operation of the male element. We have already seen that the true and essential part of "sexual" reproduction is the union or contact of the male and female elements; and a series of phenomena, like the present, when first brought to light, excited, as might readily be supposed, no small amount of surprise and speculation. By Professor Owen, however—to whom we are indebted for this term—the process of "parthenogenesis" is made to include the phenomena of "gemmation" and "fission;" in which, from a "virgin," or, at any rate, an unimpregnated individual, such as the zoophyte, a new series of beings or "zoöids," is produced by "budding," or by "fission," and certain of these "zoöids" generally develop true "sexual" elements. So that, widely applied, the term may even

include the process of "metagenesis" or "alternation of generations." But it is at once more convenient and correct to restrict the name "parthenogenesis" to the development from the "ova" of a "virgin" or unimpregnated female of new beings or "individuals," which ova thus develop themselves, without contact with the "spermatozoöids" of a male.

Professor Owen's explanation of the phenomena of true "parthenogenesis," viewed in this latter sense, rests on the supposition that the original "spermatic force," or essential male elements, are transmitted from generation to generation, and that this store of spermatic elements suffices to impregnate the ova without fresh contact with a male. Or, to use Owen's own words, so much spermatic force is "inherited by the retained germ-cells from the parent-cell or germ-vesicle as suffices to set on foot and maintain the same series of formative actions as those which constituted the individual containing them." And consistently with this continued expenditure of the accumulated sperm-cells, "every successive generation, or series of spontaneous fissions, of the primary impregnated germ-cell, must weaken the spermatic force transmitted to such successive generations of cells."

Remembering the essential and invariable facts that "sperm-cells" must originate from "spermaria," and "ova" from "ovaria," and that both "ova" and "spermatozoöids" must exhibit certain defined and constant characters, and pass through a series of defined changes or developmental stages, we are prepared to investigate these phenomena with some certainty of arriving at a correct idea of the process in virtue of which they originate.

The researches of Von Siebold on the reproduction of Bees, and of Bonnet on that of the *Aphides* or Plant-lice, have laid before us a vast store of facts relative to the details of the "parthenogenetic" process.

The *Aphides* or Plant-lice, which occur in such numbers on all our ordinary plants, produce, in the autumn season, true impregnated ova, the result of the sexual contact of ordinary male and female *Aphides*. These impregnated

ova are generally deposited in the axils of the leaves or branches of plants, and lie without change or development throughout the winter season. In the following spring, however, these ova are developed, and then the curious fact "is observed, that the resulting progeny does not include a single *male*, but consists of wingless *females*, sexless beings or "neuters." These "females" produce young larvæ without sexual congress with a male; and this second generation will in like manner, and without impregnation, produce similar beings. And this succession of generations of these "fruitful virgins," as they are called, may be traced through nine (Bonnet) and even eleven (Duvau) generations, without the birth, presence, or influence of a male individual. Kyber is said to have observed the active exhibition of this process of generation through a period extending over four years, without demonstrating the presence of a single male.

Towards the succeeding autumn, however, winged male individuals once more make their appearance in the last brood of these "fruitful virgins;" and these copulate with their female neighbours, and so produce the fecundated eggs, from which, in the succeeding spring, a new generation of females will be developed to repeat the curious phenomena we have just traced.

In Bees, also, we find an analogous series of phases. Thus the "hive" is composed of three sets of individuals: the "queen-bee;" "drones," or male bees; and "neuters," or "workers," which latter are merely undeveloped or sterile females. The reproductive life of the "hive" commences by the "queen" taking her "nuptial flight" into the air, in the course of which she is impregnated by the "drones" or "males." The "seminal fluid" or male element is received into a special sac or "receptacle," which communicates with the "oviduct," or duct of the ovarium. This communication, however, between the ovarium and seminal receptacle, is under the control of the queen-bee, and can be opened or shut at will.

The cells in the "hive" having, by the indefatigable labours of the workers, been prepared, the "queen" begins to deposit the eggs. And in the process of egg-deposition

the characteristic kind of individual which is to result from the development of each egg is regulated by the contact or non-contact with the male fluid from the receptacle, to which each egg is subjected as it passes from the "ovarium," and along the oviduct, to be deposited in its cell. Thus those eggs, from which "queens" or fertile females and workers are to be developed, are subjected to contact with the male fluid from the receptacle; whilst those ova which are destined to give birth to "drones" or males, are allowed to be deposited without contact with the male element. This latter fact has been verified by Dzierzon, who found, that by permanently cutting off the communication between the seminal receptacle and oviduct, none but males or drones were produced. The queen bee is in all probability guided in this curious and wonderful process by the shape or size of the individual cells, in each of which an egg is to be deposited; the three kinds of cells—workers, drones, and royal or female cells—being of different sizes and shapes.

The subsequent sex or kind of individual which is to result from the development of any given egg, is stated by some observers to be also dependent on the kind of food or nutriment upon which the "larvæ" are fed. The "ova" and larvæ, in this view, are of no sex, and the supposition takes origin from the fact that different larvæ are fed with different kinds of food. "Royal food," in this way, consists of a special "paste;" whilst the ordinary food is simply composed of honey and the pollen of plants. Leuckart, for example, ascertained that the effect of a worker being fed upon "royal food," is to transform it, by the development of its reproductive organs, into a "queen" or "fertile female;" and Landois has also proved that an insufficient amount of food will produce a male, whilst plenty of nutriment will produce a female.

