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Classification of Zoophytes
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Zoophyten

STRUCTURE AND CLASSIFICATION

OF

ZOOPHYTES.

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ZOOPHYTES.

BY

JAMES D. DANA, A.M.,

GEOLOGIST OF THE UNITED STATES EXPLORING EXPEDITION.

DURING THE YEARS

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PREFATORY REMARK.

The volume on Zoophytes, to which the following chapters form an introduction, includes descriptions of the species collected by the Exploring Expedition, together with a comprehensive review of this department of science. All recent zoophytes, excepting those of the groups Actinidæ, Hydroidea, and Bryozoa, are embraced in the work, with full descriptions and references to previous authorities. The whole number of Actinaria comprised is four hundred and eighty-three; and of these nearly half are for the first time distinguished and described. They are illustrated by an Atlas of sixty-one folio plates.

The volumes form a part of the series published, as the results of the Expedition under the command of Charles Wilkes, Esq., U. S. N., by authority of Congress.

James D. Dana.

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ZOOPHYTES.

CHAPTER I.

INTRODUCTION.

1. The forms of life, under consideration in the following pages, are appropriately styled *flower-animals.** In external figure, the individual animals closely resemble flowers, and no less so in brilliancy and variety of colouring. Moreover, a large number of zoophytes are so like the trees and shrubs of land vegetation, as to have deceived even the philosopher till near a century since.† The mosses and ferns of

* The word *zoophyte* is from the Greek ζωον, *animal*, and φυω, *to grow like a plant.* Blainville states that the term was introduced by Sextus Empiricus and by Isodore of Seville in the sixth century. It has been differently restricted in its use by authors, and, on account of its various applications, is wholly rejected by Lamarck. Although the species have little of the implied resemblance to vegetables in their internal structure, yet in external appearance, the compound forms as well as simple animals are so closely like plants and flowers, that we have deemed it best to retain the term. It is the popular designation, and is moreover used by some of the latest scientific writers on the subject.

Ehrenberg has proposed to substitute *phytozoa*, derived from the same roots. But the science requires a name that will apply to the whole compound structure,—the coral-tree, sea-fan, or mass of whatever shape;—and phytozoum refers only to a *single* polyp; or phytozoa, the plural, to *polyps in general.* These cannot supply the place of the very convenient terms zoophyte and zoophytes. Moreover, the term phytozoa (phytozoaires) —plant-animals—has been applied to the minute cellules—monad-like in their motions, and supposed to be animalcules or plant-entozoa—detected in the tissues or organs of some plants.

† All the early authors, till the commencement of the last century,—among whom are Dioscorides, Cæsalpin, Bauhin, Ray, Geoffroy, Tournefort, and Marsigli,—arranged corals

our woods—the lichen and mushroom—the clump of pinks—the twig and spreading shrub—have all their counterpart among the productions of the sea. The ocean-grove is without verdure, yet there is

along with marine plants; and the last-mentioned author was thought to have removed the only remaining doubt when he published to the world his discovery of the "*fleurs du corail*,"—the coral flowers,—since shown to be coral animals.[a] Peyssonel,[b] one of the first investigators that ventured to combat the prevalent opinion, was treated even with derision by the scientific men of the day; and the distinguished Reaumur gave a laboured reply to his essay, setting down the vegetable nature of zoophytes as too well ascertained to be made a subject of discussion. This took place so late as 1727. The subsequent discoveries of Trembley, in 1741, who published elaborate descriptions and figures of certain fresh-water polyps, with an accuracy of detail that has hardly been exceeded, opened anew the dispute on this subject, and Jussieu and Guettard undertook investigations in order to settle the point at issue. The coasts of France were searched, and several species of zoophytes found and figured. Reaumur was not slow to change his ground, and, in an able memoir, he reviewed the investigations of Peyssonel and Jussieu; and, with slight modifications, advocated their views. Yet, in general, philosophers were still incredulous. Dr. Parsons, in 1752, took the palm from Peyssonel before the Royal Society, and again it was believed, on grounds that were deemed satisfactory—Dr. Parsons's limited conceptions and not direct investigation—that corals were plants; for, says Dr. Parsons, "It would seem to me much more difficult to conceive that so fine an arrangement of parts, such masses as these bodies consist of, and such regular ramifications in some, and such well-contrived organs to serve for vegetation in others, should be the operations of poor, helpless, jelly-like animals, rather than the work of more sure vegetation, which carries on the growth of the tallest and largest trees with the same natural ease and influence as the minutest plant."[c]

Ellis appeared soon after, and by his accurate figures and descriptions of corals and coral animals, presented with philosophical minuteness and precision, the scientific world were arrested in their judgment. The mineral theory of Boccone[d] and Guison, and the crystallization theory of Baker,[e] were checked in their progress, and the vegetable theory at the same time began to lose its popularity.

Linnæus, then the umpire in science, received the new opinions cautiously. He was unwilling to adopt at once the views of Ellis, and finally satisfied himself, or his fancy, with the theory that zoophytes were intermediate in their nature between plants and animals, possessing the functions of animal and vegetable life combined. Excepting the

[a] Marsigli, Physique de la Mer, Amsterdam, 1725. Marsigli's first observations were made in 1706.

[b] Peyssonel was anticipated only by Ferrante Imperato, who published a "*Historia Naturale*," at Naples, in 1599. See Blainville, Man. d'Act., p. 14.

[c] Peyssonel's Memoir covers 400 pages of manuscript, and was the result of a long series of observations in the West Indies. It was sent to the Royal Society in 1751, and an abstract of it was read, which appeared in the Transactions, for 1753 (vol. x. of Abridgment). The Memoir is still extant in the Library of the Museum, at Paris, and a late notice of it by M. Flourens may be found in the Annales des Sciences Naturelles, ix. 334, 2d Ser., 1838. Dr. J. Parsons's reply to Peyssonel followed soon after the communication of his discoveries, in 1752.

[d] P. Boccone, *Museo di Fisica*, &c., Venice, 1694, 1 vol., 4to., with figures.

[e] *Employment for the Microscope*, pp. 218–220. London, 1753.

full compensation in its perpetual bloom; for each coral branch is every where covered with its star-shaped animals, the "coral-blossoms."

Although the external resemblance to objects of the vegetable kingdom is so striking, there is little similarity in actual structure. Each of these flower-animals has a mouth, and a cavity to receive and digest food; and the appendages that look like petals are organs fitted either for securing their prey or for some other animal function. Some species have actually been fed, and the process of digestion watched by the naturalist. They are not always invisible animalcules, as has been the common impression; on the contrary, many of the most common varieties are half an inch in diameter, while others are one, two, or three inches, and still others are a foot to eighteen inches. Neither have they "the consistence of jelly," for the texture is usually more like flesh, and the exterior is sometimes quite firm and even leathery.

2. The growth of coral has been considered one of the mysteries in science, and so few years have elapsed since the facts were first made known, that it remains to the many a mystery still. How the tree of stone grows and spreads its branches—what its connexion with the coral polyps which blossom over its surface, and whence the lime that constitutes it, are points which have been but lately explained; and there is still room for additional and corrected information. In

earlier publications of Dr. Job Baster, of Zurichsee, in Zealand, exhibiting singular ignorance of the subject discussed, and inaccuracy in facts, the complete animality of corals has been since admitted without opposition.[a]

The sponges have often been improperly classed with corals. There is still doubt as to their animality. The latest investigations seem to establish their vegetable nature.[b]

[a] A more extended history of this science in our own language may be found in Johnston's British Zoophytes, 8vo., Edinburgh, 1838; a work distinguished for its literary as well as scientific excellence: also, in French in Blainville's Man. d'Actinologie, 1834.

[b] Of recent authors, Grant, Audouin, Milne Edwards, Bowerbank, Dujardin, and Laurent, consider sponges as animal; while Link, Blumenbach, Owen, Hogg, and G. Johnston, have inclined to place them in the vegetable kingdom. See Grant, Edinb. Phil. Jour. xiii. xiv.; Dujardin, Ann. des Sci. Nat. x. 5, 2d ser. 1838, in which he endeavours to show, by minute microscopic research, that they are compound infusoria; Laurent, on the Spongillæ, L'Institut, 1840, pp. 223, 231, 240, and the Microscop. Jour. i. 78, who describes the reproductive organs of the supposed animals; Hogg, on the Spongilla, Linn. Trans. xviii. 390, who sums up the results of his laboured investigations in the following language,—"They have no tentacles, no cilia, no mouth, no œsophagus, no stomach or gastric sac, no gizzard, no alimentary canal, no intestine, no anus, no ovaria, no ova, no muscles or muscular fibres, no nerves or ganglia, no irritability or powers of contraction and dilatation, no palpitation, and no sensation whatever. Surely, then, we cannot any longer esteem these natural substances to be individual animals, or even groups of animals, in which not one organ, or a single function or property peculiar to an animal can be detected."

treating of these subjects, we shall dwell with some minuteness on the structure of coral animals—their habits and modes of growth and developement; and it will be our aim to give such simple explanations as will be intelligible to the general reader, although it may require the stating of some principles well known to those versed in science.

The mind should be disabused of the idea that all polyps form coral. There are many species identical in general structure with coral animals by which no coral is secreted. Among these, are the Actiniæ,—common on some parts of our own coasts,—many of which are richly coloured and occasionally measure several inches in diameter, as is well shown by the drawings of Mr. Drayton on the first five plates of the Atlas. Other species contain scattered granules of lime. Thus there is a gradual passage up to the coral-making species, whose secretions form a solid framework to the animal.

Another simple fact should be here understood. On examining any piece of coral, the surface is found to be covered either with prominent cells, or concave depressions; hundreds, perhaps, to a single branch. Each of these cells marks the position of a polyp, and counting them we may ascertain the number of flower-animals that together constructed the branch. But this compound structure is not universal. Some coral-polyps are single animals, each a separate individual like the soft Actinia; and this is apparent in the coral, for it presents but a single cell or depression. From the solitary polyp. there are all possible varieties among zoophytes, up to living masses, in which hundreds of thousands are congregated, all the progeny of a single germ.

Coral is above called the framework of the polyp. It is not a collection of cells in which polyps may conceal themselves, though so stated till a recent date. On the contrary, the coral is generally concealed within the polyp or polyps, and is literally an internal framework, having many analogies to a skeleton.

With these few introductory explanations, we may enter upon the subject before us—the Structure, Habits, Classification, and Description of Zoophytes.

CHAPTER II.

GENERAL STRUCTURE OF ZOOPHYTES.

3. The term *zoophyte* is applied to the whole animal structure, whether a single animal, or consisting of a large number of animals, as in most corals; while the several individuals are called *polyps*.

In view of their general radiated structure,—the arrangement of the tentacles around a disk as a centre, and a corresponding circular structure within,*—these animals are placed in the Fourth grand division of the Animal Kingdom—the Radiata. The distinguishing characteristics of the simple polyp, are as follows:

An inarticulate fleshy body, nearly cylindrical, having a circular or elliptical summit called the disk, bordered by one or more series of tentacles, and an opening or mouth at the centre of the disk; internally, a visceral cavity closed below, no distinct vascular system, an imperfect nervous system or none, and no senses but those of taste and touch. The body, and, in most instances, the tentacles also are expanded by means of water, which is ejected on contraction.

Polyps are thus among the simplest of animals, being even less complex in structure than the minuter Rotifers. A simple visceral cavity, and a single opening to it placed at the centre above, with traces of a radiated structure around it, are the only essential points; for even the tentacles are sometimes wanting. They have no intestine, no glands to aid in digestion, separate from the general walls of the internal cavity,—no system of vessels in any part for circulation, —an imperfect nervous system, if any,—no distinction of sex,—and no senses but those of taste and touch, with the latter of which the former may properly be included. Moreover they are mostly dependent on the fluid in which they live for the means of expanding their tenta-

* Some of these animals are represented in figures 1, 6, and 12 beyond, and numerous species are given in the Atlas.

cles, and distending the body for the reception of food. A few have powers of locomotion; but they are commonly attached by their lower surface or extremity to the rocks or some other support, where they live on such chance-bits as are thrown in their way.

4. The internal cavity, which we here style the *visceral cavity*, occupies the whole interior of the polyp. In some minute species (Hydræ) it is a mere tubular sac, so simple in its nature, that the animal may be turned inside out, and still eat, digest, and perform all the functions of life as before. In other species it is divided vertically by thin fleshy lamellæ growing from the sides, and the mouth opens first into a cylindrical organ, called the stomach, and thence into the general internal or visceral cavity. Within this cavity the water is received, by which the polyp distends by injection its body and tentacles; here also the animal fluids are aerated by air taken up from the imbibed water; and in the walls of the same cavity, or the fleshy lamellæ when these exist, the germs or ovules are produced. In the lowest grade of these animals, the Hydra, we have then the simplest form of an internal cavity, so complex in many other animals; and in the fleshy lamellæ possessing germinal functions, that proceed in the higher grades from its walls, we see represented the system of glands and the viscera generally, which have an analogous connexion, where present, with the walls of the internal cavity of the body.

5. The mouth is a simple opening through the fleshy disk; and as there are no organs for trituration, the process of digestion consists in the unaided action of the gastric fluid, or what corresponds thereto in these animals. The refuse is ejected through the mouth after digestion, this being the only opening to the internal cavity. What may be the separate functions of the stomach and visceral cavity in the process of digestion is not definitely known; but it is probable that the appropriation of the chyle to the nourishment of the polyp takes place through the latter, and the lacunal passages or openings communicating with it.

6. The existence of nerves, or at least of something acting the part of nervous matter, is necessary, in order that these animals should possess the sense of touch; but examinations hitherto have detected no centre of nervous action and no distinct nervous cords.* The sensibilities of polyps are feeble, and their movements slow.

* It has been stated that in the Actinia a nervous thread may be traced around the mouth, which sends fibrils into the tentacles. This requires farther confirmation.

7. Reproduction takes place both by means of *ovules* and *buds*.

The *ovules* form as above stated, and either pullulate from the sides of the animal, or find exit through the mouth. Soon after ejection (and sometimes before), each ovule produces a young polyp, which swims free for a while, and then, with few exceptions, attaches itself to some support, where, in very many species, it passes the rest of its existence.

The mode of *budding*, bears some analogy with the budding of leaves or flowers from a plant. In many instances, the bud first appears as a slight swelling on the side of a polyp; after enlarging for awhile, a new polyp is finally developed, with tentacles and visceral cavity complete; this cavity is sometimes continuous with that of the parent; at others, it becomes separated at base, and, at others, still, the whole young polyp becomes entirely detached from the parent. There is some variety in this mode of reproduction which will be noticed when treating separately of the different orders of zoophytes.

Buds open from different parts of polyps, either laterally from the base, the sides above, just exterior to the tentacles, or from the disk. Disk-buds, though similar to the others, in principle, are peculiar in the changes they produce and the appearances presented. For since the disk covers the top of the visceral cavity, the new bud which opens, shares in this cavity with the parent, and the two become separate only by gradual growth upward. It appears like a spontaneous subdivision of a polyp, and is so in the result, though quite different from the spontaneous fission of a monad (§§ 77–79).

Besides these modes of increase, polyps may be multiplied from sections artificially made. Some species may be cut into a dozen or more parts, and will make as many perfect polyps, each part possessing within itself the power of reconstructing a complete animal. A wound on the side of some budding species (Hydras), instead of being an injury, only opens the way for a cluster of new polyps which soon after sprout from the spot.

There are thus the following different modes of reproduction:—

I. Oviparous.—1. By ovules proceeding outward from the side of the polyps, singly or in clusters.

2. By ovules formed from vertical lamellæ in the visceral cavity, and ejected through the mouth. The *viviparous* is but an accident in the oviparous mode; the eggs within develope in the same

manner as externally, and for like reasons, as the external waters have free admission.

II. Gemmiparous.—1. By single buds, developing young, which afterwards become free and independent animals.

2. By buds, which become developed and remain persistent,—and these may be either lateral or terminal.

III. By Artificial Sections.

This mode may depend on the same cause as the general distribution of the *budding* function, and may be properly an analogous process, — both depending on the imperfect character of the nervous system, or its absence.

These modes of reproduction, as they are presented by the different tribes of zoophytes, will be farther explained in the following pages.

8. *Compound Zoophytes.* It has been stated that zoophytes are either simple or compound, the simple being a solitary animal, with a single mouth and its visceral cavity; the *compound*, a cluster, presenting as many mouths externally as there are polyps combined, and within, as many visceral cavities. This compound structure proceeds from the capability, above explained, of increasing by buds; for every coral, however large and numerous the colony, commenced from a single polyp. In some species the bud grows out as a distinct branch from the side of the parent, and branch is thus added to branch by successive buddings from the forming polyps. In other cases, the young continues attached by one side to the parent, instead of forming a prominent shoot, and only their upper extremities appear separate. Large zoophytes are thus formed, consisting of myriads of polyps united to one another by the tissues that surround the visceral cavity of each.

The several polyps in a compound zoophyte eat and digest separately, and generally carry on as individuals the processes of reproduction and aëration; yet all aid in the growth of the common mass, though each contributes more especially to its own nutriment and the part immediately adjoining. Although their visceral cavities are distinct, there are numerous communications between those of adjoining polyps, and the fluids may pass more or less freely from one to the other. An injury to one part of a zoophyte is felt by the polyps some distance around, but not always through the whole mass. On pressing the tip of a branch of a large Alcyonium, in the Feejees, there was an immediate contraction of every polyp through the whole zoophyte, although extending to a breadth of four feet.

9. *Secretion of the Corallum.** Coral secretions take place either from the interior tissues of the polyps, or from the foot or base, and in a few species only, in the exterior cuticle. The corallum in the live zoophyte is therefore in general wholly concealed within the polyps, and is in no part external.

No peculiarities of structure, external or internal, have been observed distinguishing the coral-secreting polyps from those which do not secrete coral. Animals of both kinds belong to the same family, and hence this peculiarity affords at the highest only a generic distinction† (§ 109).

* Coral has been variously designated in both ancient and modern times. The terms *Corallium*, *Corallum*, and *Curalium*, were all used by the ancients, and their derivations and use are discussed at length by Theophrastus in his work on plants, Book iv. Κουραλιον is the ancient Greek form, as says Dionysius, "*πάντη γαρ λιθος εςιν ερυθρου κουραλιοιο*."—The more recent Greeks, among whom are Dioscorides and Hesychius, wrote the word κοραλλιον. Among the Latins, Ovid says, "Sic et *Curalium*, quo primum contigit auras tempore durescit." Avienus uses Corallum: "Fulvo tamen invenire *Corallo*, quærere vivendi commercica." Among the derivations suggested, that of κορη, damsel, and αλς, sea, appears the most probable.

The word *Corallium* has been in most general use; but as it is now the name of a particular genus, it has of late been rejected for *polypifer*, *polypary*, and *polypidom*, signifying *polyp-bearer*, or a *hive* or *house of polyps*. These terms are all objectionable, for the reason that the polyps contain the coral, instead of the coral containing the polyps. On this ground neither of them has been adopted here, but instead the old word *Corallum*, which is sufficiently distinct from the name of the genus Corallium.

We have then the term *Zoophyte* for the whole polyp mass, whether simple or compound, coral-making or not; the term *polyp* for the individual animals; and *Corallum* for the framework or skeleton secreted by polyps. To express the fact that certain polyps secrete a corallum, we use the expression *coral-forming* or *coralligenous*. The animals of a coral zoophyte are *coral-animals* or *coral-polyps*.

† The definition of Zoophytes excludes the Flustroid tribe of polyps, called *Bryozoa* by Ehrenberg.[a] The peculiarities of these animals were first pointed out by Milne Edwards and Audouin,[b] who showed that in place of the simple digestive sac of the Sertularidæ, to which they had been thought allied, they have a regular stomach, and an intestine which curves upon itself and terminates in the disk; and besides, their arms or

[a] Berlin Trans., 1832.—The name *Bryozoa* is derived from *βρυον*, *moss*, and *ζωον*, *animal*. The other zoophytes Ehrenberg calls *Anthozoa*, meaning *flower-animal*,—excepting the Sertularidæ and the allied species, which he subsequently named *Dimorphæa*.

[b] Annales des Sci. Nat. xv. 1828.—Edwards and Audouin here point out the relations of these animals to the Ascidiæ.

10. *General Divisions of Zoophytes.* Zoophytes constitute naturally two distinct groups, differing in mode of reproduction and in internal structure. The visceral cavity in some of them is, as described, a simple tubular sac. In others, it is divided vertically by fleshy lamellæ, proceeding from the walls and forming a radiate series around the cavity. Connected with these peculiarities, we observe striking differences in the mode of ejecting the ovules. When there are lamellæ in the cavity, the ovules are formed by them, and appear in clusters attached to the margin, from which they are finally detached, and make their escape out of the mouth. But when there are no lamellæ, the ovules are produced in the walls of the visceral cavity, and make their readiest escape outward through the sides of the polyp, instead of the more indirect route, into the visceral cavity and out of the mouth.

The following are the divisions based on the characters mentioned:*

Order Hydroidea.

Visceral cavity, a simple tubular sac; reproductive functions residing only in the walls of the cavity; young or ovules pullulating from the sides of the parent.

Order Actinoidea.

Visceral cavity, divided vertically by fleshy lamellæ, which possess reproductive functions; ovules formed within the cavity from some of the lamellæ and ejected through the mouth.

The polyps of the order Hydroidea are mostly minute, and the coralla, when any are formed, are either horny or membranous; they are very delicate, and, when compound, usually consist of minute calicles† (or little cups), arranged in series along a tubular axis.

tentacles are furnished with vibratile cilia. Excepting their calcareous secretions and mode of budding, they are widely removed from true zoophytes. (See farther §§ 106–8.)

The definition also excludes sponges, as already intimated, which, excepting the most general attribute of animal matter (if they are animals), possess nothing in common with the polyp. No single character, except their forms, has ever been pointed out which indicates a relationship.

* The names below have the following derivations:—*Hydroidea* is from the included genus *Hydra*, and *Actinoidea* from the included genus *Actinia*. This last name (from ακτιν, *ray of the sun*,) alludes to the radiated character of the animals.

† The term *calicle* (from caliculus, *a little cup*,) is used for the prominences which contain the cells in many corals; and *cell* is restricted to the cavity itself. By *cellule*, as hereafter used, the minute pores of the corallum will be referred to.

From each cup the extremity of a polyp protrudes itself with its coronet of slender tentacles.

The ACTINOIDEA, which comprise all the common coral-forming species together with the tribe of Actinias, include polyps of various sizes, from the microscopic point to a diameter of eighteen inches. The presence of internal reproductive lamellæ, and the fact of their ejecting the ovules by the mouth, separate them widely from the Hydroidea. The tentacles are in one or more series, or scattered. The coralla may be either calcareous or horny; but the calicles, when any exist, are always calcareous.

In the remarks which follow, I shall be brief with the first order, as my own observations can contribute little to what is already known. Some general account of these animals is required in this place, to serve for comparison with the Actinoidea, on which I shall dwell more at length.

CHAPTER III.

HYDROIDEA.

11. The Hydroidea are minute polyps, of extreme simplicity of structure and delicacy of form. Though sometimes single animals, swimming at large, like the Hydra, they usually constitute compound zoophytes, hundreds and often thousands to a cluster. Some, as in

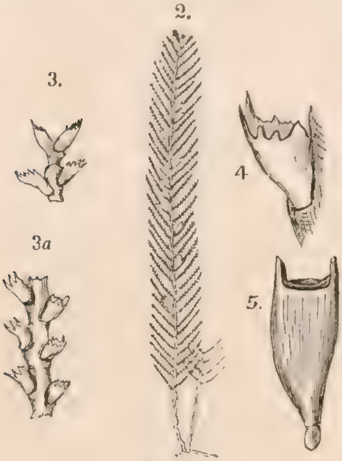
Fig. 1.

the annexed figures,* grow in crowded tufts of thread-like stems; many are much branched, and each branch is tipped with a star of

* These figures are by J. P. Couthouy, and represent a Tubularia from Rio de Janeiro, which he designates T. ornata. Figure 1 shows the natural size of the animals.

tentacles (fig. 6). In the greater part of the species, minute calicles, or little cups, but indistinctly visible to the naked eye, are arranged in one or more series along the branchlets, and the cluster is a neat imitation of the most delicate plumes (fig. 2), trailing vines, or mossy tufts; and, when alive, every calicle is the site of a polyp-flower. They are occasionally but a few lines high; yet others, no less minute in their cells and polyps, attain a length of several feet. Quite a variety of species may be gathered along our sea-shores, upon sea-weeds, shells, or the rocks of the coast; and Hydras are common among the duck-weed in almost any stagnant waters.

12. The species are sometimes fleshy throughout, forming no *cells* or *corallum*; but, in general, the zoophytes have a very delicate corneous or cartilaginous exterior, nearly or quite transparent, and the same kind of horny membrane constitutes the calicle. In the Hydroidea, having sessile calicles along the branches, faint joint-like divisions may be distinguished in the stem, yet without a moveable articulation. The corallum is commonly considered the hardened cuticle. But other observers, among whom is Dr. Fleming, make it an inner tissue secretion; and, if so, it corresponds to the coral secretions of other zoophytes.



Sertularia.

The *calicle* is usually an open cup, or short tube, generally with a slight constriction or an imperfect cross partition at base, partially separating it from the stem below. They appear to the naked eye like mere points, edging the branchlets (fig. 1); but, when enlarged, the cup-form is brought out, as is shown in the annexed figures, 2, 3, 3*a*, and 4. Though sometimes toothed, the edge of the calicles is generally entire, as in figures 9, 10, 11, on a following page. Each contains the stomach and upper part of a polyp; and, when unexpanded, the circlet of tentacles is here withdrawn and concealed. The calicles are arranged on one or more sides of the branch, and are either opposite or alternate, though generally the latter.

13. The tentacles are mostly slender tubular organs, arranged, in a single series, around a small disk containing the mouth, and the mouth, or the centre of the disk, is sometimes quite prominent, as is

represented in figure 6. The circle of tentacles is commonly symmetrical, yet is sometimes oblique. In the Tubularia group, the tentacles are often short and sluggish, and are in one or more series, or irregularly scattered. The disk is prolonged into a high cone, as in figure 1*a*, and is tipped with a row of oral tentacles immediately about the mouth opening. The tentacles of the Tubulariæ and Campanularidæ, are described as differing from those of the Sertularidæ and Hydræ, in not being properly tubular organs.

The stems and branches of these zoophytes are tubular; and the stomachs of all the several polyps—which are simple cavities directly beneath the mouth—communicate more or less freely with one another through this common tubular axis, which ramifies from the main stem into all the branchlets. Thus the polyps of a cluster are united, not only by their external envelope, but also through this internal communication. The annexed figure exhibits this character in one of the Campanularidæ from the Feejee Islands; and the same is seen in the other compound Hydroidea.

Fig. 6.

The axis is described by some as pulpy or medullary. In the author's examinations of one of the Sertularidæ (fig. 9), a vibrating motion of the contents of the tubular axis was distinctly observed, and the pulp, which had a greenish tint, appeared to have been derived in part at least from the digested food of the stomach. The investigations of J. J. Lister,* since seen, confirm this opinion. The pulpy fluid was found by this able observer to vibrate occasionally

* J. J. Lister, Philosophical Transactions, 1834, p. 369, with fine illustrations on plates ix. and x.

We quote the following from his very interesting observations. The current "flowed in one channel, alternately backwards and forwards, through the main stem and lateral branches of a plume, and through the root, as far as the opacity admitted of its being traced; sometimes it was seen to continue into the cells. The stream was throughout in one direction at one time; it might be compared to the running of sand in an hour-glass, and was sometimes so rapid in mid-tide that the particles were hardly distinguishable; but it became much slower when near the change. Sometimes it returned almost without a pause; but at other times it was quiet for awhile, or the particles took a confused whirling motion for a few seconds; the current afterwards appearing to set the stronger for the suspension." "Five ebbs and five flows occupied fifteen minutes and a half; the same average time being spent in the ebb as in the flow." Lister states that the vibrating motion of the internal axial fluids were first observed by Cavolini, and are described in his *Memorie per servire alla Storia de' Polipi Marini*, published at Naples, in 1785.

into the stomach. It appears then that this is the means by which the results of digestion, or the nutrient juices, are distributed through the zoophyte; and that the sides of the visceral cavity have throughout the power of appropriating these chyloid fluids, thus kept in circulation. There appears to be no system of circulation independent of this chyle distribution.

In certain filiform species (the Tubulariæ, fig. 1), Lister distinguished a similar motion in the pulpy fluids of the axis, except that, instead of vibrating, it was circulatory, part of the fluids moving up and part descending by a simultaneous action. They often passed into the stomach, and were continuous in their motions with the movements of this organ. It appears therefore that the tubular axis of these species corresponds with the visceral cavity in the higher zoophytes.

The visceral cavity in the Hydroidea differs widely from the same in the Actinoidea, in the absence of vertical fleshy lamellæ around the sides. Rudiments of these lamellæ appear however to have been detected by Lister in a Tubularia. It is due to this simplicity of structure that the Hydra will live and eat when turned inside out.

The food of these animals consists of minute animalcules or worms, or whatever of animal life is sufficiently small to become their prey. The prey is secured usually by means of the tentacles, which entwine around it, or together enclose it, and convey it to the mouth.

14. *Reproduction* takes place either (1) by ovules proceeding out from the sides of the polyps; (2) by lateral buds developing young, which, on arriving at maturity, separate from the parent; (3) by lateral buds which are persistent; (4) by artificial sections.

The ovules appear either single or in naked branched clusters; or, clustered and enveloped within a common receptacle or ovarian vesicle. The figure heading this chapter (1*b*) represents a branched cluster as they sometimes appear in the Tubulariæ. Single ovules also are presented by many species of this family: they characterize moreover the Hydræ.

The ovarian vesicles, in which a number of ovules are enclosed under a common envelope, belong to the Sertularia and Campanularia families. Some of these vesicles are represented in the following figures, and others in figure 2, or enlarged in figure 5. They gradually develope from the side of a branch, or at times from a creeping root-like shoot, which grows outward, like the creeper of a plant, sending up its buds and flowers at intervals (fig. 8). The ovules may be early distinguished within them, and are often arranged along a central axis, each communicating, according to Lister, with the common axis of the zoophyte.* My associate, Dr. Charles Pickering, first pointed out to me, while at sea, in 1838, that a close analogy subsists between the arrangement of the ovules in a vesicle and a contracted branchlet of the zoophyte.† The same subject has been thoroughly investigated by Professor E. Forbes, and the fact of this arrangement fully ascertained.‡ In consequence of the communication with the axial cavity of the zoophyte, the pulpy chyloid fluid of the main stem and branches is carried into the vesicle and to each ovule, and the developement of the whole promoted. On arriving at maturity, the ovules pass out in succession from the sac, which, now empty, falls off. They are carried about for awhile by means of their vibratile cilia, and then—perhaps in two or three days—they affix themselves. Each now grows and buds, till shortly "a whole grove of Corallines" is formed.

Fig. 7. 7a

Plumularia.

Fig. 8.

Sertularia.

According to Van Beneden, the Campanularidæ, when first developed from the ovule, are like minute Medusæ in shape, and have eight eyes, which are lost as the animal attaches itself. In this state, it has no vibratile cilia.§ This same author has very minutely investigated the Tubularidæ, and finds in them the same mode of developement, and eight eyes to the medusa-shaped young, at the base of the tentacles. Dalyell seems to have observed similar facts. He states that the ovules, which in this group are collected about the bases of the tentacles, drop from their attachment for evolution below. Slight prominences soon denote incipient tentacles; next the nascent animal reversing itself, enjoys the faculty of progression by means of the inverted tentacula, as on so many feet, apparently to select a site; when again resuming the natural direction, with the extremities upwards, the lower surface fixes itself below and roots there for ever.‖

* J. J. Lister, Phil. Trans., 1834, pp. 365–388, pl. ix. and x.

† Figures 7 and 8 are by Dr. Pickering; they were drawn from gulf-weed species, in September of 1838, at the time the above-mentioned observation was made.

‡ Proceedings of the British Association, for 1844.

§ Van Beneden, Mém. sur les Campanulaires, &c. Brussels, 1844.

‖ Rep. Brit. Assoc., for 1834, p. 600.

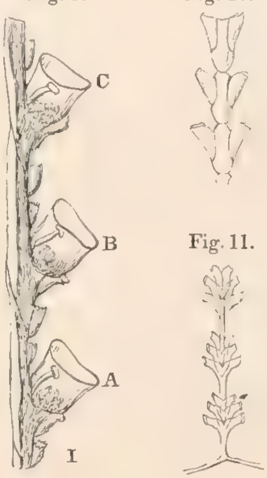
The vesicle of ovules in the Sertularidæ may generally be traced to a particular polyp, from which it is developed; in other instances, it so grows from the stem, that it seems rather to belong to the colony than to any distinct animal in it. The connexion between the polyps through the tubular cavity is such, that individuality cannot always be distinguished.

15. The pullulation of young from the sides of a parent is the usual mode of reproduction with the Hydra, though at certain seasons simple ovules are produced. A minute protuberance first begins to rise on the surface; it lengthens and becomes a rudimentary branchlet, with a tubular axis connecting with the tubular cavity of the parent; shortly one or more tentacles begin to appear at the summit of the forming branchlet, and soon the number is completed, and the young polyp is perfected. It remains for a while attached; but when matured, the young leaves the parent to swim at large and give birth to other young. They breed rapidly, and frequently new shoots commence before the animal is detached from the parent; and occasionally sprout on sprout is thus added, till a small compound group is formed. These animals also bud out tentacles without previous tubercles, which finally become complete animals.

16. Very similar to the above, in general principle, is the formation of *persistent buds*, by the successive production of which the branching zoophyte finally results. There is at first a protuberance in which the chyloid fluids gain access, and either move by vibration, or have a kind of *circulation* up along the sides and down the axis; after a while the calicle forms, and the polyp extends its arms, and begins its contributions to the body-coralline. The first polyp with which the zoophyte commences thus gives out a bud, and this another; and so a succession is formed, and the little stem is gradually lengthened; branchlets grow out, and the plume or miniature tree (fig. 2) is finally completed. The whole may be the work of a few weeks, or months, though they usually continue budding and growing for some years. Before the zoophyte has reached its limits in size, the number of polyps sometimes becomes immensely large. In a single specimen of Plumularia (P. angulosa), collected by the author in the East Indies, there are about twelve thousand polyps to each plumose branch; and, as the whole zoophyte, three feet long, bears these plumes, on an average, every half inch, on opposite sides, the whole number of polyps is not short of eight millions; all the offspring of a single germ, and produced by successive buddings.

But to understand better this process, we may refer to one or two enlarged figures of species. Figures 3, 3*a*, 9, 10, and 11, represent the principal varieties among the Sertularidæ. In figure 9, there is a single range of calicles on the stem, the polyps of which are connected with the tubular cavity within. The polyp C is a bud from B, and B from A. We perceive from the figure that the first step here in the budding process, is a lengthening upward of the tubular axis, from the polyp below: after elongating to a certain distance, the bud commences to form, and finally, from the side of the ascending shoot, the new polyp B starts out. The main trunk continues elongating, and, after a similar interval, another bud forms in like manner. The same process is illustrated in figures 3 and 10; the only difference consists in the formation of two buds on opposite sides of the axis, almost simultaneously. Figure 3 represents the apex of a branch, with the two buds, developed at the extremity of the tubular axis, and, in figure 10, the tubular axis is elongated between the buds, preparatory to a continuation of the budding process. Although nearly opposite, the polyps often become alternate afterward, as is seen in figure 3*a*, which represents a lower part of a branchlet. Moreover, the apparent jointing above, often becomes afterwards quite indistinct. In figure 11, we have an example of a periodicity in the budding process.

Fig. 9. Fig. 10. Fig. 11.



The formation of the young Hydra seems at first to be a very different process from the budding of a Sertularia, yet is closely analogous: the only essential peculiarity consists in the young polyp's detaching itself and becoming free instead of being persistent. The apparent discrepancies are owing to the absence of calicles or a corallum, and the *erect* mode of growth in the parent, instead of *oblique;* in the Hydra the buds form as lateral shoots from any part of the lateral surface; while in the species above explained, with oblique polyps, the upper part of one side of the visceral cavity gradually lengthens and buds. Some little variety in the budding process is exhibited in other groups among the Hydroidea; but the above will suffice to explain the general principles. The subject of reproduction will be discussed more at length under the *Actinoidea*.

17. Reproduction by artificial sections may require a few words in this place, as it is one of the most remarkable characters of polyps, and is strikingly exhibited in the Hydra, as was long since shown by Trembley in a series of investigations pursued with wonderful skill and perseverance.* They were cut into halves, and soon each was a perfect Hydra; one was divided into three parts, and in three or four days in summer, the tail had produced a head, the head a tail, and the middle part a head at one end and a tail at the other: and even before completion they sometimes gave out buds. From forty parts as many Hydras were soon formed. The body slit open soon reunites, even if previously laid out flat like a membrane; and new tentacles in a short time replace those that may be cut off. Two polyps may be made to change heads, for one may be engrafted on the body of another; and if the tail of a polyp is put into the mouth of another, they unite — heads and tails. It might be somewhat puzzling to decide the question of personal identity among such animals. Every portion of the animal,—unless we except the tentacles, which failed to reproduce a polyp in the hands of Trembley and Baker,—is capable of forming a perfect Hydra. And this is a consequence of the fact that there is no general nervous centre, but each part contains a complete system in itself. No distinct nerves have hitherto been distinguished.

18. Connected with the process of growth and reproduction, there is a corresponding process of dying often going on in the older parts of a zoophyte: the polyps disappear, and the lower branches often drop off, leaving the trunk in this part bare. These zoophytes are thus dying and budding in different parts at the same time. In the large species, the main stem or midrib of the zoophyte becomes lifeless, or a mere support for the numerous lateral plumes or branchlets.

Besides this mode of limiting the existence of these polyps, some Hydroidea are said to be absorbed in their cells, and after a while to reappear again; and this has been observed to take place at nearly regular intervals. All the polyp cells of a living group have been found, after a certain period, empty, or with only the remains of the

* A. Trembley, on Freshwater Polyps, 1 vol. 4to., Leyden, 1744; and Phil. Trans., vol. viii. of the Abridgment, 1742.—See also Baker's Natural History of the Polype, 8vo. London, 1743.

wasted polyps, the fluid of the trunk showing the only evidence of vitality by its continued vibration. And in the course of a few days other polyps have appeared in the vacated cells, with the same perfection of form and the same activity and life as their predecessors. The polyp heads, as Dalyell states respecting a Tubularia, sometimes seem to drop off like a deciduous flower, and again, after ten days or more, are reproduced. Harvey observes, that after he had kept his specimens two days, they began to look unhealthy; and on the third "the heads were all thrown off, and lay on the bottom of the vessel." After another three days, changing the water in the mean time, the polyps were entirely renewed, with no essential difference, except absence of colour. The cold of winter is said sometimes to strip a corallum of its polyps, which remains thus apparently dead till spring, when it is warmed anew to life, and the polyp-flowers once more appear.*

In conclusion, the Hydroidea are animals with no *external* organs but tentacles and a mouth, and no *internal*, but a simple stomach cavity and its prolongation below in the form of a tube or tubular axis. *Without any special glandular system, and but a single opening to the alimentary cavity*,—the food is digested by the gastric fluid of the stomach, and the refuse matter ejected by the mouth. *Without a special absorbent or a circulating system or branchiæ*,—the digested material of the stomach passes downward into the tubular axis, where it has a vibratory or cyclosis movement; and here it is farther elaborated by the action of air from the admitted water, and becomes absorbed and assimilated by the surface of the cavity, or of the tubular organs, cavities, or pores, connected with it—these chyloid fluids acting in place of a proper circulating fluid; aeration of the same also takes place through the tentacles and the exterior surface of the animal, which receive air from the waters about them. *Without ovarian glands*, almost any part of the polyp possesses the reproductive function, excepting the tentacles; and buds or ovules are formed, and pass out directly from the sides of the animal. *Without a distinct nervous system*, in addition to the above negative characters, every part seems equally a centre of organic forces (unless we except the tentacles), and consequently sections made almost indefinitely still live and complete the entire polyp again.

* J. G. Dalyell, Edinb. New Phil. Journ. xvii. 411; Harvey, Proceed. Zool. Soc. No. 41, p. 55; Lister, Phil. Trans. 1834, 374, 376.

CHAPTER IV.

ORDER ACTINOIDEA.

19. THE minute zoophytes, hitherto considered, constitute, along with corallines, the mosses of the coral landscape; while the Actinoidea are the larger plants and shrubs. Among the species of this group, the solitary Actinias, from their size, form, and frequently brilliant colouring, may be called the Asters, Carnations, and Anemonies,* of the sub-marine garden. The Tubipores and Alcyonia form literally its pink-beds. Here and there the scene is decorated with clusters of tinted twigs or rushes, sometimes, fancifully shaped into fans and coral network; these are the Melitæas and Gorgoniæ. The Madrepores are crowded around in turfy clumps and miniature trees in bloom, or imitate spreading leaves and gracefully-shaped vases filled with flowers; while Astreas build up, among the shrubbery, large domes, embellished with green and purple blossoms studding the surface like gems.

Words, however extravagant they may appear, convey no exaggerated impression; for Fancy's work could not be more strangely beautiful. While wondering at the grandeur of the results proceeding from means so small, the ocean-island reared by coral polyps, we are also led to contemplate and adore the wisdom and goodness of Him who createth, in mingling such beauty in all his works.

Among the animals which produce these varied results, we find a great uniformity of structure, as already exhibited in the few general remarks on the Actinoidea (§ 3). The common Actinia is a type of a large class of them, and we may commence our observations on the Actinoid polyps by a concise account of the structure and habits of these animals. This will lead the way to a description of some

* Sea-anemone is the common name applied to the Actinia.

related species, which are the types of other divisions of the order. The compound structure, the mode of growth, and the formation of the corallum, in the several groups, will come next under consideration.

I. General Structure of the Actinoidea.

20. The polyps of the Actinoidea correspond well with the character drawn on a preceding page. A circular disk, fringed with tentacles, — in shape much like an Aster with its petals, — and having a mouth at its centre, forms the upper part or extremity of the polyp. The mouth opens through a nearly cylindrical stomach into a large visceral cavity closed at bottom. The mouth receives the food and also gives exit to what remains after digestion.

The Actinia.

21. The Actinia is commonly met with attached by its flat under surface to rocks along the sea-shores. When unexpanded, it looks like a rounded lump of animal matter, somewhat leathery in appearance, plastered on the rock; it shows nothing of the mouth, and none of the fringing tentacles, these being concealed by the involuted margin of the summit. As the animal expands, the central opening at the top gradually widens, — the margin slowly rolls

Fig. 12.

Actinia.

back, and the tentacles it concealed now begin to show their tips. As the expansion goes on, the tentacles continue to enlarge, and the margin to spread outward, till finally the disk with the mouth at centre, is laid open, and the tentacles, like petals, fringe it around. Such is the general appearance of an Actinia, and such also are the greater part of coral polyps, which are nothing but Actinias, possessing the single additional function of secreting a Corallum. The preceding cut represents the closed and expanded condition of the Actinia. Their various and gorgeous hues are finely exhibited in the coloured engravings on plates 1 to 5.

Although these animals are usually attached at bottom, many of them may detach themselves and float through the water to a new resting-place; or, they will slide along slowly over the rocks, by the action of the base or foot; and some are said to turn over and walk on the extremities of the tentacles, which affix themselves by a sucker-like action. There is a small group of Actiniæ (Actinectæ), which are fitted expressly for an ocean life, by means of an air-cavity in the base, containing a vesicular or spongy disk, made up of air-cells, to serve as a float. The animal lies in the water with its base uppermost, and mouth and tentacles below, and is thus carried about by the winds and currents.

22. *Structure.** The exterior of the Actinia is fleshy, or more or less coriaceous in texture. Though frequently smooth, the lateral surface is sometimes covered with minute warty prominences or tubercles; occasionally it is furnished with small cup-vesicles, which adhere by suction like the cups of a cuttle-fish, and, by means of them, the animal fixes about it sand and fragments of shells, or aids itself in its progressive motions. The tubercles are sometimes distinctly perforated, and Lesueur and others have seen the water, from within the animal, spurted out through these perforations. Dr. C. Pickering compares the ejections of one seen by him abroad, to a shower from a watering-pot. Whether these perforations are general in Actiniæ without vesicles, has not hitherto been determined. Evidence of their existence, however, has been distinctly observed in the A. marginata of the Boston Harbour, by Dr. Wyman, and this species has not the slightest trace of tubercles; the skin is fleshy and smooth. They were detected by direct observation with the microscope, after having seen currents of water pass from them

* Dissections and descriptions of Actiniæ have been made and published by Spix, Delle Chiaje, Lesueur, Rathke, Teale, and Quatrefages. In the account here given, the facts have been mostly verified by the author's observations, or by the skilful dissections of Dr. Jeffries Wyman, of Boston. For views of the structure of the spermatic cords, and other interesting particulars respecting the *Actinia marginata* (Lesueur), of the harbour of Boston, he is indebted to Dr. Wyman's microscopic researches, many of which were made the past summer, during a short residence of the author in that city; and wherever reference is made above to this species, the observations are those of Dr. Wyman.

during the animal's contraction. In a papillose species, from the Peruvian coast, examined by the author after preservation in alcohol, each papilla contained a dark oval cavity, which communicated with the interior by a distinct duct opening in a minute puncture between the fleshy lamellæ of the visceral cavity.

As in other animals, a proper epidermis may be distinguished over the exterior skin; and the colours, which are often brilliant and various, are distributed in patches, according to Teale, below the epidermis, and do not form a separate layer.* Different individuals of the same species are often very unlike in their tints.

The only external organs in these animals are the mouth and tentacles.

23. The *mouth*, as in the preceding order, is a simple opening through the fleshy disk. It is usually oblong, and sometimes the inner surface is raised into vertical folds or lobes. While the animal is expanded, it remains open, and is usually much protruded, so as to be quite prominent.

24. The *tentacles* are slender organs, having generally a smooth or simply granulous exterior, and terminating in a minute puncture. They are tubular, and are inflated by water injected into them by the animal. The interior cavity opens into the visceral cavity between the visceral lamellæ, and it is through this cavity and its compartments that the distending water reaches the tentacles. On contraction, the water passes out again through the puncture at the extremity of some or all of these organs. The tubular interior, as observed by Dr. Wyman, in the A. marginata, is constricted near the apex of the organ, and then undergoes a slight enlargement before it terminates in the apical puncture. In the upper portion, the tissues contain great numbers of microscopic spicules of the form represented in figure 13. They are pellucid, like the body of the spermatozoa, but are only one-third as large.

Fig. 13.

The tentacles are seldom arranged in regular series, although usually forming together a circle around the disk. On close examination, they are seen to differ in size and to be placed a little irregularly; and in some species they are scattered over the surface of the disk nearly or quite to the mouth. They have some relation in

* On the anatomy of the A. coriacea, by T. P. Teale, Trans. Leeds Phil. and Lit. Soc., vol. i. I have seen only the abstract given in Johnston's British Zoophytes.

number to the intervals between the fleshy lamellæ of the visceral cavity, and often equal them; and when these lamellæ, in the latter case, increase in number, as they do with the growth of the animal, the new interval has soon its new tentacle, with which it communicates.

The tentacles are commonly described as *prehensile* in their nature. In some species, they are long and flexible, and are well adapted to render aid in capturing the food of the polyp. They sometimes have the power of stinging the hand, and when without this power, they frequently stick closely to the fingers if handled; and when their prey comes within reach, they close upon it, and force it into the mouth, usually open for its victim. In many species, the tentacles are quite short, or are reduced to mere tubercles;* and it is, therefore, probable that the passage of the imbibed water, contributing to the aeration of the fluids within, is often their more important function: in some instances they appear to subserve this purpose alone, being well adapted by their texture both to act on the external waters and upon the internal that may find passage through them.

The tentacle, as above described, is the most common variety. There are others, both simple and branched, that are furnished with suctorial vesicles, like the cup-suckers of the sides, which seem to aid them in clinging as well as sometimes in their movements. There are still others, which have a minutely divided or lobed surface, and look as if covered with delicate embroidery, as shown on plate 5. This peculiar structure seems intended to enlarge the surface of these organs, and fit them more perfectly to aid in aeration. The circle of them has much resemblance to the branchial rosettes of a Holothuria.

25. The *stomach* and *visceral cavity* occupy together the whole interior of the animal. The stomach is nearly cylindrical, and extends generally about three-fourths of the way to the base of the expanded animal. It has often a plaited or striated inner surface, and may be closed or opened by a muscular arrangement at bottom, where it communicates with the visceral cavity. Under the microscope, the surface in the A. marginata appeared smooth and covered with vibratile cilia; it was also invested with small slightly-projecting points, which become detached, on slight pressure, in the form of vesicles.

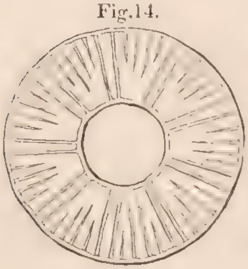
* This is the case in the Actiniæ, plate 2, fig. 16, and plate 4, fig. 32; and in many species of the genus Fungia, as shown on plates 18 and 19.

Fig. 13 *b*.

The coats of the stomach, in this species, contain the same minute spicules as the tentacles; and, in the general integuments of the body, they are still more abundant.

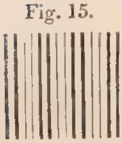
The *visceral cavity* is divided vertically by numerous lamellæ attached to its walls, the larger of which are united by their inner margin to the exterior of the stomach, and serve to fix it in its place, and at the same time to vary its shape by their muscular action. This structure is exhibited in the annexed cut of an ideal transverse section through the centre of an Actinia. The central ring is a section of the stomach, exterior to which the radiating lamellæ are shown of various sizes. All the lamellæ, large and small, extend along the under surface of the disk to the stomach; but only certain lamellæ at intervals retain this width and continue connected with the stomach to its lower extremity; the greater part narrow at once, and are of various widths, as in the figure annexed. Below the stomach, the larger lamellæ also are abruptly narrowed, so as to leave here an open space or chamber; the lamellæ afterwards extend inward again along the base of the polyp, and coalesce at centre, or are lost in the general structure of the base. The cavity or visceral chamber below the stomach is sometimes nearly bisected by the union of opposite lamellæ.