After the due development of the eggs, deposited, as we have seen, by the "queen bee," the population of the hive becomes so considerably augmented, that a portion of the community leaves the parental home as a "swarm;" the old queen heading the exodus from her

former dominions. Another swarm, led by a daughter of the old queen, leaves in a short time after the first; this second queen being impregnated in her flight through the air as in the case of the mother-queen. In this way, and by a similar process of reproduction and development, the reproductive interests of the bee-community are duly provided for.

From such facts as these, therefore, the theory of pure "parthenogenesis" has been formed. What explanation can be given of the theory, or of the facts upon which it is based? If we can consider the ova produced by the "fruitful virgins" of the *Aphides* to be truly such, then the process of pure "parthenogenesis" is exemplified; that is, virgin or unimpregnated females produce ova capable of giving rise to new beings without the presence of or contact with the male fluid. And Professor Owen's view, firstly, that the original stock of "spermatic force" derived from the male *Aphides* in the autumn is transmitted from parent to offspring through many generations; and secondly, that it suffices to impregnate the ova of the descendants of those forms in which the spermatic fluid was originally deposited, seems to account for the facts as they stand. In this view, therefore, we may either assume the existence of objective germ-cells —the transmission of the absolute male elements from female to female; or, on the other hand, we may maintain the transmission of an abstract or subjective spermatic force or principle, which may suffice for the impregnation of the ova. Considering that we do not know the essential principle of the seminal or spermatic fluid, and that we cannot argue against the existence of a subjective or abstract principle which may be transmitted from the objective and real elements, the theory of pure "parthenogenesis" on this ground has somewhat of a definite nature; although, at the same time, such a theory merely fits the facts as they stand, and leaves the exact nature of the phenomena still a matter of doubt.

But other authorities have denied that the ova produced by the virgin *Aphides* are true ova; and they have accord-

ingly been termed "pseudova" or "false ova," and have been regarded as internal "gemmæ" or "buds," the "pseudovum" uniting in some way or other the properties of an ovum and a bud. The process of "parthenogenesis" in this view, therefore, includes the "gemmative" process also; but the explanation so afforded does not coincide so perfectly with the facts of the case as the previous theory. The ideas implied in this latter process accord in some measure with the phenomena of "alternation of generations" or "metagenesis." The sexual insects, which give origin to the "virgin females," may thus be regarded as corresponding to the gonozoöid of the zoophyte with its asexual zoöids; whilst the ultimate origin from the virgin females of truly sexual forms will correspond to the production of the sexual gonozoöid—this latter once more giving origin to the asexual zoophytic-stock. The successive series of "virgin females," in this view, are produced by internal budding, just as the "gonozoöids" are produced by external gemmation and fission from the zoophyte, and as the sexual organs are in turn produced by internal gemmation from the "medusoid form."

Latterly these "virgin females" have been supposed to be hermaphrodite forms (Balbiani); that is, they are believed to be individually provided with male and female reproductive organs. If this view be correct—and further research seems necessary to confirm it—the whole subject is much simplified in its ordinary details; but the adoption or confirmation of this latter view leaves us to account for the regularly normal and periodical production of hermaphrodite offspring from "dicœcious" parents, and in turn of dicœcious progeny from "monœcious" parents.

In the case of the bees, the "drones" may be considered as having been produced "parthenogenetically" from the queen bee; since we have seen that the eggs from which drones are developed are invariably allowed to escape from the mother without being subjected to the influence of the male element. But the influence of food and situation may in other respects be more or less strongly determi-

native of sex, and of the corresponding development or retardation of the reproductive system. The queen bee, viewed after the modification of Steenstrup's theory, might be considered as possessed of the power both of true sexual and gemmiparous reproduction. Her ova may be considered as "buds," capable of development to form either asexual or imperfectly sexual beings, or to produce truly sexual individuals; these latter in turn again aiding to produce the characteristics of the being from which they were evolved.

Finally, some authorities have sought to point out and found a constant reproductive law, based on the fact remarked in the opening of the chapter, that the processes of nutrition and reproduction are antagonistic or opposed to each other. This law maintains 'that asexual modes of reproduction are merely forms of growth, and that the process, like that of typical nutrition, is an exhaustive process, culminating invariably in the production of the true sexual elements, by means of which latter the new individual is produced.' This law, applying chiefly to the lower forms of life, is simply a generalisation of the reproductive and nutritive cycles in the lower organisms. The growth of the zoophyte, for example, is rapid and continuous; active gemmation suffices for the constant repair of lost parts, and for the addition of new zoöids. Nutrition is performed in an equally active, and in every way admirable manner, by the countless tentacles and mouths of the "polypites," and by the incessant circulation through the connecting cœnosarc. But the nutritive cycle is not continuously perfect. It is broken in upon, and interrupted by the reproductive phase; and when the true sexual elements are produced, the vitality of the organism becomes as a rule impaired. Its functions in the world of being have been duly performed, and its life passes onwards through the rapidly succeeding stages of decline, and of ultimate extermination or death. So marvellously bound up together, and so harmoniously dependent upon each other, are these two chief functions of the living organism.