Fig. 14.



In the Actinia marginata, the lamellæ, as seen through the skin, have the arrangement in figure 15, two stouter lamellæ with a broader interval alternating with two thinner lamellæ and three narrower intervals. The same fact is indicated by the vertical linings on the Actinia, figure 22, plate 3; and, from some facts hereafter to be stated, it will be shown to be a very common arrangement in these animals. The vertical markings of Actiniæ, as well as the radiations of the disk, are all connected with the position of the fleshy lamellæ within. The above figure also shows that these lamellæ are very numerous,—*six* or *seven* being included in a breadth of a quarter of an inch. They are not as distant as in figure 14, which is drawn for general illustration, and is not strictly accurate.

Fig. 15.



The number of lamellæ in a certain breadth of interval is the same in different individuals of the same species. As a polyp enlarges by growth, new lamellæ form between the others, in the widening intervals, and thus a degree of uniformity obtains between the young and adult individuals, which is indicated in their coralla.

26. The process of *digestion* appears to be extremely simple. The food is retained for a while in the stomach, and there acted upon by the gastric juice supplied from its walls, after which the refuse matter is ejected by the mouth. The farther change to chyle probably takes place below in the visceral cavity, where a part of the nutrient fluid is absorbed, while another portion is distributed for assimilation throughout the various cavities, lacunes, or pores in the tissues of the animal. Thus the processes of aeration and assimilation go on together throughout the whole structure of the Actinia, and there is a water-and-chyle circulation, nearly in the same manner as we have described with regard to the Hydroidea. No proper circulating fluid independent of this, and no branchiæ, have been observed in these animals. Whether there are any excrementary secretions attending this assimilating process, as in other animals, has not been directly proved. Yet it is probable that the tissues about the visceral cavity, among their many functions, include the means of performing this part in the economy of the animal; and the waters expelled, in different ways, by the polyp, may carry off such secretions. It is remarkable, that while the biliary glands are of unusual size in the lower animals generally, in the Actiniæ they are wanting; and this is no doubt connected with the fact that these animals are bathed so freely inside and out by the sea-water, which renders special organs unnecessary. If the above supposition be true, it is not proper to consider the mouth of a polyp as alone the only passage for the excrements. It ejects the refuse indigestible matters from the stomach, but only in part the proper excrements of the animal.

The Actiniæ receive almost any animal food that falls in their way. Crabs, molluscs, the smaller fish, and other marine animals, are their common prey. They have been seen with a large bivalve in their stomachs, from which the animal had been removed by their powerful gastric solvents.

27. The function of *reproduction* belongs to the visceral lamellæ (§ 25), part of which are spermatic and part ovarian.

The spermatic lamellæ are distinguished by being margined by a white capillary cord. This cord is much convoluted, and is attached to the lamellæ by a thin and extensile membrane, which has a mesentery-like appearance.* The quantity of these cords in an

* Similar to figures 3 *b*, 3 *c*, 3 *f*, plate 30.

Actinia is very large. When the animal is contracting, they are often protruded in folds from the mouth, having come up from the visceral chamber, through the stomach (plate 2, figs. 12, 15, 16); and if the skin be fractured in any part, they escape in large bunches. These cords are sometimes seen to pass out through the perforations in the sides of the animal (§ 22), as was long since ascertained by Dicquemare.* The same fact was observed in the species examined by Dr. Wyman.

The white spermatic cords are semitransparent or nearly opaque, and are furnished with vibratile cilia. On subjecting them to slight pressure between plates of glass, slender filaments extrude. in length a little exceeding half the diameter of the cord; and, with a high magnifying power, a fragment of the cord thus under pressure presents the appearance in figure 16, exhibiting pellucid spicula, like

Fig. 16.

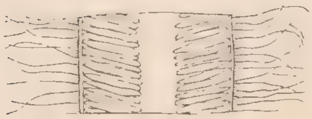


Fig. 17.

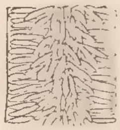


Fig. 18.

Fig. 19.

radii to the cord; the long filaments pertain to the spicula, and were extruded by the pressure. Figure 16 is properly a flattened transverse section; figure 17, a camera lucida sketch, by Dr. A. A. Gould, represents their position, as they were somewhat deranged by the pressure. These spiculiform organs, as observed by Dr. Wyman under one of the best English microscopes, are of three kinds, represented in figures 19 *a*, *b*, *c*. In *a*, the body is slightly curved and transparent, but with a more pellucid medial line, and the filament is a simple naked thread, two or three times its length. In *b*, the body is transparent, nearly as in *a*, but the filament is slightly enlarged through the latter two-thirds of its length, and this enlarged part is bristled, with the bristles reversed; the extremity moreover is obtuse. In *c*, the body appears to be filled with granulous matter; the filament is enlarged as in *b*, but it is lengthened out to a very delicately attenuated extremity; and the enlarged part, which is half its whole length, appeared spotted or chequered. These singular forms were seen frequently in cords taken from many individuals. Besides these organs, he detected minute oval points, with very short filaments,

* Phil. Trans. Abridg., xiii. 639, 1775.

as represented in figure 18, which had spontaneous motions. They were not frequently seen, and some doubt remained as to their origin.

The nature of these cords has long been a subject of speculation. The most prevalent opinion has been that they were connected with the process of digestion, and they have been called biliary vessels and cæca. They have also been considered oviducts* and ovaries.† Wagner first ascertained their spermatic character, and the general structure of the filaments:‡ yet Dicquemare distinctly states their resemblance to "spermatic vessels," and says, that they probably contain bulbs or buds, "which open in time, and, cleaving to the bodies in which these threads are extended, produce small anemonies."§ Dr. Wyman has the honour of originality in his researches, and the remarkable results throw some new light upon the structure of these spermatic organs. There is still uncertainty with regard to the functions of the parts observed. The forms represented in figures 19 *a*, *b*, *c*, have nearly the ordinary appearance of spermatozoa. But if the last-mentioned (figure 18) are the true spermatozoa, of which there is much doubt, the others, he suggests, may possibly be Spermatophora, as they have some resemblance (especially *b*, *c*) to the organs of this nature in the Cephalopoda, represented by Milne Edwards: but he ventures no decided opinion without farther investigation.

These spermatic cords appear to undergo a periodical increase and absorption, as is the case with the spermatic organs of most animals; for, at times, their length is very much less than at others.

28. Between the spermatic lamellæ are others of similar situation, which are *ovarian*. Like the "white cords," the ovaries grow from the margin, and form a series of clusters in two ranges, which fringe the lamellæ, or, when large, fold back and lie in the spaces between them. Figure 20 shows the double line of clusters, as they were seen attached to the margin of an ovarian lamella in the Actinia marginata.

* Sharpey, Cyclop. Anat. and Physiol., i. 416.

† Cuvier's Reg. Anim., iii. 290; Amer. Ed., iv. 388. Also, A. de Quatrefages, *Sur les Edwardsies*, Ann. des Sci. Nat., xviii. (1842) 65. The spermatic cords and spermatozoa are well figured.

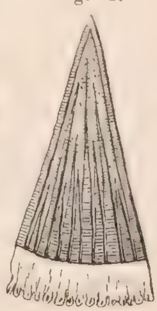
‡ Wagner, *Sur la Generation*, Ann. des Sciences Nat., viii. (1837) 282, and Wigemann's Archives, ii. 215 (1835). Also, Milne Edwards, Ann. des Sci. Nat., xiii. (1840) 196, on the Structure and Sexual Organs of the Dendrophyllia.

§ Phil. Trans. Abridg., xiii., 639, 1775.

This margin is very thin, and in folds, mesentery-like, similar to that supporting a spermatic cord. The ovules are enveloped in an extension of it, and a narrow projection of the same may be observed at the line of junction between the two series of clusters. Figure 21 represents part of a transverse section enlarged, of the Actinia florida (p. 131), from near the base of the animal, examined after contraction in alcohol; the dotted portion represents the position of the ovarian clusters, which lie between the lamellæ, although distinctly attached to the margin. The adjoining ovaries of different lamellæ appear, in some instances, to coalesce.

Fig. 20.

Fig. 21.



The ejection of the ovules appears to take place by the mouth. The extremity of the tentacles,* and supposed openings near the base of the same, have been stated to give them exit. But the existence of these openings is not proved; and the punctures at the extremities of the tentacles are certainly too small for that purpose, in the majority of species, if not in all. The visceral cavity in which they are formed, communicates freely with the exterior waters through the stomach, affording them a direct and open passage. The mouth is made the place of exit by Spix;† and Dalyell also asserts that, according to his frequent observations, they are "produced by the mouth." Both ovules and living young, in the course of his investigations, were often disgorged by the parent in numbers along with the half-digested food.

As the tubular interior of the tentacles communicates freely with the interseptal spaces of the visceral cavity, it is no anomaly that ovules should be found within the tentacles, as stated by the last-mentioned observer. By amputation, he frequently obtained them from these organs; and one ovule thus procured, became a mature animal, began to "breed in fourteen months, and survived nearly five years."‡

* Delle Chiaje, Bull. des Sciences Nat., xvii. 471. See farther on this subject, in Johnston's Zoophytes, from whom this citation is made, p. 201.

† Carus Comp. Anat. Trans., ii. 308, pl. 1, figure 10.

‡ Dalyell states, that "fourteen animated beings" were produced at once by an Actinia equina, or mesembryanthemum, in his possession. Six were young with tentacles, and eight, ovules undeveloped. "All were sufficiently vivacious, sometimes moving, sometimes reposing." In eight days the vibratile cilia disappeared from the ovules, and they became stationary; in eleven days incipient tentacles were distinguished in one; and in

The developement of young from the ovules before their ejection, has been for a long time asserted, and Dalyell and others have shown that it is of common occurrence. The ovules being bathed by the sea-water, which gains access to the visceral cavity, there is little occasion for the doubt with which the statement has been by many received. The ovules have a white milky appearance, and are of various sizes in the same cluster. They have usually a globular form, but are often a little oblong or of irregular shapes. Wagner has shown that they have the characters of true eggs. On leaving the parent, they are said to move about by means of the vibratile cilia with which they are provided. After a short time the young Actinia appears, and generally fixes itself shortly after to some object at hand. When first produced, the tentacles are scarcely apparent; a single series gradually developes, and afterwards they go on increasing as the animal grows, and do not attain their full number until it is a perfect adult.

29. The Actiniæ have the same power of reproduction from artificial sections as the Hydra. Portions cut or torn off are soon resupplied, and the parts separated develope what is needed to become perfect animals. The process of budding has been observed only in the coral-making species.

The Zoanthidæ.

30. The dissections, by which this division of the Actinoidea is here illustrated, were made on a living specimen of the Palythoa cæsia, at the Feejee Islands, representations of which are given on plate 30. This species grows in rounded attached masses, of the size of the fist, which consist of a large number of united polyps. When unexpanded, the mass has externally a grayish leathery appearance, with small

nineteen days eight or nine could be enumerated in another, which now "affixed itself as a young Actinia by the base." (Jameson's Journal, xxi., 1836, p. 89.) "In the course of six years, a specimen preserved by the author produced above two hundred and seventy-six young, some pale, like mere specks, with only eight tentacula, others florid, and with twenty. They are frequently disgorged along with the half-digested food, thirty-eight appearing thus at a single litter. An embryo extracted artificially from the amputated tip of a tentaculum, began to breed in fourteen months, and survived nearly five years. Monstrosities by excess are not uncommon among the young: one produced naturally consisted of two perfect bodies and their parts, sustained by a single base, exhibited embryos in the tentacula at ten months, bred in twelve, and lived above five years. While one body was gorged with food, the other remained ravenous." (Dalyell, in 4th Rep. Brit. Assoc., 1834, p. 599.)

openings scattered over it, each of which is the centre of a slightly-raised prominence. On expanding, these openings enlarge, the margin of each rolls back, and finally the whole mass, before seeming lifeless, is covered with radiated disks, half an inch broad, having a lilac centre, and bordered with a fringe of short tentacles. These are the flower-animals—the polyps—of the Palythoa. They are represented of the natural size in figure 3. Some of the polyps on the right are yet closed, while others are partly, and others wholly, expanded. An enlarged view of the expanded polyp is shown in figure 3 *a*, exhibiting the circular disk—the fringe of short tumid tentacles, in two series, one directed more upward than the other—and, upon the disk, elevated greenish lines, extending, like radii, from each tentacle to the convex centre in which the mouth is situated. The texture of the general mass of the zoophyte is peculiar, in consisting of coral sand agglutinated by animal matter; particles of various colours are here mingled,—white, red, and black. The sand, as it falls upon the growing zoophyte, is enclosed by the slimy secretions of the surface, and is finally introduced into its texture; and thus firmness is secured by calcareous granules from a foreign source. This is imperfectly represented in the figures 3 *b* and 3 *c*.

31. The *tentacles* are naked—that is, without papillæ—as in the Actiniæ, and each has a minute puncture at apex. These organs are tubular, and they communicate internally with the visceral cavity through a duct concealed under the radiated lines of the disk. The mode of expansion by injection with water is the same as in the animals above described. The *mouth* is without appendages of any kind—a simple opening through the fleshy disk.

32. The *visceral cavity* is cylindrical, and extends down below the disk, into the polyp-mass, to its base. Its form and size, as compared with the expanded animal, is shown in figure 3 *a*. The mouth opens into this cavity, through an oblong *stomach*, which is about one-fifth the length of the cavity, and is connected with its walls by a series of radiating fleshy lamellæ, as in the Actinia. There is also another series of smaller lamellæ intermediate between these. The stomach has a vertically striated or plaited structure within, and closes at bottom at the will of the animal. Figure 3 *b* is a vertical section of the unexpanded polyp, through the mouth (opposite *b′*) and stomach (*b′* to *c′*), and the general visceral cavity; and figure 3 *d* is a transverse section, cutting across the œsophagus a little

obliquely, and showing the radiating visceral lamellæ, which connect it with the sides of the visceral cavity. In figure 3*b*, only two opposite lamellæ are in view, while in figure 3*c*, which is an oblique section, crossing the cavity *below* the stomach, the edges of several of the intersected lamellæ are exposed. In the last-mentioned figure, the stomach is seen to terminate in a kind of disk, which is the muscular arrangement for closing its lower extremity. The oblique position of this disk is unnatural, and resulted from the section of part of the lamellæ and their consequent unequal contraction; the animal is drawn just as it was presented in the dissection. In 3*b*, the upper extremity shows the tentacles as they are concealed in the contracted animal. It thus appears that the visceral cavity is divided by the lamellæ into a series of compartments, as in the Actinia. A second series of narrower lamellæ lies between the larger, as is shown in figure 3*d*. These narrower lamellæ, however, are prolonged on the under side of the disk to the stomach, so that in making the section here referred to, the upper portion removed, presented below twice as many radiating compartments as were seen in the part figured. There is hence a close analogy with the Actinia, although the animals differ so strikingly in the relative sizes of the stomach and visceral cavity. This resemblance is seen farther in the position of the spermatic cords.

33. *Spermatic* cords border the larger lamellæ, and extend from below the stomach nearly to the bottom of the visceral cavity. They are convoluted throughout their length, as is shown in figures 3*b*, 3*c*, and 3*f*. It is remarkable, that in one of the specimens, the convolutions are very few, and the cord stops far short of the bottom. This fact may be accounted for on the principle that they are periodically developed.*

Spermatozoa were not observed in these cords, yet it is altogether probable that on farther examination they will be detected, as in the Actinia. Vibratile cilia were distinct on the cords, but were not seen on the lamellæ to which they were attached.

The specimens examined contained no ovules. From analogy, we should expect that in the proper season they would be found in clusters, attached to the intermediate series of narrow lamellæ.

34. Besides the spermatic cords, there is attached to the edge of each larger lamella, immediately below the stomach, a pair of flat

* The season when these observations were made was the month of August, 1840.

branchia-like organs. In figure 3*b*, they are seen in profile in their natural position (*c′* to *d′*), and in the vertical view in 3*d*, one appears either side of each lamella; this is shown still more distinct in figure 3*e*. These organs are enlarged in figure 3*f*. They are transparent, and are transversely divided into narrow compartments, each about $\frac{1}{800}$ of an inch in breadth. The margin is crenated, corresponding with the compartments. Each compartment, as is more distinctly exhibited in figure 3*g*, is traversed along its middle by a distinct vessel, which terminates in a small process on the margin. Vibratile cilia were apparent on these organs, as is represented in figure 3*g*, and they were observed to continue in motion for an hour after separation from the animal. These cilia were about $\frac{1}{3000}$ of an inch in length.

The two organs of each pair were united to a common duct, which, in the specimen examined, had a bluish colour, as shown in figure 3*f*; and by this duct they were attached to the margin of the lamella—one being situated either side—and thus their surfaces were free to be bathed by the water with which the animal distends itself.

35. The structure of these organs is such that we can hardly doubt their branchial nature: yet no circulating fluid was detected within them. Lesueur, who observed them in his excellent dissections of West India species, calls them arcuated organs, and supposes them to "perform the functions of the liver."*

The modes of nutrition in the Zoanthidæ, are the same as in the Actinia.

The Tubipora.

36. The structure of the Tubipora has been illustrated by Quoy and Gaymard, in the voyages of the Uranie and Astrolabe. The dissections made by the author confirm in general their observations, yet differ in some points of interest.

The Tubipora is a cylindrical animal, expanding above a star of eight tentacles. The animals are often of a lilac or rose tint, and grow in large clusters; and, as they appear beneath the water about the reefs, they are as perfect beds of pinks as those of our gardens. Figure 1, on plate 59, represents some of these polyps of the natural size; and figures 1*a* and 2, two individuals of the same genus enlarged. The eight tentacles are fringed on either side by small papillæ, each of which has a minute puncture at apex. Both the papillæ and the

* Jour. Acad. Nat. Sci., Philad., i. 183, 184, 185, and plate viii., fig's. 1, 5, 9.

tentacles are tubular, and expansion takes place, as in the species before described, by means of water, received from without, and injected into these organs and other parts of the animal. The Tubipore secretes a calcareous tube, or corallum, which is stiff and firm below ; but near the extremity it is still flexible, and the animal contracts by drawing its head and tentacles into the tube, like turning in the end of the finger of a glove. Figure 1*b* represents one of the contracted animals, with the tube laid open by a longitudinal section, showing the interior structure. The pear-shaped part above contains the withdrawn and contracted tentacles; and the dark spots, near the bottom of the same, are the openings into four of the tentacles, by which water enters from the visceral cavity, when the animal expands itself.

37. The visceral cavity is long, tubular, and contains eight fleshy lamellæ. These lamellæ aid, by their muscles, both in the contraction and expansion of the polyp, in a manner which will be understood without explanation, by a glance at figure 1*b*. The stomach is cylindrical and very short compared with the whole length of the visceral cavity; and, as in the preceding species described, it is connected with the sides of the cavity by the visceral lamellæ.

Six of these lamellæ were spermatic, being bordered below by the white convoluted cord, while the other two gave origin to large clusters of milk-white ovules, which occupied nearly the whole diameter of the cavity. These ovules were of various sizes, and spherical in shape, or nearly so. Figure 1*b* shows their position in the tube, and 1*c* the appearance in profile of one of the lamellæ with the attached ovules.

Some observers have found all the lamellæ bordered with the white filament, and others describe them as all bearing clusters of ovules. In these instances, it would seem that the sexes were distinct, in one case the animal being *male*, and in the other *female*. The subject requires farther investigation.

In the characters of the Tubipore we have the characters of the Alcyonaria generally, a large tribe of zoophytes. The eight fringed tentacles, and the eight visceral lamellæ attaching the stomach to the sides of the cavity, and extending below to the bottom of a tubular visceral cavity, distinguish them at once from other Actinoid polyps. The ovules in some species have been seen to escape by the mouth, and this therefore appears to be the general mode in all the Actinoidea.* We have nothing to add on the processes of digestion and circulation in these animals, in addition to what has been already presented, in our remarks on the Actinia and Palythoa. Nothing like branchiæ were observed in the Tubipore examined.

General characteristics of the animals above described.

38. The species described in the preceding pages, have been selected from the most widely-separated groups among the Actinoidea, and are types of important divisions. The points of agreement constitute the characteristics of this order, and may be here enumerated.

1. The Actinoid polyp contains a large cul-de-sac visceral cavity, divided radiately into compartments by fleshy lamellæ, and a stomach suspended in it beneath the centre of the disk. Several lamellæ are united by their inner margins to the stomach, and aid, by their muscular action, in the expansion of the stomach and the expansion and contraction of the whole animal.

2. The *stomach* communicates below with the visceral cavity, through an opening which may be closed by muscles. Its walls are muscular, and the organ admits of great dilatation, or may be contracted, at the will of the animal, to a slender tube.

3. *Digestion* takes place in the stomach; and thence, after excluding the refuse matter by the mouth, the results of digestion pass into the visceral cavity, to be aerated and elaborated through the air in both the external and the admitted waters, at the same time that these fluids are distributed, by an imperfect circulation, throughout the animal, and assimilated wherever needed for changes in progress. It is probable that excretions take place through the sides of the polyp, and by the waters which the animal ejects elsewhere on contraction.

4. *Reproductive* functions reside in the visceral lamellæ, part of which are *spermatic* and part *ovarian*. All of these lamellæ are thus genital, excepting probably the upper portions of the larger lamellæ, which are attached to the stomach, and in this part are muscular. The testes or spermatic organs have the form of white convoluted cords, and are attached to the margin of the lamellæ. The ovarian

* This has been observed in certain species of the tribe, by Professor Grant and Milne Edwards.—For an interesting account of the developement of the ova, see a paper by Dr. Grant, in Jameson's Edinburgh New Philosophical Journal, vol. i. p. 152; and also on the general structure and reproduction of the Alcyonida, a memoir by Milne Edwards, in the Annales des Sci. Nat., 2d ser., iv. (1835), p. 321.

clusters are attached in a corresponding manner to the margin of the ovarian lamellæ. The ovules, though sometimes retained in the cavity till they are developed, generally pass out before, and, in either case, escape takes place through the stomach and mouth.

The similarity between these animals and the Hydroidea is hence very close. The localisation of the genital functions in distinct organs appears to be the character upon which their principal differences depend. The relation of the visceral cavity of these animals to the tubular axis of the Sertularia is obvious. Though extremely short in the Actinia, we find it several times longer than the stomach in the Zoanthidæ, and still longer, and taking the form of a slender tube, in the Tubiporæ and Alcyonia.

Subdivision of the Actinoidea.

39. The facts considered lead to a natural subdivision of the group Actinoidea. In the Actinia and Palythoa the tentacles are numerous and naked, and have a puncture at apex, while, in the Tubipora and allied species, these organs are but eight in number, and are fringed with papillæ, each with its minute puncture, and none at the extremity of the tentacle. The Actinoidea are hence naturally subdivided into the two following groups:

I. Actinaria.—*Tentacles, (with few exceptions,) naked or not papillose, six, twelve, or more in number.* This division includes the Actinias, Madrepores, Astræas, &c. (The cells in the coral-making species are more or less perfectly radiate within.)

II. Alcyonaria. *Tentacles fringed with papillæ, eight in number.* This division includes the Tubipores, Gorgonias, Alcyonia, &c. (The cells of the coral-making species are never radiate or striate within.)*

* The fact that in a compound Alcyonium the tubular visceral cavities of the several polyps branch from one another, with a free intercommunication, has been considered as widely separating the Alcyonaria from the Actinaria. In the Tubiporæ among the former, however, this connexion is not more perfect than in the Zoanthidæ, and the same is true of the young state of the polyp-bud in many species. The seriate polyps in a Meandrina have even a more open communication, and in some of the compound Fungidæ adjacent polyps have scarcely any thing but a mouth that can be said to be private property. The peculiar character of this connexion between polyps in certain Alcyonaria merits notice, but not the importance which has been attached to it.

We glance at some of the principal varieties of structure in each of these divisions.

I. Actinaria. 40. In one of the divisions of this group—the *Antipathacea*—the polyps have but six tentacles.* In the tentacles and the general appearance and habit of the polyp, they resemble the Madrepores, but no dissection has yet been made of them.

41. The polyps of the *Madreporacea*, another division of the Actinaria, are distinguished by twelve tentacles in a single series.† There is among them but little variety of structure. In a few species the alternate tentacles are of unequal size, and it is probable that the visceral lamellæ have the same inequality: and in some Madrepores one of the tentacles is elongated and more flexible than the others:‡ again, all are sometimes obsolete.

The character of the cells formed by Madrepores show that in many of them two opposite interlamellar spaces in the visceral cavity are generally broader than the others, as in the Actiniæ, and usually these two are very unequal.

The only fleshy species known, which has the twelve tentacles of the Madrepores, is the *Actinia clavus* of Quoy and Gaymard,§ found by them entangled in the tentacles of a Medusa, off the coast of New Holland. By their dissections, the stomach and visceral lamellæ are shown to have nearly the characters of those in the Palythoa, except that the lamellæ are equal and are twelve in number, corresponding to the tentacles. The appearance of this Actinia expanded is very similar to that of a madrepore polyp.

The most marked variation from the usual character of the Madreporacea is found in the Porites family. In these the visceral cavity does not extend to the base of the animal, as in the other species of the group, and the visceral lamellæ cannot be traced through the tissues of this portion. This structure is indicated by the porous coral secretions formed by this part of the polyp. In external characters these polyps present few peculiarities. A few allied species (Goniporæ) appear to have more than twelve tentacles, though all are in a single series, as in others of the Madreporacea.

42. The polyps of the *Caryophyllia* and *Astræa* tribes have more than twelve tentacles, and they are in two or more series or scattered.

* Plate 56, figures 1 and 2. † Plate 31, figure 1. ‡ Plate 33, figure 1.

§ Voyage de l'Astrolabe, iv. 150, pl. 10, figs. 6 to 11. It is yet doubtful whether this species was actually an adult with its full number of tentacles. Several individuals were seen, which were about three-fourths of an inch long when expanded.

Here belong the Actiniæ and the Zoanthidæ, and a large part of coral animals. The Zoanthidæ are closely related to one division of the coral-making Caryophyllacea — the family Gemmiporidæ. They spread a wide disk, with a somewhat convex centre, and sometimes the margin of the disk, bearing the fringe of tentacles, becomes much reflexed by expansion, curving downward towards the base of the polyp, so as to appear like a cap over the extremity. The tentacles are short, and correspond each to a radiate line on the disk; and in some species I have found one of these rays to have a different colour and size from the others, evincing some peculiarity of function in the tentacle, corresponding, apparently, to the long finger-tentacle in some madrepores. The Gemmipores* resemble these in general form and in their fringe of short tentacles, but the disk is not striated. In another division of the Caryophyllia tribe—the Caryophyllidæ—the tentacles are much like those of the common Actinia; and in external form we distinguish no important peculiarity, except that the disk containing the mouth becomes more prominent, when the animal is fully expanded,† sometimes having nearly the shape of an oblong inverted cone.

The polyps of the Astræa tribe of zoophytes have numerous unequal tentacles, and a flat or simply convex disk. The distinction between the Astræa and Caryophyllia tribes depends on a different mode of *budding*, as is pointed out in a following chapter. The visceral lamellæ in the Astræas appear to retain their identity through the side tissues or walls of the polyp, and, in compound species, these lamellæ may be traced by their secretions through the intermediate spaces between adjoining polyps. These characters are strongly marked in the coralla of the different animals, although not so apparent, as far as I have examined, in the recent Actiniæ (§§ 48 and 76, fig. 34).

43. The only variation from the Actinia type which we here notice is presented by the Fungiæ and other allied zoophytes. The Fungiæ‡ are the largest of known polyps, some species attaining a diameter of eighteen inches. The form of the animal, instead of being cylindrical, as in the Actinia, is that of a large disk, an inch or two thick, circular or elliptical in outline, and either flat or convex above. A large oblong mouth occupies the centre, and from the mouth narrow ridges radiate, with regular intervals, to the circumference—a few

* See plate 30, figure 4. † Plate 27, figure 1. ‡ See plates 18 and 19.

commencing immediately at the mouth, and others rising to fill up the spaces between them as these diverge Although so unlike the type in external shape, yet the actual structure is closely similar, for the Fungia is nothing but an Actinia spread out laterally into a broad flat disk. The inequality in the lamellæ is much greater, though of the same character, and the tentacles are more widely scattered, so as to lose all appearance of being in series. The connexion between the formation of a tentacle and a new lamella within the animal, is finely exemplified in the Fungia; for each tentacle rises where a new ridge reaches the surface, and their formation is constantly going on as the animal enlarges and new ridges rise. This may be seen by reference to the figures of Fungiæ on plates 18 and 19, where the small prominent tubercles scattered over the surface are the tentacles.*

The close relation of the Fungia to the common Actinia is thus evident; yet in the actual form of the visceral cavity they are quite unlike. Instead of a cylindrical space, divided into shallow compartments by erect fleshy lamellæ, we have here long horizontal compartments, commencing at the mouth, and as they enlarge outward, constantly subdividing by the growth of new lamellæ: these lamellæ, for a while before rising to the disk, range along the bottom of the cavity. Unlike the Astræas, the Fungiæ never cover the contracted tentacles by the involution over them of the margin or surface from which they rise; there is actually no margin to the disk in these animals: moreover, in compound species, the visceral lamellæ of adjoining polyps are continuous from one to the other, and it is probable that the subdivisions of the visceral cavity are also directly continuous, so that in these compound Fungiæ we appear to have a community of visceral cavities, as in the Hydroidea, differing from the latter, however, in having the communications by lateral or interseptal spaces, instead of by the lower extremity of the cavity. In the Astræas, the same communication in effect takes place, though less perfect, through the open pores or lacunes, which pass laterally from one polyp to another. The Fungiæ afford the nearest approach, among zoophytes, to the Acalephæ.

There is often in a Fungia, a line running from one or more sides of the oblong mouth to the circumference, along which some of the

* On account of the small size of these organs, it has been denied that they are tentacles. Yet, whether so called or not, they correspond to the tentacles of the Actiniæ; and in some species of Actinia they are as short and scattered (see plate 4, figure 32).

lamellæ meet at a small angle and coalesce. This proceeds from a slight distortion of the circular animal, and is most common in species which have the lamellæ undulated, by which irregularity they are often brought into contact. When the Fungia retains a perfectly circular form, this union of lamellæ is seldom observed. It is not unusual for the lamellæ in an Actinia to grow together by their edges when in contact.

b. The number of tentacles in this group, or the number of lamellæ, is very commonly a multiple of six. In one division of the Astræas (the Orbicellæ), we find the numbers 18, 24, 36, 48; in other species of the genus, the mode of indefinite increase and subdivision, prevents our ascertaining how nearly they correspond. The Oculinæ, Dendrophylliæ, and Caryophylliæ conform generally to the same series, and so also the Madrepores and Antipathi, which contain twelve and six tentacles respectively.

In many instances, however, *four* is a submultiple, and this is shown by the lobed margin of the Lucernariæ, and the divisions in the mouth of some Actiniæ. That this should often be the fact is apparent from figure 15, § 25, in which *one* larger and *three* smaller intervals alternate; and it appears that generally when a multiple of *six*, the numbers are also multiples of *four*.

While, therefore, the Alcyonaria have *eight equal* lamellæ, the Actinaria may have *six* or *twelve equal lamellæ*, or a number of *unequal* lamellæ, *exceeding twelve*, which is a multiple of *four* or *six*. The mouth and margin of some Actiniæ is *five* lobed; but these may still conform to this principle. In the Antipathi, there are six equal tentacles; in the Madreporacea, twelve tentacles, with six alternate, often distinctly larger than the others: and the calcareous lamellæ of the cells, in other species, are usually either alternately large and small, or one large alternates with three smaller, or one with five smaller.

There is, moreover, in the Actinaria, a relation between the size of a polyp and the number of its internal lamellæ. In many Astræas, there are fourteen or fifteen—large and small—to a breadth of a quarter of an inch; and, where the number has the above relation, 18, 24, 36, 48, there is nearly the same relation in the diameter of the cells of the corallum. This relation admits of considerable variation, which is sometimes seen to be dependent on a part of the lamellæ being obsolescent. The Astræa hyades and A. pleiades both have twenty-four lamellæ to the cells; but in the former, which has the larger cells, they are nearly equal; while in the latter, half are obsolescent. In the Merulinas, there are seven or eight larger lamellæ to a fourth of an inch, with three or four intermediate nearly obsolete, making in all ten or eleven in this breadth. The same is generally true of the Euphylliæ and Meandrinæ. In the Mussæ, much larger species, there are seven or eight to a fourth of an inch, as in the Actinia marginata (§ 25), and half of these are quite small or obsolescent. It appears, therefore, that the number varies, in different species, from seven to fifteen. The last number is seldom exceeded, yet instances of this are found in some Meandrinas and many of the attached Fungidæ.

II. Alcyonaria. 44. The simple polyps, among the Alcyonaria, have a great similarity throughout. The number of tentacles being fixed, there is not room for the same diversity of form as in the Actinaria. The principal varieties in external appearance proceed from variations in the length and position of the papillæ. These appendages to the tentacles are sometimes quite long, and give a graceful delicacy to the flower, scarcely exceeded in the vegetable kingdom.* Usually, they form a short fringe in two or three series on either side of the rays, as shown in the Tubipora, already described.† In one of the species of this genus (T. syringa), they are so evenly laid together that the fringe seems to be wanting. In one of the Xeninæ, found at the Feejee Islands,‡ the papillæ are minute wart-like prominences, scattered over the surface of the ray. Each little prominence has the minute puncture at apex, which is characteristic of the Alcyonia group.

II. Secretion of the Corallum in the Actinoidea.

45. The corallum has been described as in general an internal secretion, formed within the polyp, and not a covering enclosing the same, as in the Mollusca.§ We may examine more particularly the mode of its secretion and its relations to the animal.

There appear to be two kinds of coral secretions among the Actinoidea:—

1. Secretions formed within the animal which are mostly *calcareous*.

* See plate 59, figure 3. † See plate 59, figures 1, 2. ‡ See plate 57, figure 2.

§ This character of these secretions was first pointed out by Ehrenberg, in his Memoir on the Corals of the Red Sea, in the Transactions of the Berlin Academy, for 1832. Since then, they have been more fully explained by Milne Edwards, in the Annales des Sciences Naturelles, for 1838, x., 2d series, 321.

2. Secretions, from the foot or base of the polyp, which are either *calcareous* or *horny*, or of an intermediate nature, and rarely siliceous.

The former may be called *tissue-secretions*, the latter *foot-secretions*.

46. *Tissue-secretions.* These secretions take place from the tissues of the sides and the base of the polyp. In a few species—the coralligenous Alcyonaria—even the skin often adds to these secretions by depositions of lime in its texture; but in the other Actinoidea, the exterior of the polyp remains soft and fleshy, so that every portion of the Corallum, even to each spine and lamella, is entirely concealed within the polyp, as completely as the skull of an animal beneath its fleshy covering. All corals are more or less cellular, and through these cellules the animal tissues extend, forming, together with the exterior, a complete animal structure, corresponding closely with the coral structure. Even the most solid plates of the latter are more or less penetrated by fibres of animal tissue.* By comparing the radiated cell of a coral,† with the radiated visceral cavity of the Actinia or Palythoa, as described in §§ 25 and 32, the relations of the two will be as apparent as they can be made by any explanations. The radiated calcareous plates of the one alternate with the radiated visceral lamellæ of the other.

These secretions do not take place from all parts of a polyp. The disk, the stomach, and the upper portions generally of the animal, remain fleshy, as well as the interior of the visceral cavity, in order that the polyp may be free to expand or contract, and perform the various functions essential to life. The tentacles, however, may secrete lime, and not unfrequently the calcareous lamellæ of a cell project by this means into these organs; and, in the same way, some corals are covered throughout with short spines.

The corallum has a close correspondence, therefore, to an internal skeleton. It is not a collection of cells containing polyps, like the cells of a bee-hive, but is contained itself wholly within the polyps.

* This has been shown by Hatchett, and also by Milne Edwards and Bowerbank, and may be easily verified by dropping a piece of compact coral into a dilute acid. These tissues may be distinctly seen on examining with a high magnifying power, thin fragments polished down, till they admit the passage of light. A minutely reticulated structure may be distinguished, though much irregular; and it appears probable that the tissues consist in part of the animal cellules within which the lime was secreted. The results of some microscopic examinations by the author upon different species of corals, will be given in the Appendix to this volume.

† See plates **10, 11, 12,** and others; also, figure 34, § 76.

The existence of surface-cells on a corallum, is due simply to this,—that the upper and interior parts of the animal do not secrete lime. In some species, these secretions are confined to the basal portions of the polyp below the visceral cavity, as in many Porites, and consequently these zoophytes have no cells to the corallum. The terms *polypary*, *polypidom*, given to coral, are, therefore, in every respect, inapplicable.

Where cells occur, there is some appearance of a retreat into them by the contracting polyp. But it is only the upper part or disk of the animal that is thus withdrawn; and this happens only because the projecting part of the animal, on contraction, will necessarily collapse upon the solid part below, and into a cavity, if there be one. Figure 1*a*, on plate 6, represents one of the contracted coral-polyps, and some parts of figure 1, on plate 7, represent others. There is here no retreat into a cell: indeed, from the external appearance, even the existence of coral within would hardly be suspected, so closely do the separate polyps resemble some of the Actiniæ. In a Fungia, there is no cell whatever, but the small cavity at the centre below the mouth, and contraction produces no change in the appearance of the animal, except that the tentacles collapse and are not seen; the mouth falls a little, and the fleshy exterior, owing to the expulsion of the inflating water, lies somewhat more closely upon the coral plates beneath.*

The calcareous secretions begin to form in the young animal after the last metamorphosis, which takes place when the animal leaves its free swimming state and attaches itself to some support. The rays of the cell in this state indicate the number of visceral lamellæ, and generally of the tentacles; and as these increase in number, so also do the calcareous lamellæ. It has been stated that in the growing Actinia new visceral lamellæ are developed to fill up the enlarging intervals, and at such a rate that there is always the same number in a certain interval. The same is true of the calcareous lamellæ; there is a remarkable degree of similarity between the cell of a young and adult polyp; it is very rare that the lamellæ in the former are more crowded than in the latter, and generally, when quite young, they appear more open.

* Where the polyps have most perfectly the appearance of withdrawing into a cell, as in the Sertularias, it is still no more the case than that a turtle retreats into its shell when it draws in its head.

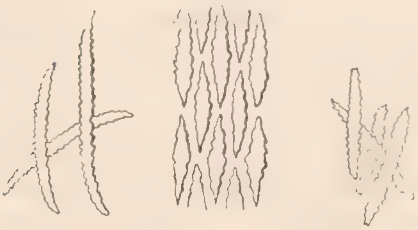
The secretion of a calcareous lamella or plate takes place between two visceral lamellæ, but whether from the surfaces of these fleshy lamellæ, or from a prolongation inward of the membrane forming the walls of the visceral cavity, has not been ascertained. The secretion does not always commence at the central plane of the plate, but often either side of it; for they are sometimes hollow within. In some species the spines of the surface are tubular, as in the Echinopora reflexa. We have observed, with regard to the visceral lamellæ, exhibited in figure 15, § 25, that a large compartment alternates with three narrower; and also that the large calcareous lamellæ in the Dendrophylliæ and many other species, alternate with three smaller: it appears therefore that the larger rays of a cell are formed between a pair of large visceral lamellæ, and the smaller in the narrower spaces which are intermediate.

The calcareous secretions forming these corals are often deposited at successive intervals or as layers in the zoophyte. In a Madrepora the surface between the cells becomes covered with minute points by the continued secretions, and then a layer forms, connected with the preceding by these points or columns. The interior usually becomes, afterwards, nearly solid by additional secretions. This variety of structure may be observed also in the Dendrophylliæ; and even the compact species, in which there are no traces of cellules, will often show evidence of having been deposited in layers. I have seen it brought out with singular distinctness in a specimen half fossilized, the layers easily peeling off from one another. In many corals, however, we fail to detect this deposition in layers. This is the case in the Astræa tribe. The Pocilloporæ, and some allied corals, have transverse plates crossing the cells internally, which are intermitted secretions from the lower part of the polyp; but no appearance of layers has been detected in the spaces between the cells. The Favosites and many Cyathophyllidæ are examples of similar interrupted secretions across the cells.

47. Our explanations thus far, apply more especially to the *Actinaria*. The *Alcyonaria* secrete no rays within the cells, nor even striate the inner surface of the same, while rays or striating lamellæ belong to the cells of all the Actinaria. Moreover, in the Alcyonia group, the secretions, instead of forming layers, constitute disseminated granules or spiculæ, some of which are represented in figure 22, and there is every gradation, from the purely fleshy species to those which are quite firm, from the secreted calcareous grains. These

secretions are nearly or quite absent immediately about each polyp-pore, in order that these parts may be flexible to admit of the animal's contracting and expanding itself; elsewhere they are more or less abundant, according to the species. In the genus Tubipora, the species form a thin calcareous tube for each polyp, smooth within, as well as without, yet perforated by minute pores.

Fig. 22.



48. Among the *Actinaria*, the principle, that the calcareous and fleshy lamellæ have a general correspondence in number, leads to important distinctions in the coralla. Madrepores, on this principle, can never have over twelve rays to their cells, and the number is usually from six to twelve; while the Caryophyllia and Astræa tribes have an indefinite number. The two tribes just mentioned are distinguished in their coralla by another character depending on the structure of the animals, as explained in § 42. The lamellæ of the stars in an Astræa, and the allied corals, extend through the interstitial spaces between the cells, striating lamellately the surface; while in the recent species of the Caryophyllia group (and also the Madrepores), these spaces are smooth, granulous, or irregularly porous, instead of lamello-striate. Besides, in the *former*, the calcareous lamellæ are united by numerous transverse dissepiments, which, when oblique, as in plate 11, figure 4*c* (showing a vertical section of an Astræa), they cause the star in a transverse section to be divided into numerous cellules (fig. 4*d*); but, if horizontal, or nearly so, as in plate 10, figure 2*a*, they do not show their edges in a transverse view, and the star appears simple. In the recent Caryophyllidæ, there are seldom any cross dissepiments, and in the few cases in which they are observed, they are distant, being separated by longer intervals than the breadth of a lamella.

49. *Foot-secretions.* The foot-secretions appear to be entirely independent of the tissue-secretions. The former are often horny, when the latter are calcareous, and when they occur together they constitute separable layers, one enveloping the other.

The united polyps of a branch have their mouths opening outward on every side, while the bases are directed inward towards a common central or axial line. The simultaneous secretions of the bases, therefore, must necessarily produce a solid axis to the branch.

Thus is produced the horny stem of the sea-fan (Gorgonia), which was long considered of vegetable origin. The polyps, which, in these corals, form a coating around the horny axis, often secrete, within their tissues, lime enough to give considerable firmness to the coating, making it a crust to the axis: yet in some species this crust, when dry, so readily peels off, that the specimens in cabinets are often the mere black branching axis of a Gorgonia. The coating of polyps, in other species, remains entirely fleshy, and in these, the axis is always stripped of the polyp-exterior, after drying and washing: the Antipathes are examples of this, in which the axis is corneous—and the red or noble coral of the Mediterranean (Corallium), an example, with a calcareous axis.

The texture of these secretions in Gorgoniæ, was long since well illustrated by Ellis; and plates ii. and ix., of his posthumous work, contain illustrations of some of the principal varieties. Sometimes they are solid throughout, with but slight indications of a concentric structure. In other species, the interior is less firm, and appears like a pith to the stem,—a peculiarity easily accounted for by the fact that this portion is the production of the *young* or apical polyps alone (§§ 70, 74). Occasionally, they consist of an aggregate of short fibres, placed longitudinally, and compacted more or less firmly together.

From a general survey of the facts, it is evident that these secretions are epidermic: moreover, they appear to be generally elaborated in short fibres, successively applied to one another, and form thus successive layers, which may occasionally be distinguished. They have a relation in origin, use, and composition, to the fibrous *byssus*, secreted by the foot of certain molluscs, and are formed like the epidermic appendages generally (nails, &c.) of the higher animals.

The common Actinia is said to attach itself at base by means of a glutinous secretion, which may be analogous to those of the Gorgoniæ, although differing in not admitting of accumulation. It seems probable, as was suggested to me by my valued associate, Dr. C. Pickering, that the Velella and Porpita are closely allied to the Actiniæ; and the structure of the tentacles and mouth seems to confirm this opinion. If this be true, the cartilaginous shield, with the thin process called *the sail*, corresponds to the foot-secretions here described. The animal floats with the tentacles downward, and the sail raised to the wind, by which it is wafted over the surface of the ocean. The air-disk in the base of the Actinectæ, acting as a float for the animal, is apparently similar in origin to the disk of the

Porpita and Velella, though different in its cellular texture. Excluding these doubtful instances, foot-secretions are confined to the group Alcyonaria, and the single genus Antipathes among the Actinaria.

50. *Chemical Constitution of Coral Secretions.* We find as early as in Marsigli, the results of some experimentings on corals, in the rude chemical methods of the day; but the first examinations of any value, are those by Charles Hatchett, in the Philosophical Transactions, for 1800;* and these give us at the present time the most definite information hitherto published with regard to these secretions.

Mr. Hatchett found the stony corals, as far as he examined them, to consist of carbonate of lime, with some fibrous membranes or "loose gelatinous substance," which, in certain species (Dendrophyllia ramea, Myriozoon truncatum), retained, in some degree, the form of the coral after its digestion in nitric acid. In a Nullipora, (now classed with the vegetable kingdom,) he found, besides carbonic acid, a small proportion of phosphoric acid, together with a substance retaining the form of the nullipore, "of which a strong white opaque membrane formed the external part, and a transparent gelatinous substance the interior."

His observations were most extensive with the Alcyonia tribe. The horny axis of the Gorgonidæ afforded him generally a large proportion of cartilage, with some phosphate and carbonate of lime. In the Gorgonia ceratophyta, and flabellum, the proportion of phosphate was large, and, in one species, the composition was very near that of stag-horn. While in others, the G. umbraculum, verrucosa, &c., he found no phosphate. The cortex in these zoophytes consists largely of animal membrane, with much carbonate of lime, and, in some instances, a trace of phosphate. The tubes of a Tubipora afforded a like constitution without phosphoric acid, and the Corallium, the same, with a small portion of phosphate. The red colour of these species was destroyed by the acid, but that of a Melitæa was precipitated in nitric acid as a fine red powder.

Mr. Hatchett concludes, from his investigations, that corals, bone, and horn, have an analogous constitution differing only in the proportion of the ossifying ingredients.

Mr. J. E. Gray has shown that the interior of some Gorgonidæ

* Philosophical Transactions abridged, vol. xviii., pp. 706, 725.

consists of siliceous spiculæ, and has founded upon this character his genus Hyalonema.*

51. Mr. B. Silliman, Jr., has been engaged in a series of analyses for this work, the detailed results of which will be given in the Appendix. We merely state here, that he has found in most of the calcareous corals examined, a small per-centage of magnesia, alumina, iron, silica, phosphoric acid, and fluorine, besides the carbonate of lime, which constitutes, after separating the animal matter, from ninety-seven to ninety-nine per cent. The horny stem of the Gorgonia setosa afforded him a considerable proportion of alumina, besides phosphoric acid, some carbonate of lime, and ninety-three per cent. of animal matter.

We have a sufficient source for the elements of these ingredients in the food of the polyps united with the waters of the ocean. Through their animal functions, such changes and recompositions take place, in the material thus received, as are required for the coral secretions.

III. Reproduction by Buds—The Compound Structure.

52. In the preceding pages, on the Actinoidea, we have considered merely the simple polyp, in which reproduction takes place only by ovules, produced from the internal lamellæ, and escaping by the mouth of the parent-animal. These polyps, in very many species, increase also by *buds*, and thus, from the single parent, perhaps but a fraction of an inch in size, zoophytes may spread their branches to a height of many feet. As we find the origin of the various forms of corals, in this power of developing buds, connected with some peculiarities in the animals themselves and their mode of growth, this subject is one of prominent interest. We may first consider simply the process of budding, and afterwards point out the different modes by which the budding process gives rise to the forms of zoophytes.

1. The Process of Budding. 53. Buds proceed from different parts of a parent-polyp: those from the sides are called *lateral* or *inferior* buds; and those from the upper extremity, either just exterior to the tentacles, or from the disk, are *terminal* or *superior* buds.

The nature of the process is, in general, very similar to that described under the Hydroidea (§§ 15, 16). In lateral budding, a small protuberance appears on the side of the parent, into which the visce-

* Proceedings of the Zoological Society of London, 1835, p. 62.

ral cavity of the same is usually prolonged: developement goes on, and shortly a mouth and a circlet of tentacles appear at the extremity. In some cases, the visceral cavity of the young continues afterward to open into that of the parent; yet, generally, the communication gradually closes as the young grows, leaving usually an imperfect cellular connexion.

In other instances, especially when the buds appear outside of the disks (a variety of terminal budding), there is not at any time a connexion with the visceral cavity of the parent, except through the intermediate lateral pores or lacunal spaces.

In disk-budding, a new mouth opens in the disk, without any previous external indication of the changes in progress; and, as the disk is situated over the visceral cavity, the new polyp for awhile, at least, shares with the parent in this cavity: in many instances, the two animals subsequently become separate by a process of growth, hereafter to be described (§§ 77, 79). There is no satisfactory evidence, as yet, that the budding polyp divides the stomach of the parent as well as the visceral cavity.

The budding process goes on without any necessary connexion with coral secretions. These secretions, however, are usually in progress at the same time within.

The buds, both inferior and superior, in many instances, become nearly adult polyps, before they give out other buds. Very frequently, however, a budding *shoot* continues lengthening uninterruptedly, like the creeper of a plant, and gives out buds at intervals. These shoots are called *stolons* or creepers by Ehrenberg, who first laid down the distinction among zoophytes. Broad plates of polyps, and the margins of many massive species, increase in this manner, by a gradual extension outward, and an accompanying production of buds.

54. Milne Edwards has shown, that the lateral buds in an Alcyonium are developed from one of the visceral lamellæ—the same parts that produce ovules. He found that the new visceral cavity, where it opened into that of the parent, intersected a lamella, and that this bisected lamella was deflected into the cavity of the young polyp. It would hence seem, as Edwards suggests, that the bud is the developement of a germ or germinating cellule laterally through the sides of an animal, instead of its maturing within and escaping through the mouth. This indeed should be inferred from the nature of germination. The general result is the same, whether a cellule developes an ovule, or a bud; for it is an animal with like powers and

structure in the two cases. The germinating power required is, therefore, similar, and might be expected to belong to the same reproductive organs. It hence appears, that while the margins of the ovarian lamellæ develope ovules, the inner portions often develope buds. Milne Edwards farther states, that the side of a visceral cavity which gives out buds, does not produce ovules within. The formation and growth of the bud absorbs, for the time, the general reproductive powers of that part of the parent-polyp.

The disk-buds, like the lateral, probably proceed from one of the same lamellæ, and they differ from the latter principally in the position of the budding-point, which is immediately below the disk, instead of from an inferior *lateral* origin.

2. INFLUENCE OF THE POSITION AND CHARACTER OF THE BUDS, AND MODE OF GROWTH, ON THE RESULTING FORMS OF ZOOPHYTES. In the exposition of this interesting subject, it is important in the first place that some idea be given of the various forms which zoophytes assume. We shall next consider how far modes of growth influence these forms, and then to what extent they depend upon the additional function of gemmation, and proceed from the positions, character, or periodicity of buds.

A. FORMS OF ACTINOID ZOOPHYTES.

55. Many of the various shapes which these zoophytes assume, are familiarly known. Madrepore shrubs and trees, and the sea-fan and other Gorgoniæ, from the West and East Indies, are common in collections. The hemispheres of *brain-coral* (Meandrina), and also of *star-coral* (Astræa), are often met with. It is very generally supposed, that these are by far the most frequent, if not the only shapes presented; but, on the contrary, the varieties are extremely numerous, as we have already intimated. Some species grow up in the form of large leaves rolled around one another like an open cabbage, and *cabbage-coral* would be no inapt designation for such species. Another foliated kind consists of leaves more crisped and of more delicate texture, irregularly clustered;—*lettuce-coral* would be a significant name. Each leaf has a surface covered with polyp-flowers, and was formed by the growth and secretion of these polyps. Clustered leaves of the acanthus and oak, are at once called to mind by other species; a sprouting asparagus-bed by others. The mushroom is here imitated in very many of its fantastic shapes, and other fungi, with mosses and lichens, add to the variety.

The vases of flowers, to which allusion is made on a preceding page, are common about the reefs of the Pacific. They stand on a cylindrical base, which is enveloped in flowers when alive, and consist of a network of branches and branchlets, spreading gracefully from a centre, covered above with crowded sprigs of tinted polyps. The vases in the collections of the Expedition, at Washington, will bear out this description, although but the lifeless coral.

The domes of Astræas are of perfect symmetry, and often grow to a diameter of ten or twelve feet without a blemish. The ruder hillocks of Porites are sometimes twenty feet across. Besides these, we might describe columns, Hercules' clubs, and various strange shapes which are like nothing but themselves.

56. Each one of these compound zoophytes commenced from a single polyp; bud followed bud, and so the germ grew up into the coral tree or dome. Calculating the number of polyps that are united in a single Astræa dome, twelve feet in diameter,—each covering a square half inch,—we find it exceeding one hundred thousand; and in a Porites, of the same dimensions, in which the animals are under a line in breadth, the number exceeds five and a half millions; there are here, consequently, five and a half millions of mouths and stomachs to a single zoophyte, contributing together to the growth of the mass, by eating, and growing, and budding, and connected with one another by their lateral tissues and an imperfect cellular or lacunal communication. There is hence every variety, as to number, among compound zoophytes, down to the simple polyp, which never buds at all, and has, for its corallum, a simple calicle;—it may be a tiny goblet, with a stellate cell, as in the Cyathina—a cylindrical cup, as in some Dendrophyllias—or a radiated disk, as in the Fungias and Cyclolites.

57. To give a more complete survey of the subject, the following varieties of form are here enumerated.

1. A simple cylindrical or turbinate calicle: Cyathinæ, some Caryophylliæ and Cyathophylla.

2. A simple radiated disk: Fungiæ, Cyclolites.

3. A conical cap, or inverted basin or cup: Polyphylliæ, Zoopili, Halomitræ, some Fungiæ.

4. An upright basin or cup on a short pedicel: some Pavoniæ and Manoporæ.

5. Solid hemispherical domes: many Astrææ and Meandrinæ. These are sometimes nearly or quite globular. In some Cyathophyllidæ, these masses consist of separable columns.

6. Rude hillocks, gibbous or nodular masses : many Porites, Alveoporæ, and some Astrææ, Meandrinæ, Gemmiporæ, and Manoporæ.

7. Plates incrusting dead corals, in some species, sending up rude branchings: many Manoporæ, Milleporæ, Agariciæ.

8. Simple and branched columns and club-shaped masses: many Porites, Gonioporæ.

9. Clustered leaves or folia, which may be erect, as in some Milleporæ, Pavoniæ, and Echinoporæ; or, spreading from a base, and rolled round one another, as in certain Gemmiporæ, Manoporæ, Echinoporæ; or, clustered into convex or hemispherical clumps by upward and horizontal growth from a centre, as in many Merulinæ, Pavoniæ, Tridacophylliæ.

10. Clumps of clustered branches from a common base; a mode of growth described as *cespitose*, and often producing very regular hemispherical zoophytes, as in many Mussæ, Euphylliæ, Caulastrææ, Caryophylliæ, Porites, and Madreporæ. In many species of the last two genera, the branches often grow together by coalescence.

11. A horizontal network of branches spreading outward and bearing erect branchlets: many Madrepores.

12. A horizontal plate produced by a complete coalescence of horizontal branches, and bearing above short finger-like branchlets: many Madrepores.

13. The spreading tree, a mode of growth styled arborescent: many Madreporæ, Dendrophylliæ, Gorgonidæ, and Antipathes.

14. The slender twig, either clustered or simple, straight or twisted: many Gorgonidæ and Antipathes.

15. Fan-shape, or with the branches spreading in a single plane, a form styled flabellate: many Gorgoniæ.

16. Reticulate; produced by a coalescence of branches and branchlets into a kind of network: some fan-shaped Gorgoniæ and the Auloporæ; also, less perfectly in some horizontally-growing Madreporæ.

17. Pinnate, where the branchlets proceed regularly from opposite sides of the branches: some Gorgonidæ and Antipathes.

18. Clumps of clustered parallel tubes, united or not at intervals by transverse plates or processes: Tubiporæ, Cornulariæ, Syringoporæ.

19. Similar to the last, but the tubes embedded below in a loose calcareous mass: Anthophylla.

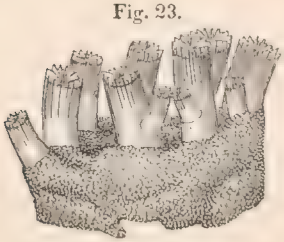
These varieties of form are illustrated in the accompanying Atlas.

B. Modes of Growth.

58. There are several ways in which the mode of growth affects the forms of zoophytes, depending on the two following considerations:—1. The mode of connexion between the bud and parent; 2. The mode of growth of the parent and its budding polyps.

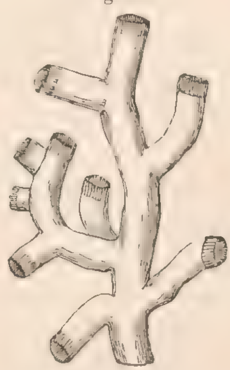
a. 59. The union between the bud and the parent may be simply basal: the young starts out from the sides of the parent and forms finally a prominent branch. Such is the case with the species here

Fig. 23.



Anthophyllum cespitosum.

Fig. 24.



Caryophyllia arbuscula.

figured. In figure 24, the branches thus formed are all distinct; but in figure 23, representing an Anthophyllum, the polyps are united below in a common base, which gradually increases, as the whole grows upward, and surrounds the lower part of the cells.

60. In other instances, the bud and parent have a lateral connexion nearly or quite to their summits, as is illustrated in the Astræas, Porites, and the massive corals generally. When this connexion extends to the very summit, the polyps appear embedded throughout: but otherwise they are more or less prominent above the general surface; and when the prominent part of a polyp secretes lime, the corallum is covered with *calicles*, as in the Madreporæ, Dendrophylliæ, Oculinæ, Gemmiporæ, and some Astrææ.* But if no calcareous secretions take place in this part, as in the Porites and Goniopora (§ 46), the cells are immersed, as in the case of immersed polyps. The Goniporæ, and many Porites, when alive and expanded, have the polyps standing prominent over the whole surface of the

* See the figures 27, 28, 29, 31, and 34, as well as those of these genera in the Atlas.

zoophyte, arising from the fact that the coral secretions take place only from the lower parts of the polyps.

It is hence apparent, that by this single difference in growth, the same mode of budding may produce either massive forms—globular or ramose—or a branched zoophyte, in which each branchlet is the growth of a separate polyp. The former mode of growth produces what may be styled *aggregate* zoophytes, as is exemplified in figure 23, and in the various genera just referred to. The latter gives rise to *segregate* zoophytes, the polyps being separate from one another, excepting a basal connexion. The coralla, in the latter case, may be described as *calicularly* branched. This subject will be farther illustrated when treating of the modes of budding.

b. 61. Germ-polyps differ essentially in their mode of increase,—a process intimately connected with that of budding. The adult animal, commencing a zoophyte, sometimes seems to raise itself on the coral it secretes, and, although but a fraction of an inch in height itself, gives rise to stems many times its own length. This is the case with the species represented in figure 24, in which only the tips of the branches, for a line or less, are alive. The part below dies as growth proceeds above, and so growth and death go on at equal pace till the small polyp is finally supported upon a long pedicel of dead coral. This is styled an *acrogenous** mode of increase. In the example referred to, and many others among coral zoophytes, there is no connexion whatever between the several polyps of the group, except for a short time after a bud first starts, the process of growth causing after awhile a complete separation between each bud and its parent.

Other species are incapable of this indefinite upward growth; and these consequently scarcely exceed their adult size in height, above the point from which they start into existence. Yet many of these give origin to large zoophytes. Instead of increasing upward, they extend themselves laterally, or *widen* by growth and budding. This result may be connected both with *lateral* and *terminal* budding, as shown in figures 27 and 33.

62. The singular process of dying below, while upward increase goes on, is illustrated by nearly the whole class of coral zoophytes, and may receive here some farther illustration.

An Astræa dome, twelve feet in diameter, although solid coral through its interior, is alive for only half or three-fourths of an inch

* From αxρον, top, and γεννaω, to increase.

from the surface; so that the live portion, could it be separated, would form a thin hollow hemisphere. The depth to which life extends, may, in general, be estimated from the diameter of one of the polyps; for in the Actiniæ, as well as the Astræas and Caryophylliæ, the depth (or height) often exceeds but little the diameter, and very seldom, in any species, three diameters.

Even the branching Madrepores are usually lifeless along the axis of the branches; and in the Porites, whether forming a branch half an inch in diameter, or a glomerate mass of twenty feet, the polyps do not extend within, beyond two lines. The interior is dead coral, the former animal tissues of which have dried up.

The branching or columnar coral zoophytes are not only dead along the axis, but they become *throughout* dead at bottom, after attaining a certain height. The addition of an inch at apex is death to an inch below. Some Goniopores, which grow in columns, two feet or more in height, have a head of live polyps—a capital to the column—of only two or three inches.

Upon this principle of growing and dying, depends the vast power and geological influence of the coral polyp. But a few lines in height themselves, they would otherwise be limited in their coral-making to as many inches at the most, and what is now styled the coral-garden, would be but a bed of mosses or incrusting lichens. Like the sphagnous moss of a peat-swamp, coral zoophytes continue growing at top, with none the less luxuriance, though supported on several feet of lifeless trunk. Death follows on "æquo pulsat pede" up the stem of a zoophyte "regumque turres."

The nature of this dying process seems to be simply this: that circulation loses its activity below, as growth proceeds above, and, consequently, the parts dry up in the pores of the corallum. In the Astræas, this takes place continuously, at the same rate as increase above, and produces a gradual change of the animal. In some Cyathophyllidæ, the same process goes on interruptedly, as explained by Ehrenberg The tissues of the polyp disappear at intervals from the sides, leaving a row of unoccupied cellules; and the animal afterwards goes on to increase from its contracted size, without refilling the cellules, which are, therefore, left vacant, though usually closed above at the time of the retraction. Thus the surface of the zoophyte becomes covered with encircling ridges, and the corallum appears to consist of a series of inverted cones inserted one in the other. There is a gradual transition from species, in which these interrupting ridges are prominent and large, to others, where the surface is smooth. Some traces of them are seen in the recent Mussæ and Euphylliæ.*

The transverse dissepiments secreted across the cells of the Pocilloporæ, Favosites, and many Cyathophyllidæ (§ 46), appear to be connected, as suggested by Ehrenberg, with this process of dying or removal below. The base of the polyp, or, at least, the central part of it, is withdrawn at intervals, and after each withdrawal, a new plate is secreted by the base of the animal.

It is obvious from the preceding, that the polyp, which is the germ of a compound zoophyte, loses its identity, and cannot be said, in any proper sense, to have the long life which is attributed to the full-grown zoophyte itself; or else, we might have, among the huge Astræas of the Red Sea, polyps that were cotemporaries with the builders of the pyramids.

C. Coalescence of Branches.

63. The forms of zoophytes are farther modified by the frequent coalescence or growing together of branches. A clump is sometimes so united in this way, that only the branchlets at the extremities are entirely free; and occasionally a branching corallum finally becomes nearly solid, a few holes intersecting or riddling the mass, being the only indications within that it was a ramose species. When the species ramifies in a plane, the coalescing branchlets sometimes produce a complete network, as in the sea-fan (Gorgonia flabellum) of the West Indies. The vase Madrepores are other examples of the same. This coalescence is so complete in some of the horizontally growing Madrepores (M. palmata and flabellum), that they form broad solid plates or folia, with perhaps an inch or so of the coalesced branches, free at the margin of the plate.

In foliaceous zoophytes, the same coalescence may take place. In certain species, the folia curve around until the edges meet and grow together, and produce a chimney or tubular form, as in the Echinopora reflexa. Again, a plate folds upon itself, and the parts unite, back to back, so that a species, which usually has polyps only on one surface,—unifacial,—may change its character and resemble *bifacial* species, in which polyps open on both sides.

A broken piece of live coral, placed against another of the same species, will soon grow to it and continue its existence as if unin-

* See plate 6, figure 3*b*.

jured. Or, if fixed upon a piece of dead coral-rock, where it will not be disturbed, it attaches itself, in a short time, at base, to the rock, and becomes the germ of a future clump or tree.

D. On the Modes of Budding and their connexion with the Modes of Growth.

64. In the preceding pages it has been explained, that budding-polyps may have either an *acrogenous* or a *prolate* mode of increase, or that *the two modes may be combined;* and also that buds may be either *lateral* or *terminal*—in other words, *inferior* or *superior;*—and, farther, that the new polyps may be united to the parent at base only, or *segregately;* or they may be united by their lateral tissues also,—that is, *aggregately*.

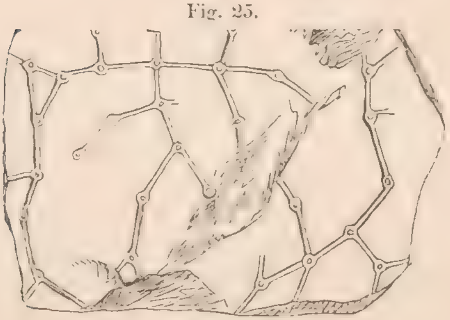
The distinction of inferior and superior buds, is of fundamental importance, and may receive separate consideration. The latter characterize the Astræa tribe of zoophytes, and the former, all other species.

I. Inferior or Lateral Budding.

1. *Lateral budding, without acrogenous growth, in the polyps.*

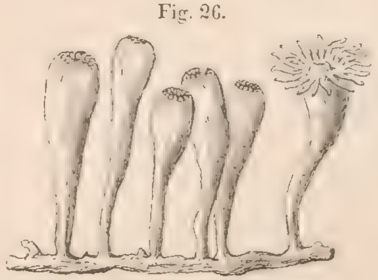
65. When the bud proceeds from the base of the polyp, and in lines, the form represented in the following figures* may result. In the Aulopora, of which figure 25 represents the corallum of a recent

Fig. 25.



Aulopora filiformis.

Fig. 26.



Zoanthus Ellisii.

species, the polyp sends out a root-like tubular fibre from its base, which, after creeping along over the supporting rock to a certain distance, sends up a bud,—a young polyp,—which becomes, after

* See tab. 1, figures 1 and 2, of the Natural History of Zoophytes, by Ellis and Solander, from which the above figure of the Zoanthus Ellisii is taken.

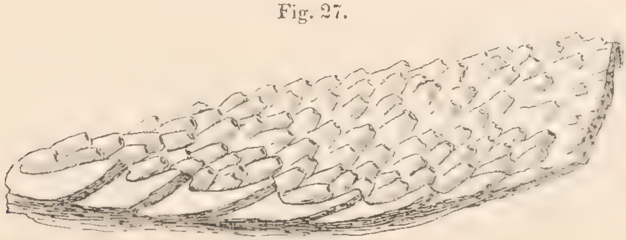
The Aulopora encrusts dead coral. The corallum is a delicate red tube, with small round cells at intervals, from which the polyps expanded themselves when alive.

awhile, an adult, and continues the mode of propagation, until lines of polyps are formed; and these coalesce at intervals, and form a network. The creeping-shoot, in many species, continues growing indefinitely, and sending up buds at intervals, as in fig. 26.

It is plain, that if the buds passing out from the different sides of the base of each polyp should all coalesce by lateral extension, we should have an incrusting plate instead of a simple thread network. And, moreover, when these animals coalesce also by their sides above, as often takes place, the plate would have a thickness equal to the height of a polyp. These different varieties are all well illustrated among the Zoanthidæ, and the last is exemplified in the Palythoa, described in § 30.

66. The same process is also illustrated in the following figure of a Gemmipora, in which the budding is lateral from near the base of the polyps. The buds open at the margin of the growing plate, and each young animal may be traced within to the preceding, as is indicated by the lines of the cells on the broken edge forming the

Fig. 27.



Gemmipora.

front of the figure. Other instances are found in the genus Manopora. Such forms have been called *explanate* or foliaceous.

67. Very different forms result when the buds are not confined to a single side of the parent, as in the Gemmipora, just described. In the Oculinæ, they pass out obliquely from different sides; each one gives out a bud, and that another, and so on successively, somewhat like the budding of the Sertularidæ (§ 16); and the zoophyte, proceeding from the process, is an erect or ascending stem, as in the annexed figures of the coralla of two species of this genus. Each bud is for a time at the apex, but it gradually becomes lateral and then gives off another bud from its upper side. Thus bud follows bud, and the stem slowly lengthens. In these corals there is often a distinct spiral

Oculina.

arrangement of the polyps around the branch, especially apparent at the apex. The spire, in some species, goes around by the right, and, in others, by the left; and a single circuit of the spire appears to contain five polyps, though with some irregularity. In figure 31, this mode of arrangement is seen in an end view of a branch enlarged. The calicles are numbered, to show their relative positions, commencing with the apical as number 1. At the same time that the figures exhibit the spiral order, they also indicate the fact stated, that there is some irregularity in this arrangement.

2. *Lateral budding, with acrogenous growth, in the polyps.*

68. When polyps have the upward mode of growth, different forms result, according as the budding power is general throughout the zoophyte, or belongs only to a limited number of polyps,—the older individuals losing the power by age.

69. *Unlimited symmetrical budding.* If each polyp, as soon as produced, buds like the parent, and retains this power indefinitely, or without limit, the zoophyte will necessarily take on globular or hemispherical forms; for increase, in such a case, takes place equally in every direction. There are certain species among the massive Porites, in which these forms thus result. Yet, owing to a slight irregularity, or the more rapid developement of buds in some parts than others, these zoophytes have generally a form irregularly glomerate, rather than symmetrically globular.

Globular or hemispherical forms are produced in the same manner among the *segregate*, as the massive or *aggregate* zoophytes. The Columnariæ are examples of species consisting of adnate prisms. In the Tubipores, the polyps form, by their secretions, parallel tubes, which, as they grow and give out buds from their sides, necessarily diverge a little, and a convex or hemispherical form is the result. The tubes are united at intervals by transverse plates, which are formed at the budding process, as is apparent from the fact that the buds proceed from these plates; and the internal cavity may be traced into them, though very much reduced in size. The process of budding is similar to that of the Aulopora, except that the polyps have an acrogenous growth, and bud periodically as they grow upward; and, moreover, the buds, at the time they are given out, coalesce laterally into a plate, like the Xeniæ, instead of forming a network: after this coalescence, they lengthen upward between the other polyps, and thus add new tubes to this "organ-pipe" coral-zoophyte.

The Caryophylliæ* afford still other examples of *segregate* zoophytes, with convex forms, arising from the budding function being received equally and retained indefinitely by each polyp. The multiplication of lateral buds causes the ascending stems to diverge, and the clump becomes rounded above. Yet the outer portions of the clump, owing perhaps to their receiving first the waters around, often extend a little the most rapidly, and the form becomes thus flattened convex, rather than regularly hemispherical. The spaces between the branches are quite uniform in the same species, as well as the length of interval between successive buds from the same branch.

70. *A budding cluster.* But when with an acrogenous mode of growth, the polyps, after a certain age, lose the function of budding, the zoophyte, commencing as a small hemisphere, lengthens upward into a cylinder, whose diameter is determined by the breadth of the *budding cluster*. This cluster constitutes the extremity of the stem or branch, and, as it is constantly forming new buds, the older polyps of the cluster, at the same rate, are turned out, and joined to the lateral non-budding polyps of the branch. By this process, the branch continues to elongate. The Porites, Sideroporæ, and Pocilloporæ, afford examples.

Stems produced from a budding cluster have generally rounded or flattened summits. Exceptions to this are found in some Seriatoporæ. In these species, the budding cluster is quite small, containing but six or eight polyps; the three or four alternate push out buds nearly simultaneously at the very apex, and then the others, another set beyond these, each set constituting successively the apex, which is consequently pointed. In some Gorgoniæ, also, in which the budding cluster is very small, the stems are pointed.

71. *Budding from an apical or parent-polyp.* Instead of a budding cluster, the Madrepores and Dendrophylliæ have a single *budding* or *parent-polyp* at the apex of each branch, from the sides of which the lateral buds are given out.

This is shown in the following figure of a Dendrophyllia. The terminal polyp is the parent from which all the polyps of the branch have proceeded.

Each branch of a Madrepora, in the same manner, has its parent-polyp. In these genera, the branches have a conical or tapering extremity, while in those which grow and bud from a *cluster*,

* The Cladocoræ of Ehrenberg.

the branches have no one polyp at apex more prominent than the others. In the Madrepores, a spiral arrangement of the polyps may sometimes be distinguished, resulting from some regularity in the developement of buds, in turn, from the different sides of a parent-polyp.

Fig. 31.

Dendrophyllia.

72. A periodicity in the budding process is well illustrated in the jointed corals of the Gorgonia family. The Melitæas form *foot* and *tissue* secretions, like the true Gorgoniæ; but, instead of having the former as an axis, within the others, the two appear to constitute alternating joints. This may be accounted for by supposing the budding to be periodical at the apex of the branch, the new buds adding to the extremity, first, their foot-secretions, and then their tissue-secretions.

73. It is obvious that the form and position of the growing stems must also depend on the *symmetrical* or *unsymmetrical* production of buds. The stem will be cylindrical when the buds are equal and open alike in every direction. If they form only in two opposite directions, in a single series, we have a zoophyte with two-edged branches, as in some Pterogorgiæ.* Or if the buds opening in two directions spread sidewise, instead of forming a simple vertical series, the zoophyte produced is an erect plate, with polyps opening on the opposite surfaces, as in some Milleporæ.

When the budding is *unsymmetrical,* the zoophytes formed are oblique or horizontal. The buds, having an oblique tendency, may pass off at a different angle on opposite sides, or elongate more rapidly on one side than the other, or they may be confined to one side alone.

Cylindrical stems, in consequence of this oblique or unsymmetrical mode of budding, become horizontal, as in many Madrepores; the buds open equally in every direction, but elongate most rapidly on one side of the branch in a horizontal direction. By this mode of increase, the vase Madrepores are produced,† some of which are several feet in diameter.

A few remarks may be added upon *the mode of branching* in these

* The Gorgonia anceps and other species with seriate polyps. † See plates 32 and 33.

corals, before we proceed to consider the peculiarities of growth connected with *terminal* budding.

74. There are two modes of branching:—1. *By a simple furcation of the extremity of a branch;* and, 2. *By the sprouting of a branch from the side of a stem or branch.*

a. Branching by furcation. Furcation of the summits occurs in species which grow by means of a parent-cluster of polyps. It generally proceeds from the accumulation of buds, and the consequent enlargement of the extremity. The budding of polyps in the midst of a budding cluster causes a slight divergence between them, inasmuch as the budding goes on more rapidly than the elongation of the branch. The extremity consequently enlarges a little, and, beginning in this way to exceed the normal breadth of the budding-cluster, furcation commences. The central polyps at the apex lose their budding powers after attaining a certain age, and, as the cluster is thus divided, each part goes on lengthening independently. This effect may be due to the fact that the zoophyte is able to sustain only a budding cluster of a certain size; a variation in the amount of nutriment or other causes affecting the vitality of a species, appear, however, to vary this size, and many irregularities in the same specimen may be traced apparently to this cause (§§ 84, 85). It is not possible generally to detect a periodicity in the developement of buds causing the furcation. Yet it is apparent in some instances in which the stem retains its cylindrical form for a considerable length, and then rather abruptly enlarges and subdivides. In all instances, there is much uniformity in the frequency of furcation, or the length of a branch before the process begins. The forms resulting from this mode of branching are crowded cespitose clumps, and have rarely the arborescent shapes, common where branching takes place by lateral shoots.

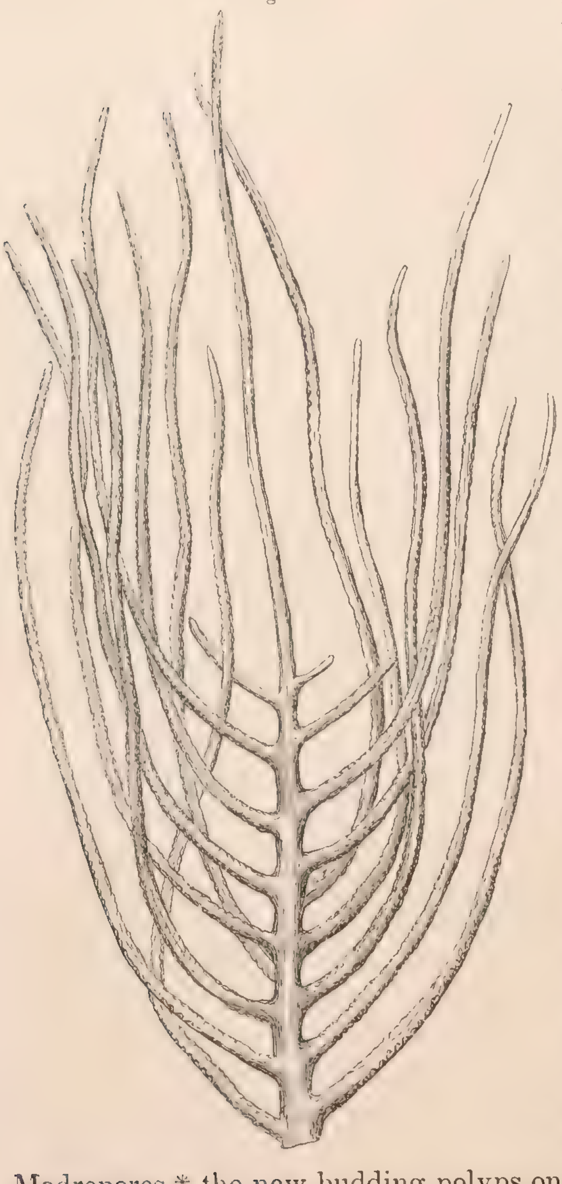
When the polyps of a parent-cluster rapidly elongate, the cluster does not enlarge at apex, and such species, therefore, cannot branch by furcation. The Gorgoniæ afford illustrations of this.

Other examples of furcation are connected with terminal budding.

b. Branching by lateral shoots. In species which branch by lateral shoots, the process of branching depends generally upon the capability of certain polyps, below the summit, to become, after a certain time, budding polyps. The growing stem of a Madrepore would retain unchanged its simple cylindrical form, were it not possible that some of the polyps below should develope gemmating functions. This actually takes place. A polyp from those of the lateral surface commences to enlarge, and then to bud and lengthen, till finally a branch is formed, the new budding polyp being the parent-polyp of the branch.

c. This change occurs at certain intervals upon the branch, though with considerable irregularity, depending on exposure, position, food, and other circumstances. The uniformity is, however, so general that a particular mode of branching is characteristic of each species, and is readily distinguished. In some Madrepores, the branches are distant and long, and often between the large branches, are others, short and rudimentary, at nearly regular intervals. The gemmating powers of the apical polyp in these smaller branchlets are soon exhausted, and only at considerable distances can one of them continue to bud and become one of the larger branches. The lateral polyps sometimes assume budding functions very early, and then the branchlets are numerous, and crowded.

Fig. 32.



d. In certain species, the gemmating polyps are developed only on a particular side of a branch. In the horizontally growing Madrepores,* the new budding polyps on the main branches are con-

* See plates 32, 33, and 34.

fined to the side which faces obliquely outward and downward; and it is by this means that the horizontal growth is carried on.

e. Again, the budding polyps are sometimes confined to two opposite sides of a branch, and pinnate forms result—that is, branches, with two opposite rows of branchlets, as shown in figure 32, representing part of a branch of the Gorgonia setosa. In this species, there are one or two rows of minute polyps on one side of a branch, and one on the other; the branch elongates by a succession of buds, the new buds opening at the very apex. Branchlets—or pinnules, as they are called—bud from both sides, and from either of the rows, on the side which has two, but from only one at a time. There is usually an interval of five or six polyps on each side between the pinnules, and owing to this they are mostly about one-third of an inch apart. The buds are sometimes alternately from the two rows, but often continue in one for some distance, and then change to the other, or alternate again. Owing to this want of perfect uniformity, and sometimes a spiral twist in the stem, the pinnules are somewhat irregular, or a little zigzag in position. The pinnules elongate by apical budding to a certain length, without any increase in diameter; but they sometimes give out lateral pinnules below, and thus commence to become branches. In the change of a pinnule to a branch, one or two from among the lower polyps begin to bud: the growing pinnule goes on elongating, and shortly, on the other side of the same, another polyp, or pair of polyps, buds, and originates a second branchlet; and then, when lengthened at apex a little farther, another starts on the opposite side, each new budding-point being at a nearly uniform distance from the apex. In this manner, the lengthening pinnule becomes a pinnate branch.

f. The positions of branches, as well as their size, are strikingly alike in different specimens of the same species. The angle which the polyps make with the axis of the stem, is the angle with which the new branch begins. This angle varies little in the same species; it is sometimes quite small, and the branchlets are then nearly erect and crowded together; but sixty degrees is the more common angle, and in some instances it is ninety degrees, or the branch is even reversed a little. The branches, when spreading, usually curve upward as they elongate themselves, and sometimes become vertical, an effect which appears to proceed in part from the influence of light; that is, the propensity of the polyp to grow upward towards the light. The horizontal Madrepores (plates 32, 33) follow the same principle, and every new branchlet, though at first nearly horizontal, soon becomes erect. The Madrepora prostrata, plate 33, figure 1, is a good example of this process, as well as the other corals of the same plate, and all the vase Madrepores. Were it not that the new budding-polyps were developed on the *outer* side of the branches, the zoophyte would at once lose its horizontal position. The branchlets in these species, after becoming erect, are symmetrical in their mode of growth. The formation of parent-polyps, on the outer side of the main branches, is favoured by the more perfect exposure to the fresh ocean waters than is enjoyed in any other part of the zoophyte.

This mode of branching produces generally arborescent forms, and is mostly confined to species budding from a parent-polyp. Yet the Gorgoniæ, Seriatoporæ, and Porites, afford examples of the same result, from parent-clusters. The wart-like prominences over the surface of a Pocillopora, may be produced by an analogous process. As the budding-cluster of the apex enlarges by growth, and the older polyps join those of the lateral surface, small clusters of two or three in each, at nearly regular intervals, retain the budding power, until these prominences have a certain length, usually not exceeding two lines.

Budding of a branch.

75. Besides the budding of a single polyp, there are some species which form a group at a single budding process. This fact is pointed out by Milne Edwards, in his description of an Alcyonium.* A knob or protuberance swells out from the surface, which, on dissection, is found to be penetrated by tubes branching and subdividing towards the surface, and all proceeding from a common trunk, or a collection of trunks, which branch from one or more, as the case may be, of the old polyps. The young polyps were distinguishable at the extremities of the tubes before they made their appearance externally; and finally a cluster of animals was developed, and a new branch added to the zoophyte. This process appears to be confined to this division of the Actinoidea.

II. Superior or Terminal Budding.

76. While in *lateral* budding, increase, in the prolate growth of a zoophyte, takes place from the extension of the lower part of the polyps, in *terminal* budding it proceeds from the extension of the summits. This process of widening in the budding-polyps may be confined to the parts exterior to the disk and visceral cavity below, or

* Ann. des Sci. Nat., 2d Ser., iv. (1835.)

the disk and cavity may continuously enlarge; in the latter case, the buds open in the disks, the process of budding being the cause of their enlargement.

b. The following figure of a foliaceous Echinopora illustrates the process where the growth is a simple marginal prolongation not extending to the disks.

Fig. 33.

Echinopora.

By the prolate mode of growth, the polyps gradually extend outward, and new buds open, from time to time, a short distance from the edge, and have no connexion at base with the preceding polyps. The corals of these species have the upper surface striated, indicating the presence of visceral lamellæ within the extending part, from which buds may proceed. The contrast between this and the Gemmipora (§ 66), in each of the above particulars, is made apparent by a simple comparison of the figures; for in the latter, the buds, besides opening at the very margin, may be traced within to a preceding polyp, from which each is a lateral shoot: and, moreover, the surface is not striated.

c. The above Echinopora, and other foliaceous corals among the Astræidæ, are examples of *prolate* growth without the *acrogenous.* But the massive Astræas are produced by the united action of these two modes of growth, and their hemispherical forms result from the perfect regularity and symmetry in the process of budding.

Fig. 34.

Astrea argus.

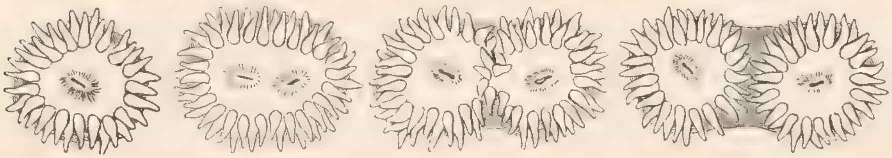
d. Several species of Astræas afford examples of the mode of gemmation, illustrated in the Echinopora, among which is the Astræa argus. While the margin of the hemisphere is extending by the multiplication of buds, precisely similar to that above, the whole surface is also gradually enlarging by a widening of the intervals between the polyp-disks. But this widening is kept within limits by the appearance of new buds in these intervals when they begin to exceed a certain breadth. In the annexed figure, a small cell between four polyps belonged to a young polyp, which was one of these new buds. The young continue enlarging, till the adult size is attained, and then the intervals going on to increase, other buds open. The elevated lines, which striate radiately the spaces between the cells or stars, indicate what we have before stated, that the visceral lamellæ are prolonged beyond the visceral cavity, through the interstitial spaces between adjoining polyps; and it is possible that the new bud proceeds from one of these lamellæ, though appearing at the middle of the interstitial space.

77. When the prolate growth is attended by a widening of the *disks*, the buds, as stated, open in the widening disk. In the Meandrine zoophytes (plate 8, fig. 1, and plate 14), bud follows bud, and the widening continues, until the disk, instead of being circular, as in the *Astræa argus*, or in the germ-polyp with which the Meandrina commenced, has at last a long linear form, often very flexuous, and contains a large number of polyp mouths; and, *beneath*, as many polyp stomachs, all communicating apparently with the same visceral cavity, or connected with one another by a system of large interlamellar spaces. In the Merulinæ, we have *foliaceous* corals illustrating well this mode of growth; and they are the analogues, in this division of the Astræidæ, of the Echinopores, among the preceding. The lines of polyp mouths continue extending outward, separated by narrow lamellate ridges, and the new buds open near the margin of the folium, on the surface of the extending disks (plate 15).

b. The length of these meandering disks, and their flexuous furcations, seem sometimes to be indefinite. Yet in other species they have their limits. After elongating for a while, a ridge forms across, and a subdivision is produced. The proper Astræas, with prolate disks, differ from the Meandrinas in this subdivision taking place after the opening of each new mouth in the disk, in consequence of which, the form may become a little oblong, but is soon restored to a circular shape again. This is illustrated in the following figures, which show the progress of external changes.

The simple disk becomes oblong (fig. 36), and a new mouth opens. A subdivision commences (fig. 37) as growth goes on, and finally the disk entirely subdivides (fig. 38), and each part is surrounded by its own circle of tentacles. This division appears to commence whenever the number of lamellæ—which is constantly increasing—has reached the limits that belongs to the adult animals. In the corallum, it may be seen to begin by the union of two opposite calcareous lamellæ, and the gradual formation of other lamellæ, each side of the united pair, in completion of the circle in each cell.

Fig. 35. Fig. 36. Fig. 37. Fig. 38.



This process resembles somewhat the spontaneous fission of the monad, and is compared to it by Ehrenberg. From the illustrations given, it appears to be altogether analogous to budding exterior to the disks, and differs only in the position of the point from which budding commences. This subdivision, though sometimes apparently central, yet often separates only a small portion of the parent; and, instead of being a fission of an individual, it results by a slow divergent growth of the parent and bud. In the Meandrinæ, Merulinæ, and others, the disk-buds open successively in long series, *without* any proper subdivision of the polyps. Moreover, the Astræa stellulata, A. stelligera, and A. intersepta, bud exterior to the disks, and sometimes also within the disks. The Merulinæ occasionally exhibit a few cells very similar to those of the Echinoporæ, thus bringing together these two divisions in the Astræa family.

c. In the Monticulariæ, the elongating lines of disks are united by cross-lines, so that the whole surface appears like a single reticulate disk, with numerous polyp-mouths distributed over it, and having small scattered conical prominences, around which the tentacles are clustered. These species are thus closely related to the Meandrinæ, and the prominences are the remains of the ridges (plate 13, fig. 13).

78. *Relation of the Fungidæ to the Astræidæ.* In the Astræidæ, the lamellæ of the cells, which striate the interstices in massive species, are generally interrupted half-way between adjoining cells, as in fig. 34: in other words, each polyp has its limits distinctly marked in the corallum. But in the Fungidæ, which are closely allied species, there are no cells, and the lamellæ are continuous from centre to centre. We are aided in understanding the relation of the two families, by observing that in some Meandrine species, there are along the bottom of the trench, one to three narrow lamellæ, running

uninterruptedly from one polyp-centre to another. If the polyp-disks, therefore, should be coalescent in a plane in all directions, instead of in simple meandering lines, there would be no proper interstices between the polyps, and no cells, and the lamellæ would be continuous in every direction, from one centre to another. It hence appears, that the peculiarities of the Fungidæ consist in the absence of all interstices between the stars, and a uniform continuation of a single compound disk-surface over the whole. The *process of budding*, therefore, although seemingly like that of the Echinoporæ, is actually identical with that of the Merulinæ, in which buds open in the extending disks. The compound free Fungidæ, the Agariciæ, the Pavonæ, are equally good examples of the characters here explained. In the Polyphylliæ, the union of adjacent polyps is so close, that there is not even a separate series of tentacles to each polyp-mouth, and this character separates these species from the allied Herpetolithi.

79. *Modes of branching.* In species of Astræidæ, which form calicularly-branched coralla, the disks widen and subdivision takes place as in the Astræa above explained, except that the subdivision continues in progress until the two polyps are distinct at base, and each forms a separate branch. The annexed figure represents the whole process. On one branch, two polyp-mouths already exist in the enlarged disk, and at the extremity of the other, furcation has commenced; the furcation seen below, is an example of the subdivision completed. The difference between separation by this divergent growth, and the spontaneous fission of a monad, is obvious. The Mussæ, Euphylliæ, Caulastrææ, grow, and bud, and branch, in this manner; and the process goes on so regularly that the zoophytes are usually perfect hemispheres; the size of the branches, their length before furcation, and the intervals between them, being very uniform in the same species.

Fig. 39.

This mode of branching by furcation is analogous in many respects to that which proceeds from the growth of a budding-cluster.

b. Branches also form by a successive accumulation of buds, nearly as in the Oculinæ. The foliaceous species result from prolate growth, new series of polyps developing successively near the margin: the same foliaceous corals often form elongating processes or stems. One or more polyps at a point in a folium begin to bud and grow prolately *upward;* and bud follows bud, until the protuberance becomes a branch. This may be seen in some foliaceous Merulinæ,* and the ramose species are other examples of the same.

c. These ramose species branch, either by furcation or by lateral shoots. The latter process does not differ from that just described. In the former, the polyps at apex commence simultaneously two or more lines of buds, which lengthen out in the cumulate manner elucidated. This same principle is illustrated in many Meandrine corals. The lines of polyps, as above stated, result from a succession of buds in a single series. These lines frequently furcate or give out lateral branches; the polyp, at the extremity of a line, by originating side-buds, each commencing a separate series, produces thus the furcation. The margin of almost any Meandrina, or of the folium of a Merulina, affords examples of this. The process is connected with the increasing breadth of the margin, like the marginal growth and budding of an Astræa.

In the foliate corals, the folia are constantly subdividing or becoming lobed, on the principle explained in the latter part of § 74 *a.*†

80. *Relation of the Astræidæ to the recent Caryophyllidæ.* The distinction in the mode of budding, and the prominent peculiarities of their coralla, as laid down (§ 48), seem to draw a wide line of division between the Astræidæ and Caryophyllidæ. Yet, as in other departments of nature, there are in fact no such lines; gradual transitions, much to the annoyance of the systematist, link the whole together. By observing the transitions, we may distinguish more definitely where the distinctions actually lie. The Astræas, which commence this transition, instead of budding from near the centre of the parent, or its summit disk, give out buds exterior to the same, as in the A. argus. The polyps differ commonly from those of other Astræas, in being more prominent above the general surface, and the aggregated individuals are not coalescent so nearly to their summits. The interstices are lamello-striate as before, though hardly as prominently so. Following down the transition, we find certain species (A. microphthalma and A. ocellina) in which the polyps stand their diameter in height above the general surface. The union of the

* Plate 15, figure 1.

† See the remarks under the genus Pavonia.

polyps in these is much less near the summits than in the A. argus; and budding, therefore, from the extending margin, approaches inferior budding in position and in character. Moreover, the striæ of the surface, which are prominent lamellæ in the dichastic Astræas (in which the lateral union is most complete), become almost obsolete in these species; and they have, therefore, very nearly the characters of the Oculinæ among the Caryophyllidæ. The Echinopores are other examples of *prominent* polyps, and *obsolescent* striæ to the coralla. The transition is thus so gradual that scarcely a line of demarcation can be laid down: and, in the A. ocellina, although the buds open *near* the extending margin on the upper surface, as in the Astræas and Echinopore, the cell has generally a porous connexion internally with a preceding one.

Yet, in separating the A. argus and allied species from the Astræas, and placing them with the Caryophylliæ and Gemmiporæ, as proposed by Ehrenberg, we should overlook the prominent affinities of the animals themselves as well as of their coralla; and even also the true relations indicated by the mode of budding.

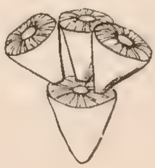
In view of the above, it appears that the Caryophyllidæ ought to have prominent polyps, which is almost invariably the case; this is shown by their prominent calicles, except in certain species (Astroites), in which only the *bases* of the polyps secrete lime.

81. Among the Cyathophyllidæ, there is exemplified a mode of terminal budding, which should properly be classed with lateral budding, as it is not connected with a prolate growth of the upper part of the polyp, and the buds proceed actually from the lower part of the animal, although opening upward. It is illustrated in the following outline figures, made as long ago as 1749, by Fougt.*

Fig. 40.

Fig. 41.

Fig. 42.



Although old, they illustrate sufficiently well the mode of budding to which we refer. In figure 40, each succeeding polyp seems to come from the centre or mouth of the one below, the parent yielding its

* Linn. Amœn. Acad., i., tab. i.

existence at the developement of the young, which thus starts from it. In figure 33, three polyps proceed together from the centre of the parent; and, in 34, the new polyps sprout just exterior to the centre.

Nothing in the history of corals seems more remarkable than this strange mode of reproduction. Yet the fact, that the Tubulariæ and some Sertularidæ, drop their flowers, and renew them at intervals, as explained in § 18, appears to be quite analogous. In these Cyathophyllidæ, the parent, at the budding period, appears to lose its tentacles and disk, as in the Tubulariæ, which may disappear by the withdrawal of nutriment, needed for the new developements in progress; life remains only about the centre, and from this part, the germ rises and the young is produced, the parent surrendering its existence at the birth of its successor, or soon afterward. In the second of the above figures, three young proceed from the ashes of the parent, instead of one. The third figure shows that many germs may exist and grow out from different parts of the summit in the same course of changes. This process is closely related to the interrupted mode of increase explained in § 62.

82. From the preceding discussions, we perceive that glomerate, foliaceous, and ramose forms may occur under each mode of budding and growth. Yet glomerate zoophytes are most common among the Astræacea, and here alone they assume hemispherical or globular shapes of perfect symmetry; branching and foliaceous species are few in number in this tribe, and are distinguished by having the buds open a little below the apex, as well as by their lamello-striate surface. The Madreporacea and Caryophyllacea present occasional glomerate forms, usually of rude shape; but generally they are ramose, and often foliaceous. The branches are not lamello-striate, and the buds open at the extreme apex or margin. The Alcyonaria may produce branching coralla through their foot-secretions, and occasional segregate forms, like the Tubipores; but none are yet known which are properly massive.

Both massive, foliate, and ramose species often belong to the same genus, and in some instances, as before stated, a coral is thin foliaceous in one part, and glomerate in another, or covered with rudimentary branches.

In conclusion, the principal distinctions, as to modes of growth among zoophytes, are as follows:

1. *Acrogenous*, when polyps grow upward indefinitely, death taking place at a corresponding rate below; and the reverse, *non-acrogenous*.

2. *Aggregate*, when the polyps of a compound zoophyte are united to one another by their sides.

3. *Segregate*, when the buds are separate from the parent, except at base, each forming a distinct shoot or branch.

Aggregate corals are covered with calicles when the polyps secrete lime to their summits, but are united to one another laterally only by the lower part of the body.

In *aggregate* zoophytes, *without acrogenous* growth in the polyps, when (*a*) budding takes place in a single extending plane, more or less oblique, *explanate* forms are produced, as in the Gemmipora and Echinopora, the former by *inferior*, the latter by *superior* budding; (*b*) when budding takes place upward, in an ascending cumulate series, more or less cylindrical stems are formed, as in the Oculinæ, branching Echinopores, and also the branch-like processes on the Merulinæ.

In *aggregate* zoophytes, *with acrogenous* growth in the polyps, when (*c*) budding is not limited to certain polyps, nor lost by age, glomerate forms are produced, often regularly hemispherical or globular;—(*d*) when the polyps, after a certain age, lose the function of budding, and consequently this budding power is limited to a number of the younger polyps,—a budding-cluster,—ascending stems are formed, as in the cumulate process;—(*e*) when the function of budding is limited to a particular polyp (*parent-polyp*), similar ascending stems are formed.

Branching takes place by *furcation* (*f*), through the *gradual* accumulation of buds from a parent-cluster, which widens the cluster beyond its normal limits;—or (*g*), through a *periodical* developement of buds in a parent-cluster at apex, widening in the same manner the extremity, and, for the same reason, leading to a subdivision;—or (*h*), where there is no proper parent-cluster, as is exemplified in the cumulate process, by a periodical budding at apex, each bud giving origin to a separate branch. The two last, are but varieties of the same process, and the first is closely allied to the second.

Branching takes place by lateral shoots (*i*), when a polyp on the side of a branch receives budding functions and becomes a parent-polyp;—or (*k*), when a cluster of polyps, on the side of a branch or stem, become gemmating.

In *segregate* species, *without acrogenous* growth, when (*l*) the buds proceed as shoots from the base of the polyps, the zoophyte forms single lines of individuals, which, by coalescence, often become reticulated, as in the Aulopora;—or, *with acrogenous* growth (*m*), the polyp forms an ascending stem, either cylindrical or turbinate. Branching takes place (n) either by lateral shoots, as in the Caryophylliæ, or (o) by subdivision or furcation at apex, as in the Mussæ, Euphylliæ, &c.; and the coralla of these species are, in both instances, styled *caliculato-ramose*. When (p) the branches are laterally in contact, as in the Columnariæ, or are united transversely at intervals, as in the Tubipores, *fasciculate* forms result.

83. We thus perceive the principal steps by which corals take on their specific forms, and see reason for the fact that these forms are constant in the same species. The many varied shapes of zoophytes,—the tree, the shrub, the clustered leaves, globes and hemispheres, clubs, twigs, and coral network,—require for their explanation only the few principles here adduced. The germ-polyp, growing upward and budding as it grows, gives rise to the various branching and nodular zoophytes, while by growth laterally, the *explanate* or oblique foliated species originate. In the upward mode of growth, when all the polyps bud equally, globes and hemispheres are produced; but if the gemmating power is retained only by the recent polyps, the zoophyte lengthens into stems and cylinders. When, in this last process, budding takes place symmetrically, the zoophyte is erect; if unsymmetrical, it is oblique or horizontal; and the zoophyte, when erect, is cylindrical or a flattened plate, according as buds form alike on all sides of a centre, or open in two opposite directions. In some acrogenous species, there is a terminal polyp,—*parent-polyp*,—from which the buds proceed; in others, a terminal *cluster of polyps*. The *former*, ramify by lateral shoots, common polyps changing to parent-polyps, and thus becoming the germs of branches, which take their direction from the position of the budding-polyp; the *latter*, branch generally by furcation at summit, the size of the terminal cluster determining the diameter of the branch, and indirectly occasioning the furcation.

In other species still, each polyp gives out its single polyp in succession, and the continued accumulation produces the rising stem, which ramifies either by the processes just mentioned, or from buds at apex, forming periodically and becoming the germs of branches.

There is much to surprise and interest us in tracing out the simple causes of results so remarkable. The small polyp, incapable even of extending its arms without a drop of water to inject them, is enabled, by means of a simple secretion in its texture, in connexion with the process of budding, to rise from the rock and spread wide its branches, or erect, with solid masonry, the coral domes, in defiance of the waves that break over them. The microscopic germ of a Gorgonia developes a polyp barely visible to the naked eye, which has the power of producing a secretion from its base. The polyp buds, and finally the growing shrub is covered with branches and branchlets, many a mere thread in thickness, which stand and wave unhurt in the agitated waters. The same secretions fix it to its support, and so strongly, that even the rock comes away before the zoophyte will break from its attachment. Tens of thousands of polyps cover the branches, like so many flowers, spreading their tinted petals in the genial sunshine, and quiet seas, but withdrawing when the clouds betoken a storm.

"Excelsior" is the grave motto of the zoophyte. Ever upward, they continue growing and elongating, although death is at work below, with as rapid progress. A beautiful provision protects the branching coral-tree—often the work of ages—from being destroyed by the dissolving waters, when exposed, on the death and removal of the polyps. Certain minute incrusting corals—the Bryozoa and Sertularidæ, together with Nullipores—make the surface their resting-place, as soon as it is laid bare, and go on spreading and covering the dead trunk, and so prevent the wearing action of the sea. The Madrepore may thus continue to enlarge beyond its adult size; the Caryophyllia may multiply almost endlessly its cylindrical branchings, although the living animal but tips the extremities of each; for protection is given at once, when needed, and the polyps die, only to leave the surface to other forms of life, more varied and no less strange.

Finally, the coral becomes subservient to a still higher purpose than the support of polyps and nullipores. The debris, produced by the waves over a reef, settles into the many crevices among the dead trunks, and fills up the intervals, often large, between the scattered coral-patches; and, by this combined action of living growth and detritus accumulations, a solid rocky basement is formed, and kept in constant increase. In this way the coral-reef gradually nears the surface, and finally becomes the foundation of one of the fairest of

> "The sea-girt isles,
> That, like to rich and various gems, inlay
> The unadorned bosom of the deep,"

the coral polyps now yielding place to the flowers and groves of the land, which fulfil their end in promoting the comfort and happiness of man.

CHAPTER V.

THEORY OF ZOOPHYTIC GROWTH AND REPRODUCTION, AND OF ORGANIC DEVELOPEMENT IN GENERAL.

In the preceding pages, we have dwelt upon the structure of the simple polyp, and traced out the principal steps in its germinating and gemmating processes, to the production of the various compound forms of life, which this class of animals presents. We propose to inquire into some of the relations which the several individuals in a compound mass, sustain to one another, and to illustrate the structure of these animals, and the nature of the organic forces within them.

The process of budding opens to us an illustration of the laws or principles of growth and reproduction, in actual and visible progress, and requires, therefore, our first consideration in these investigations; and since vegetation affords us parallel facts, there will be occasion in these discussions, to recur often, and at length, to the vegetable kingdom, and not so much to exhibit merely the relations of plants to zoophytes, as to elucidate, by means of the facts which both present, *the general laws of organic developement.*

84. The reader has already perceived the relation between the position of buds and the form of the zoophyte, and that in connexion with the mode of growth, they determine its character even to the size and direction of each branch, and the number and length of the branchings. The facts have shown, moreover, that there is a simple law governing the formation of buds, and a *system* in their developement. In the Madrepores, which bud from a parent-polyp,—the apical one of each branch,—new branchlets form at certain intervals; of the hundreds of polyps, on the lateral surface of the branches, only here and there one at nearly regular intervals, becomes capable of budding, and so gives origin to a branchlet: and of the budding-polyps, which are thus developed, the most of their branchlets are often short;

gemmation soon ceasing, except in certain shoots, at still longer intervals, which continue growing and lengthen out into large branches. This principle admits of some irregularity, arising from an unequal amount of nourishment, or a difference of exposure, but in general there is a remarkable uniformity. And it is due to this fact, that species have their specific characters displayed in their modes of branching; that some species spread widely, with long even branches, and others, with numerous crowded ramifications; and, moreover, the individuals of a species are alike in their general forms.

This principle determines the distance of a lateral polyp from the apex of a branch, before it can commence to bud, as well as the distance separating branches. The *Gorgonia setosa*, the subject of our illustrations, in § 74, is a beautiful exemplification of this subject, and well merits farther remark. In this species, the lateral polyps rarely bud and form branchlets nearer than six to nine inches from the apex,—eight inches is the average distance,—and, as there are about eighty polyps on the lateral surface to an inch in length, it follows, that generally more than six hundred polyps are situated above the first branchlet. And, moreover, as the branchlets are about a third of an inch apart on each side, polyps enough are added, by budding, to lengthen the apex correspondingly before another side-polyp buds, and another branchlet starts.

What is here indicated, but that the process of budding exerts an inductive influence for some distance from the centre of action,—that there is a concentration of nutriment and of forces required, measured by the interval between the budding centres? In the Gorgonia, just alluded to, some hundreds of polyps are thus, in one sense, tributary to the budding polyps at the extremity; for, until the budding apex has grown beyond to a certain distance, one of the side-polyps, though ready to bud, cannot summon gemmating force enough to develope buds; but when the former is so far removed, that the required nutriment and vital force are supplied, then the excess, which goes on increasing, concentrates upon one of the side-polyps below. The lateral polyp, which becomes a new centre of gemmation, is a certain distance above the preceding branchlet, owing to the fact, that this branchlet exerts its influence for a short distance around itself, though already considerably elongated. The same principle is illustrated even in the irregularities or apparent exceptions. When side branches form low on the stem, the intervals are often much larger than above stated, owing to the less amount of nutriment which these half-covered polyps receive; while at the extremity, in the purer waters, with a large supply of nutriment and more active vitality, the intervals are short.

This principle is not limited to zoophytes: there is evidence that it prevails throughout the animal kingdom; and most decidedly and beautifully is it exhibited in the vegetable kingdom.

85. In the vegetable kingdom, we have, in general, compound individuals, analogous to those among zoophytes. The plant commences with a single bud—a simple individual rises from the ground, the germ of the tree which is in time developed. This parent-individual enlarges and lengthens, and, after a while, buds shoot out from its sides, which become new lateral individuals. Some of these lateral buds, as the stem lengthens, begin themselves to bud and form branchlets, and, at still longer intervals, now and then one continues budding and growing, till a large branch is formed. There is thus a perfect parallelism with the mode of growth in the zoophyte; the same law, with regard to *interval*, holds, and the same general principle with reference to a *gemmating influence*. The terminal bud is analogous to the apical polyp, and the lateral buds to the lateral polyps; moreover, the branchlets and branches are formed by the continued gemmation of certain of the lateral buds, the particular bud, which becomes a parent-individual, depending, in each case, on its distance from other parent-individuals; for, only within such certain distances, is sufficient vital force and nutriment concentrated on any centre or budding point.*

The distinction in plants of *budding* and *ova-bearing* individuals, should be here remembered, as it leads us to still closer analogies between plants and zoophytes. The former produce leaves, and lengthen out the extremity of the branch, as the summit polyp of the growing Madrepore or Oculina. The latter take the form of a flower, and develope ovules or seeds.

It is altogether probable that buds alone proceed from the budding polyps at the extremity of a branch in zoophytes. It is definitely stated, by Milne Edwards, with regard to an Alcyonium (§ 54), that the side of a polyp, which gave out buds, produced no ovules; and, as all sides of an apical or parent-polyp in a Madrepore

* The other modes of branching among zoophytes are illustrated among plants; but it is sufficient for our present purpose to refer particularly to the above. Branching, by periodical budding at apex (§ 82, *h*), is exemplified in some species, and the same principle, depending on intervals, holds, as has been explained.

bud alike, though successively, there are certainly strong reasons for admitting the above supposition. In the Sertularia tribe of zoophytes, the analogy is perfect; for, it is well known that buds and ovules are never simultaneously produced by an individual polyp. Budding lengthens the branches, and vesicles of ovules proceed like a cluster of flowers from the side of some polyp on the branch, that long before had ceased to bud.

86. We may glance here at a few interesting relations between the structure of a *flower* and of an *Actinia*, which, although not essential to the subject before us, may suggest some deductions in illustration of each. The flower or plant individual, has, in general, its radiate series of sepals and petals,—one or both,—for the elaboration of the parts within: so has the polyp its star or coronet of tentacles, which often contribute to the aeration of the nutrient fluids. The flower contains, in other internal series, stamens and pistils (spermatic and ovarian organs), concentric with the sepals and petals: the Actinoid polyp includes within, corresponding series of organs around the centre, part of which are ovarian, and part spermatic, and these organs have some relation in number to the number of tentacles. The clusters of ovules, which form from the ovarian lamellæ, have, therefore a very similar situation in the polyp to the ovules or seeds of a common flower; the circular series of ovarian lamellæ corresponding to the circular series of carpels or the placenta within, and the ovules they form to the seed produced within the carpels. The coincidences are as near as are consistent with the different modes of nutrition in the two kingdoms of nature, and they may be received as sufficient evidence, if such were needed, that the flower is a simple plant-individual.

Between the budding individuals in plants and the budding Actinoid polyp, there seems to be a less perfect resemblance; for the budding polyps in these zoophytes are similar to the oviparous polyps in external form and in the number and character of their tentacles. Yet, as it has been shown by physiologists, that the green leaves of the leaf-bud and the petals of the flower, are nearly identical organs in origin and structure,—the latter being only a variety of the former, —the discrepancy is more apparent than real. The parts of a flower, though seemingly in circles, have a spiral arrangement, as well as the leaves of the leaf-bud; and the difference in general form arises from the fact that the leaf-spire is long drawn out, owing to the continued and rapid elongation of the bud, while in the flower, the spires are extremely short, great concentration being required for the new developements which are to take place. The spiral arrangement, observed in the vegetable kingdom, has not been detected in the tentacles of an Actinia. Yet as this arrangement is due merely to developements taking place successively from the different sides or reproductive points of an individual, in regular order, it is altogether probable that something similar to it may yet be made out. Reproduction is an exhausting process, and on this account it does not take place twice successively from the same side.*

In the developement of polyps in the Oculina, a spiral arrangement is apparent (§ 67); but, as the number of budding points in these polyps is twenty-four, and only five in very many plants, as great a regularity cannot be expected in the former as in the latter; for the intervals between the budding points are so small, that slight causes, especially a freer exposure to the external waters from being less crowded by the polyps in one part than another, will affect the position of the point from which the next bud proceeds.†

* Since this work was put to press, the author has found that Agassiz describes the plates of the Echini, as developed in a spiral order. See Agassiz on the Echinodermata.

† From the above analogies, it would seem that the *gemmating* individuals in plants, as well as the *oviparous*, consist of several leaves combined, and, therefore, that we cannot properly speak of each leaf as a complete individual in itself. Yet the conclusions we would deduce, follow equally well whichever view be adopted. A few other analogies between the plant and zoophyte may be noticed here, on account of their bearing upon the point just discussed.

The developement of flowers exhausts the energies of a plant, sometimes so far as to lead to immediate decline and death. There is a species of palm, which flowers, and soon after dies.[a] The Century Plant is another remarkable example.[b] Have we not an analogous fact in the strange mode of reproduction in certain Cyathophyllidæ, represented in the figures, to § 81 ? The parent, in this case, surrenders its existence soon after the developement of a young bud, which, when completed, actually stands upon the dead remains of its progenitor, preparing to make the same self-sacrifice. A still more perfect analogy to this process is found in the growth of the Colchicum and some allied plants, in which the root of one year dies as it developes the bud of the next. And the general process of growing and dying, in corresponding progress (§ 62), has frequent illustrations in the vegetable kingdom; for instances of which, we may refer to the Botanical Text-book, by Dr. A. Gray,[c] or other Treatises on Vegetable Physiology. In

[a] The Corypha or Talipot tree. Gray's Botanical Text-book, 2d edit., New York, 1845, p. 165.

[b] Ibid., p. 168.

[c] See Botanical Text-book, p. 63, § 86. "The Solomon's Seal and Diphylleia offer simple illustrations. They make an annual growth by the developement of a bud, which, rising into the air, forms the flowering stalk of the season; this falls away in autumn, leaving a broad scar, and meanwhile a new bud is

87. We pursue the subject by looking more minutely into the elements engaged in the process of budding, to ascertain how the principles drawn from the visible bud or polyp bear upon the internal structure of the same. Plants afford us examples that illustrate the facts in both kingdoms of nature. Growth, in its simplest condition in plants, takes place by the budding of minute cellules, each in succession from a preceding; and although vascular tissue and woody fibre are added to the higher species, to give strength, yet, in all

the interrupted surface of other Cyathophyllidæ (§ 62), a similar effect appears to be indicated, but dependent probably upon the developement of ovules rather than buds, (and the preceding case may possibly be the same), the narrowing of the polyp being consequent, as Ehrenberg suggests, on reproduction. This exhaustion is a well-known fact in the animal kingdom; the peculiarity in the case in question, is only in the mode of exhibiting it, and the extent to which it is carried. There is an analogy in the polyps of certain zoophytes, dropping off and reappearing at intervals (§ 18), to the fall of the flowers and leaves of a plant. Moreover, some species (Sertularidæ) lose, from age, their lower branches like vegetation, the trunk or stem, as in the vegetable kingdom, still remaining alive. Buds often spring from a wound in a plant in greater numbers than elsewhere; and the Hydra affords an example of the same fact among polyps.

The growth of palms has some resemblance to increase, among zoophytes, from a terminal cluster; while budding from a parent-polyp, and the consequent lateral branching, produces forms more like those of our common trees. In the former, the buds proceed from the summit alone, and produce a lengthening cylinder, whose size depends on the size of the cluster; and, as the polyps lose the power of budding, they are turned out from the summit cluster to join those of the lateral surface, just like the bases of the falling leaves in the palm. This mode of increase, is still more like that in the Lycopodium; for, in this genus, there is no internal growth, as there is in the palms: it is simply *acrogenous*, like the elongating coral stem.

The explanate corals appear to be represented in the incrusting or foliaceous lichen, and the massive hemispheres and globes in the globular Cacti; and not only in external form, but in actual constitution, for the Cactus consists of an aggregation of plant-individuals, as the Astræa is composed of individual polyps united.

Farther, we state that the modes of reproduction are as varied in the zoophyte as in the plant. As we may obtain a perfect plant from a section, which includes, with a leaf, its budding axil, so we may cut up a polyp, and, almost to the same extent, form perfect individuals from sections: and, as the leaf will sometimes grow without the axil, so in the rare instance of the Hydra, the tentacle alone is said to develope a complete individual.

Moreover, the mode of aeration, in many species, by the general surface, instead of by special organs, affords another striking analogy to the vegetable kingdom.

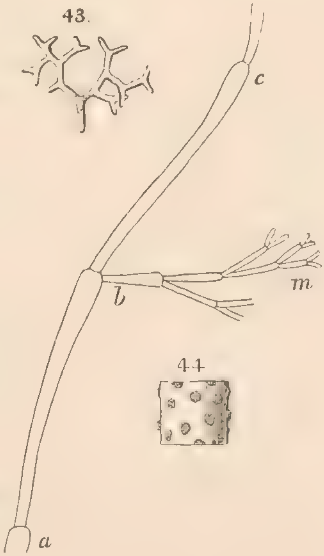
produced at apex, to form the stalk of the next season, and so on. In this manner, the rhizoma slowly moves onward, from year to year, the scars marking the annual growth, and the *more ancient portions gradually decaying, as new parts are formed at the other extremity.*"

instances, the budding leaf-bud or flower proceeds from some one or more of these cellules, which develope new powers of secretion within themselves. These gemmating cellules go on developing new cellules in lines, which frequently subdivide, until, in connexion with the other attending conditions of growth, the bud forms and developes, and the branch commences.

88. The principal steps in the process, are exemplified in the annexed figures. Figure 43, is a branch of the natural size, of one of the coralline Algæ, taken from a clump, an inch and a half high, and three or four inches through.* The lower part is covered with minute dots about $\frac{1}{120}$ of an inch in diameter, which are magnified in figure 44. Figure 45 represents one of the longitudinal vessels of the interior, magnified one hundred and fifty diameters, consisting of oblong cellules, *a b*, *b c*. These cellules are $\frac{1}{100}$–$\frac{1}{150}$ of an inch long. From the summit of one (at *b*), a cellule proceeds laterally, which gives out two smaller cellules, and these two others, and so on, and the last connect with the sporules (not here figured), which constitute the surface dots alluded to: about five hundred sporules being clustered in a single one of these dots.

Fig. 45.

43.



These sporules are each about $\frac{1}{2000}$ of an inch long. Thus we trace out the beginning of the germinant process in the first cell which takes its outward course, and follow the progress of developement, till prepared to form sporules at the extremity.

With reference to the germinant process, in this case, it should be remarked first, that it is not apparent within a third to half an inch from the extremity of a branch, for sporules are formed only below this distance: above this, the necessary nutriment is drawn off by the growing summits, the younger parts of the coralline; as in the zoophyte, germination does not take place, except where the parts are beyond the influence of the reproductive force at the budding apex. As the alga lengthens above, the sporidia form below successively, at nearly equal distances, in analogy with the branching of zoophytes.

* I have illustrated this point from dissections of a species of Liagora (L. rubriceps, D.), obtained in the Feejees.

89. In the process of germination, above illustrated, a cellule forms laterally from the apex of a longitudinal cellule (*b*, figure 45). This new germ-cellule enlarges, until that reproductive agency, whose over-accumulation started its existence, has attained its maximum in the new cellule; and, going on to accumulate from the vital action within, new cellules bud out from that now formed: and so cellules bud from one another, two from each preceding, till they are prepared to form the sporules at the extremity. The cellules decrease in size; and if the view just expressed is correct,—that the same amount of force causes the successive buddings,—the process in the formation of sporules consists, in part, in the successive condensation of the germinating material of the future sporule, until it is collected into a space not $\frac{1}{200}$ the size of the ordinary cellules in the plant, and a gradual concentration of its germinant powers. The final cellule at last gives rise to one or more sporules: apparently the mere result of continued budding, and a farther elaboration and concentration of the germinating product. Some facts, however, seem to show that the consummating change may consist in the union of a final cellule, with some other which is antheridial in its nature; and after this union, the sporules bud out from the combined cellule, or form by mere spontaneous fission of the same.*

I have dwelt upon this example, not because there is any novelty in this developement of successive cellules, but from its affording so simple and apposite an illustration of the germinant process. The same, in the opinion of the best physiologists, is the general mode of developement in other plants, except that anthers intervene to afford material to aid in the final elaborations. And in animals, the process of growth by cellules, and the modes of developement, are quite analogous.

90. The germinating process may be illustrated by a few more comparisons between plants and zoophytes. The Aulopora has been described (§ 65) as sending out slender creeping shoots at base, which, after reaching to a certain length, develope a polyp, from

* The character of the sporules and their position, as observed, are shown on the last plate of the Atlas: figure 1*a*, the Liagora rubriceps natural size; *b*, a branch magnified with the sporidia below; *c*, sporidia magnified one hundred and fifty diameters; *d*, part of transverse section of stem, showing the internal cellules cut across and partly disarranged; *e*, *e′*, longitudinal cellules magnified one hundred and fifty diameters; *f*, longitudinal cellules, with the lateral branch of cellules, and the sporules at apex; *g*, one of the sporules magnified four hundred diameters.

which, when adult, similar shoots proceed. Compare this with the strawberry and its creeper, which, in like manner, after growing to a certain length, developes a bud of leaves,—the plant-individual,—again to send out other creepers, and form, at intervals, other leaves. Here we see that the bud acquires a certain length before it is finally perfected; the line of cellules, with which the forming bud begun, was gradually acquiring the requisite elaborations, and concentration within, to develope the new individual. And after the distance is reached, the process is still gradual in both cases. The polyp rises first as a small protuberance, which gradually lengthens into its tubular cylindrical base, and finally the polyp-flower is formed at apex. Very similar, as is well known, is the fact with the strawberry.*

91. The production of a branch in zoophytes, at a single budding process (§ 70), is another of those singular facts, which appear to find their analogies rather among vegetables than animals; and we see it exhibited on a large scale in the thyrse of lilac blossoms. The general principles of the process are shown in the figures of the Alga, on page 91. The budding cellules, from *b* to *m*, if viewed as separated from the coralline, form together a similarly ramose branch: and if, instead of each cellule, there were elongated series, and the whole, with accompanying tissues and fibres, formed a prominent ramose branch, instead of being embedded, as in the coralline, we should have a clump of flowers like the lilac blossom: or, if still partly embedded, the cluster would resemble that of the Alcyonium. This subdivision of the flower stems in the lilac, takes place at nearly regular intervals, and these intervals decrease towards the flowers, as in the cellules of the Alga. The process appears to be similar, except, that instead of one cellule, we have a series of them before subdivision, precisely as we have a series in the

* There is little doubt that were the cases equally well brought out to view in all the steps, we should find as much reason to say that the ovarian lamellæ of the polyp are altered tentacles, as that the seed-vessels and petals of a flower are altered leaves. The same kind of cellules, under different circumstances, originate both. Excessive nourishment is known to cause the production of leaf-buds in place of flowers, and also to make a petal from a stamen; and for the reason, as has been explained, that the latter, in each instance, differs from the other only in requiring, for the production of its few peculiar characters, a slower and more quiet and concentrated action of the forces at work, while the former may result from a less delicate process of vital chemistry. Only under circumstances in the utmost degree favourable, will certain chemical compositions take place, and here, in like manner,—for the difference is in the resulting combinations,—the forces must be nicely balanced and not of too rapid application.

Aulopora and strawberry-creepers, before the final developement of the complete individual. This budding of cellules, moreover, is closely analogous to the budding of polyps and branches in the zoophyte.

92. The ovarian vesicles, which pullulate from the sides of a branching Sertularia (§ 14), contain the ovules arranged on the same general plan as the polyps of a branch formed by the process of budding, though much contracted. They communicate internally with an axis, branching from the trunk of the zoophyte, just as the several polyps of a branchlet communicate internally with its tubular axis. There is the same condition of things in this case as in the last-mentioned,—the same process of branch developement:—and all cases of the production of numerous ova in animals, appear to be analogous. The fact, that the kind of ramification is similar to that of the zoophyte, as a whole, is not peculiar; for the same is true of the lilac thyrse: and generally among plants, the mode of branching in the flower clump, is but a miniature representation of that which characterizes the whole plant.*

* Professor E. Forbes has drawn a comparison between the vesicle of a Sertularia and a flower, in which he compares each ovule of the vesicle to the carpels or parts generally of the flower-bud (§ 14). The analogy, as exhibited by this distinguished physiologist, is highly interesting, and was the result of much minute research. But, while admitting the correctness of the analogy, in a certain light, we may doubt if the comparison gives us a correct idea of the actual nature of these vesicles. In the Actinia, with its circle of tentacles, and its inner series of ovaries and spermatic organs, we appear to have the true analogue of the flower, as perfect as can be presented by animal life. And in the vesicle of the Sertularia, we see the analogue simply of one of the clusters of ovules in an Actinia. These clusters project into the interior cavity in the Actinia, as the animal has ovarian lamellæ there, but become external in the Sertularia; in other respects, the cases are wholly identical. It is, therefore, more in accordance with the developements in other zoophytes, to consider the vesicle as the analogue of a cluster of flower-buds; and we may, with much justice, compare it to the branching clump of flowers proceeding from a single budding-point,—the axil of a single leaf. Professor Forbes's comparison holds only on the ground of the general analogy which subsists between all reproductions; the same principle presiding over the origin of a flower, or a leaf, or the cellules that give origin to the leaf. The cluster of seed attached to a placenta, of ovules to an ovarian lamella, the external vesicle of a Sertularia, and a compound flower-bud, are therefore proper analogues.

The observations afford exemplifications of the fact, that each ovule is connected in origin with the production of a certain part of the general ovarian envelope; and this is as true of the internal clusters of an Actinia, as the external of a Sertularia. In the latter, the fact becomes apparent, through the horny secretions of the exterior, which conform to certain principles, exhibited in the production of a calicle.

It is a just conclusion, therefore, that while the polyp, by its form, and its mode and direction of growth, and mode of budding, determines the general form of the zoophyte; or, the bud, that of the plant,—the cellule, by its form, mode, and direction of growth and mode of reproduction, determines the general form of both flower-bud and polyp, plant and zoophyte.

93. The analogy between plants and zoophytes is, therefore, not one calculated to embarass us by suggesting false affinities. On the contrary, the two orders afford interesting and important illustrations of the organic processes in each. We may say farther, that the modes of developement throughout the animal kingdom are here elucidated, and, also, with no less truth, that the principles which flow from these facts, bear upon all the elaborations in organic beings.

The tentacles of an Actinia, as also the lamellæ, which correspond, are often but eight or ten in number in the young when first developed; but afterwards, as the Actinia grows, and the interval between two lamellæ increases beyond the normal breadth (for the species), a new lamella begins to form; and so other lamellæ, in succession, appear. Here the same law depending on breadth of interval holds, as in the developement of branches on a tree or a zoophyte. As these intervals widen by growth, there is unappropriated nutriment and vital force, and these acting upon the cellules intermediate commence the formation of a lamella. So, also, this principle, which determines the scattered character of the leaves on a tree, or of processes or branchlets over a coral branch, determines the closer or more scattered distribution of the hairs on a leaf or an animal. A certain space around the reproductive point, is tributary to each hair, and the size of this space is determined by the distance to which the reproductive centre can exert an influence. This space is measured by the intervals between adjacent hairs. But let this interval enlarge, by the growth of the part, beyond this amount, and immediately there is an excess of force and nutriment, which commences the formation of a new hair. We might add illustrations, but this will suffice. Reproduction proceeds on the same principles, whether a hair or an animal is the result. The same is admitted with respect to the developement of germinating functions in animals; for it is a recognised fact, that while the growth of the body is in progress, the vital forces and nutrition are dispersed in every direction; but, on reaching the limits of growth,—that is, the limit in radiate extent, to which the peculiar structure of the animal is able to carry on the reproductive processes of growth,—the vital forces and nutriment become directed within, and the new function of germination is developed. The whole animal and vegetable kingdoms contain throughout illustrations of this principle.

94. We have thus prepared the way for the following law, which holds equally, whether the germ-cellule be that of an organ of an animal or plant, or that from which a living being itself proceeds:—*The developement of a germ, from a cellule or cluster of cellules, requires the concentration of a specific amount of vital force, and a certain tributary space where this force exists; proper nutrition being afforded, reproduction necessarily takes place; and, when existing reproductive centres cannot appropriate all the reproductive force and nutriment, new reproductions commence.**

* The existence of vital force as a cause has been of late doubted, and its supposed effects attributed to mere chemical forces. This is not the place for a display of argument upon this subject: neither does the point seem to require it. The single fact, often urged, that inorganic matter takes on *angular* forms, and organic *rounded*, seems to decide the question. The perfect individual in the former, has plain faces of fixed angular dimensions, and proceeds from attractions in straight lines, having fixed mathematical relations. Solidification is in fact only the union of particles by these axes, which are assumed generally at the time the change of condition commences. Crystallization and solidification are, therefore, one and the same process; for the particles of a solid are always possessed of this crystalline attraction, although they may constitute together an amorphous mass. Even those so-called *organic* substances, which the chemist claims to have made, still show the same powers of crystallization on becoming solid.

But in the tissues of plants and animals, there are no planes or solid angles, except such as may result from pressure. Where, indeed, is there the slightest analogy to a crystal in an oblong cellule filled with fluids? And in the budding of cellules from one another, and the formation of linear series, what resemblance to a solid filament of crystals? Crystals or crystalline masses are secreted by organic life; but these proceed from, and never take the place of, living cellules. There must, therefore, be some controlling influence, which prevents the particles from uniting into crystal shapes, and moulds them into growing cellules,—some power which makes the curving outline as characteristic of the organic kingdom, as straight lines and fixed angles of the crystal kingdom. This power or influence is called vitality. By it, the constituent molecules of a germ are themselves controlled, and are enabled also to bring other molecules into the same living state.

The functions of a germ, however, are not simply its vitality; chemical attractions are a principal source of the various compositions and decompositions in progress; and all those causes that influence chemical combinations, such as light, heat, and electricity, and the various laws under which such combinations take place, are here in action. Chemical *inertia* plays an important part in continuing processes which have been begun. It is possible that some compounds are formed, which chemistry, without vitality, would

95. The applications of the law laid down, seem to extend even to determining the number of germs which may proceed from different animals, and afford some data for ascertaining the amount of germinant force in each. We observe that the centres of reproduction are more numerous as the nervous system is smaller or less concentrated. The production of hair from the epidermis illustrates this fact; but a small portion of force and nutrition is brought to bear upon any one point, and these points are often exceedingly near, although varying according to the amount of vital force and nutrition. In the lowest animals, consisting of cellular tissue mostly, a concentrated nervous

not effect, and this is generally admitted; and, if so, vitality must be considered one of the causes influencing chemical combinations.

But it may be a question whether this vital influence admits of accumulation in an organized structure, as electricity, for example, may be accumulated under certain circumstances, in a properly constructed machine:—whether we may speak of vital *force*, as in the case supposed, of electrical force;—and whether the former, by accumulation, effects changes in a manner corresponding to what the latter is known to do. Although analogy is a dangerous basis for argument, yet we may venture an affirmative reply to the above queries. In animals, nerves convey and serve to concentrate the vital force, and the levers of the organic structure are thus, through the muscles, put in action. In late investigations by Matteucci, the force of electricity, applied as a moving power to the muscles of limbs, has been calculated; and why not, in like manner, estimate the force of vitality? The same distinguished investigator has ascertained, by direct experiment, that no electric currents circulate along the nervous cords of living animals.[a] Admitting that this accumulation of vital force is possible, we may understand why certain chemical combinations take place only in more advanced states of an organic structure, when its organization is more complete. Its concentration may be required for other purposes than muscular action, and, if any where, would be especially so in the function of reproduction.

In the discussions in this chapter, the principle here urged, with regard to vital force, has been assumed, as seemingly most consonant with the various operations to be explained; it has appeared more satisfactory, than to refer the developements or changes simply to the abundance or absence of proper nutriment, as is done by many physiologists. If the latter proves still to be a true and complete statement of the case in living beings, or if the force in action is some other known power, the principles adduced in the preceding and following pages will no less stand, although some modification may be required of the mode of expressing them. The whole subject is beset with difficulties, and it certainly becomes one venturing upon it to move with caution. This chapter will hardly be perused by a reader more ready to doubt the views presented, than the author, when its first lines were written. The results have gradually forced themselves upon his mind from the developement of the various facts, which the study of the structure and growth of zoophytes gradually opened to view.

[a] See Electrical Magazine, 1845, 490, 495, 497.

system cannot exist, but if muscular fibre be added, the nervous may receive its different degrees of developement.

There is abundant reason, therefore, in their constitution, for the larger number of ovules in the inferior animals; for, from their nature, they can concentrate only a small amount of reproductive force on any centre; and, as the cellular tissue produces myriads of hairs, so animals of this composition may produce immense numbers of small ovules. Add muscular and nervous tissue, and the animal system may concentrate a much larger amount of force and nutriment, proceeding from a wider sphere of action.

As the species among the inferior grades diminish in size, there is also a consequent decrease—the general constitution being the same—in the number of germs they produce; and, in the simple monad, we appear to have a single isolated sphere of reproduction, producing its single germ: the texture is mostly cellular tissue, and the size must be just that required to give vital force enough for a single germ; for when this animal enlarges, by nutriment received, so as to exceed its normal size, there is a tendency at once to form two centres; and, as enlargement goes on, subdivision actually takes place, and two animals are formed of the one. The enlarged size produces more vital force than can belong to a single animal so constituted.* In larger animals, of similar constitution with the monad, the number of ovules produced is very large, for the reason, that the animal can concentrate on any single cellule only a small amount of vital force, and, as there is a large amount present, the germs must be numerous. As we ascend in the scale of being, the number of young diminishes.

In the higher species, where a large nervous system is to result from the germinant cellule, the force required is greater than when this cellule is the germ of an inferior species, with an imperfect nervous system. The physical structure of the animal must therefore be larger to produce the vital power needed for the elaborations that originate the germinant cellule of an animal of the higher grades. Size is, therefore, an important element in the system of organic life.

96. Although the question is complicated by many circumstances

* The relation between the number of germs and *size* is still farther illustrated by the visceral lamellæ in different species of Astræas, as exhibited in the closing paragraph of § 43 *b*.

in action influencing the amount of vital force produced by the individual and its concentrating energies, which cannot be estimated, yet there is reason to conclude, that, for the production of a single germ, there is required a determinate amount of force, characteristic of each species, which is equivalent to that which the animal can bring to bear upon a single germinant cellule. This amount being fixed, may be one element at the basis of species, of specific characters and specific distinctions. It aids in producing the elaborated cellule or cellules, which, with the envelopes (constituting thus an ovum or ovule), give origin to the young individual. It is possible that some mode of designating this force may yet be ascertained.

97. In view of these considerations, we are led to conclude that the law of developement laid down, determines not only the intervals between the polyps, branchlets, and branches of zoophytes, or the leaves and ramifications of trees, but presides over the whole animal and vegetable economy, limiting the number of reproductive centres, and the extent of their sphere of influence, equally in the formation of ordinary cellules, or the production of germs or individual animals.

It appears farther that a cellule—the germ of a species—has certain powers distinct from, though perhaps connected with, their powers of secretion; and these are different for different species. They are—1. A *specific budding force*, which fixes the size and frequency of buds, each cellule enlarging, till this force has reached its maximum, and then budding from the excess afterwards accumulating. 2. A *specific number of budding points*, which determines the number and relative position of the cellules that may bud from a preceding cellule. 3. A *specific budding angle*, which fixes the angular divergence that a budding cellule may make with a preceding. These powers are wholly independent of any thing like catalysis, or any known chemical forces, and there is no reason to believe that any but creative energy can change them.

98. From the facts brought forward, it is obvious that although zoophytes are so much like plants in their forms and flowers that we might almost fancy them to have been modelled after the trees and shrubbery of the land; although as simple in their system of aeration, and similar in the position of their reproductive organs, and in the character of the budding process; yet the two classes of objects have nothing essential in common, except in those points, which depend upon the general principles of organic life, and in which all animals are equally allied to plants. The nature of their tissues and their

mode of developement,—the character of their food, it consisting of organized and not unorganized matter—the peculiarities of the process of digestion and the ejection of excrementitious matter—the influence exerted on the atmosphere by the aeration of the circulating fluid—as well as their voluntary motions, remove zoophytes far from the vegetable kingdom. The fact of an imperfect nervous system, explains the apparent resemblances. The simplicity of their internal organization is due to this; and it also accounts for the great number of possible organic centres in a polyp, each exerting an influence around only to a very limited extent, capable of budding out a young animal, either while connected with other parts of a polyp, or when separated as an artificial section. It is even probable that the radiate form, characteristic of the lower orders of animals, and also of a great part of the vegetable kingdom, is due to the simple laws of organic developement, which, in these cases, are either uncontrolled by other directing forces that act through the developing nervous system, or are so controlled only to a very limited degree.*

* See farther, the note to § 108.

CHAPTER VI.

GENERAL REMARKS ON THE GEOGRAPHICAL DISTRIBUTION OF ZOOPHYTES.

99. Heat, light, pressure, and means of subsistence, influence more or less the distribution of all animals; and to these causes should be added, for water species, the nature or condition of the water, whether fresh or marine, pure or impure, still or agitated. Next to the character of the water, heat is the most prominent limiting agent for marine animals, especially as regards latitudinal extent, while light and hydraulic pressure have much influence in determining their limits in depth.

Although these causes fix bounds to species and families, they do not necessarily confine tribes of species to as small limits. This is sometimes the case, and is nearly so with a large group of zoophytes; yet other tribes and orders include species whose united range comprises all the zones, from the equator to the polar ices, and every depth, to the lowest affording traces of life which man has explored.

Order Hydroidea.

100. The Hydroidea are met with in all seas and at great depths, as well as at the surface. The tropics, and the cold waters of the frigid zone, have their peculiar species, and a few are found in fresh waters. The rocks and common marine plants of the sea-coast, the dead or living shell, or the floating Fucus of the ocean, are often covered with these feathery corals; and, about reefs, they occasionally implant themselves upon the dead zoophyte, forming a mossy covering, taking the place of the faded coral blossom.

The species are most abundant, however, in the waters of the temperate zone, and are common upon some portions of our own coast.

Order Actinoidea.

101. The Actinoidea are marine zoophytes. All oceans have their species, yet in the torrid zone they more especially abound, and display most variedly their colours and singular forms.

The soft Actinidæ and the Alcyonaria have the widest range, occurring both among the coral reefs of the equatorial regions, and, to the north and south, beyond the temperate zone. The Mediterranean affords species of Gorgonia, Corallium, and Alcyonium, besides numerous Actiniæ. The coasts of Britain have also their Alcyonia and Actinias, and from far in the northern seas, come the Umbellularia, and some other species of the Pennatula family.

Among the coral-making Actinaria, the Madrepore and Astræa tribes are almost exclusively confined to the coral-reef seas,—a region included between the parallels of 28° north and south of the equator, —while the Caryophyllia family are spread as widely as the species of Actinia. Several species of Caryophyllidæ occur in the Mediterranean, and others in the high northern seas, and they are met with at depths of several hundred feet. They are also common among the coral-reefs of the tropics.

The Madreporacea and Astræacea, with the Gemmiporidæ, are the principal constituents of coral reefs. The temperature limiting their geographical range is about 68° F., this being the winter temperature of the ocean on the outskirts of the reef-growing seas. The waters sometimes sink to 66° or even 64°, but this appears to be a temperature which they can endure, and not that in which they germinate. The extremes which they will survive prove only their powers of endurance, and do not affect the above statement; for their geographical distribution will be determined by the temperature which limits their powers of germination.

The temperature in the warmest parts of the Pacific varies from 80° to 85°, and here Astræas, Meandrinas, Madrepores, &c., are developed with peculiar luxuriance, along with thousands of other strange and beautiful forms of tropic life. From the above temperature to 72°, does not appear to be too great a range for the most fastidious species. At the Sandwich Islands, which are near the northern limits of the coral seas, Porites and Pocilloporæ prevail, and there are very few species of the genera Astræa, Mussa, and Meandrina, which are common nearer the equator.

102. The range of these reef-forming corals in depth is singularly small. Twenty or perhaps *sixteen* fathoms will include very nearly all the species of the Madrepore and Astræa tribes.* Temperature has little or no influence in occasioning this limit, as 68° F. will not be found under the equator short of a depth of one hundred fathoms. Light and pressure, the latter affecting the amount of air for aeration, are probably the principal causes. The waves, moreover, not reaching, when most powerful, to a greater depth than fifteen or twenty fathoms, cannot aid in renewing the expended air below, as they do at the surface.

In recapitulation we state that the Astræacea, Madreporacea, and the Gemmiporidæ among the Caryophyllacea, are, with few exceptions, confined to the coral-reef seas,† and to within twenty fathoms of the surface. The Caryophyllidæ extend from the equator to the frigid zone, and some species occur at a depth of two hundred fathoms or more. The Alcyonaria have an equally wide range with the Caryophyllidæ, and probably reach still farther towards the poles. The Hydroidea range from the equator to the polar regions, but are most abundant in the waters of the temperate zone.

103. Besides the above-mentioned limiting causes, there are others of importance, one of which only may be alluded to in this place, the remaining belonging more properly to the Geological Report on Coral Reefs and Islands. The cause referred to, is that proceeding from original sites or centres of distribution. There is sufficient evidence that such centres of distribution, as regards zoophytes, are to be recognised. The species of corals in the West Indies are, in many respects, peculiar, and not one can with certainty be identified with any of the East Indies. The central parts of the Pacific Ocean appear to be almost as peculiar in the corals they afford. But few from the Feejees have been found to be identical with those of the Indian Ocean. A more complete acquaintance with the corals of these different seas may multiply the number of identical species; but observations, thus far made, seem sufficient to establish as a fact that a large part of zoophytes are confined to a small longitudinal range. This will be seen from the following table, exhibiting, in a general manner, as far as known, their geographical distribution. Each column gives the number *peculiar* to the region specified at top.

* The evidences on this point will be presented in the Report on Coral Islands.

† The exceptions belong mostly to the genus Euphyllia.

	East Indies, Indian Ocean, or Red Sea.	Pacific Ocean.	West Indies.	Pacific and the East Indies, or Indian Ocean.	Extra-tropical.	Doubtful.	Total.
TRIBE ASTRÆACEA.							
Fam. Astræidæ, ...	37	50	29	4	3	16	139
Fungidæ, ...	14	29	6	6	0	10	65
TRIBE CARYOPHYLLACEA.							
Fam. Caryophyllidæ, . .	13	7	9	2	13	5	49
Gemmiporidæ, . .	4	5	1?	2	0	2	14
TRIBE MADREPORACEA.							
Fam. Madreporidæ, . . .	30	42	4	8	1?	7	92
Favositidæ, . . .	14	15	5	3	0	4	41
Poritidæ, ...	5	14	6	2	0	1	28
	117	162	60	27	17	45	428

From this table, it appears that only twenty-seven species out of three hundred and six are known to be common to the East Indies and Pacific Ocean. With regard to those common to the East and West Indies, for which no column is assigned, there is but one,—the Meandrina labyrinthica,—about which much doubt remains.

104. We have no authority for accrediting to the West Indies any species of the genera Fungia, Pavonia, Herpetolithus, Merulina, Monticularia, Gemmipora, Anthophyllum, Pocillopora, Sideropora, or Seriatopora, all of which are common in the opposite hemisphere. The Agariciæ, with the exception of a single osculant species, are confined to the sub-genus Mycedia, exclusively West Indian, which contains very firm compact corals, with an Astræa-like character. The Millepores are the only known Favositidæ, and but half a dozen Madrepores have yet been distinguished. The Manicinæ, Caryophylliæ, and Oculinæ, are more numerous in the West Indies than elsewhere, and the Ctenophylliæ (Meandrinæ, with stout entire lamellæ,) have been found only in the West Indies. The genus Porites contains several species, but they are uniformly more fragile and more porous species than those I have seen from the Pacific and Indian Oceans; and the polyps, as figured by Lesueur, are more exsertile, approaching, in this particular, the Goniophoræ.

CHAPTER VII.

CLASSIFICATION OF ZOOPHYTES.

105. ZOOPHYTES constitute an order of the group or sub-kingdom RADIATA. The limits of this sub-kingdom have of late been the occasion of much discussion. In order to explain their relations to other animals, a few remarks upon the general system of arrangement in the animal kingdom are here offered.

In Cuvier's Classification of Animals, the division Radiata includes all invertebrate animals not comprised in either of the other sub-kingdoms, Articulata and Mollusca. Consisting thus only of refuse species, and not limited by positive characters, as Owen states, we should not expect that the group could be a *natural* assemblage. No line of subdivision, however, has yet been made out, which has met with general favour; yet greater precision has been given to our views of the affinities that run through the animal kingdom, by appealing to the nerves, the seat of sensibility and sentiment, as a basis in classification; and, in this manner, the subdivisions have been characterized as follows by Dr. Grant.

I. The *Vertebrata*, having a brain and a spinal cord, constitute the SPINI-CEREBRATA;—II. The *Mollusca*, having the nerves forming generally a transverse series of ganglia disposed around the esophagus, the CYCLO-GANGLIATA;—III. The *Articulata*, having no proper brain, and the main cords, which run the length of the body, double, the DIPLO-NEURA;—IV. The *Radiata*, having a radiate structure in the body, and the nervous ganglia arranged in a circle, the CYCLO-NEURA. The orders of these sub-kingdoms are given as follows:

I. SPINI-CEREBRATA or VERTEBRATA. Mammalia, Aves, Reptilia, Amphibia, Pisces.

II. CYCLO-GANGLIATA or MOLLUSCA. Cephalopoda, Pteropoda, Gasteropoda, Conchifera, Tunicata.

III. DIPLO-NEURA or ARTICULATA. Crustacea, Arachnida, Insecta, Myriapoda, Annelida, Rotifera, Entozoa.

IV. CYCLO-NEURA or RADIATA. Echinoderma, Acalephæ, Polypiphora (zoophytes), Poriphora (sponges), Polygastrica.

An objection might be made to this system, on the ground of the apparent absence of nerves in some of the lower orders. But a real absence can hardly be concluded, from our inability to distinguish them. Many of these animals show by their voluntary motions and sensibility that nervous influences traverse the body: moreover, nervous matter is secreted only in lines. We can, therefore, only infer the indistinctness, and not the absence of nerves, from our ineffectual efforts to trace them out; and we must consequently be guided by general structure, in determining the relations of groups, when the nerves fail of giving aid.

106. The above arrangement fails, in some respects, of presenting a clear idea of the system in nature, although highly philosophical in its general features. A study of the animal kingdom, as has been lately shown, brings to light, lines or general systems of developement branching up from the lowest infusoria to the higher grades of life. It is not true that the forms among the *lower* grades are actually copied in any of the imperfectly developed young of the *superior;* yet there is some general analogy, sufficient to indicate that the former commence on the same system of developement with some of the latter, although carried essentially out of the direct upward line by the peculiar vital forces of the species. The Rotifera are decidedly Crustacean in type. The stout mandibles are precisely those of some of the Cyclopidæ, even in position, and also in general form; and in certain peculiarities in the mode of reproduction, the animals are closely similar; yet no young Crustacean is ever a Rotifer. The latter belongs to the same system of developement with the former, but is a distinct branch, from the regular line, characterized by peculiar natatory organs, which appear to be analogues of the branchial or basal appendages to the feet in Crustacea. The Bryozoa,* or Flus-

* The Bryozoa have been placed near the Rotifera; but the absence of mandibles, as well as their peculiar type of structure, separates them widely from these crustaceoid species and allies them as closely to the Tunicata, with which they were first associated by Thomson, under the name of Polyzoa. Lister has a finely illustrated article on this subject, in the Philosophical Transactions, for 1834, p. 365.

troid polyps, illustrate the same principles, and are as nearly allied to the Tunicata as the Rotifers to the Crustacea. It is a side-developement from the imaginary line, which connects the Infusoria with the Tunicated Molluscs. The Entozoa afford other examples, one branch of them passing into Crustacea, through the Lernæidæ and Caligidæ, and the other into the Annelida. The Lernæoid division appears to reach the Polygastrics in the Acephalocyst.

These remarks are intended to support no monad or Lamarckian theory, but only to elucidate the established principle that there are in nature certain distinct systems or types of developement. Each species is developed with some reference to one or the other of these systems, but, through the agency of the vital forces peculiar to it,—forces which, there is reason to believe, only creative power can change.

107. In accordance with these principles, the several orders of animals may be arranged as follows:

I. VERTEBRATA.

III. ARTICULATA. Insecta, Myriapoda, Arachnida, Crustacea, Annelida,		II. MOLLUSCA. Cephalopoda, Pteropoda, Gastropoda, Conchifera, Tunicata.
Rotifera, Entozoa,	IV. RADIATA. Echinodermata, Zoophyta, Acalephæ,	Bryozoa.

V. PROTOZOA or INFUSORIA.

108. A radiated structure characterizes the simplest form of animal life.* Passing up from the monad globule, this structure has its

* As suggested in the close of § 98, it appears to be more than a plausible conjecture, that we may attribute the radiated structure to the ordinary uncontrolled principles of cellule budding; the results of which are seen in the varied forms of zoophytes and vegetation. It gives origin to the radiated form of the flower; and the spiral arrangement of the leaflets,—the result of a succession in the developements,—is one of the consequences of it (§ 86). The nervous system, in its lowest condition, conforms to this character; but, as it becomes more perfect, it has a peculiar mode and direction of developement,—as the zoophyte has its peculiar characteristics in this respect,—and thus developing, it guides all the other elaborations; for it seems to be the channel along which vital influences operate. The developement of nerves, therefore, carries the animal structure more or less widely from the radiate type. This is well illustrated in the relation of the Rotifers and Crustacea, the former, as shown above, having the general structure of the latter under a radiate form. The Rotifers have, as organs of motions, a series of plates arranged in a circular series around the mouth at one extremity of the animal. In the

highest developement in the Echinoderms. Among zoophytes, the Hydra forms the first step upward, in which the digestive cavity is a mere sac, which will work equally well turned inside out, and the mode of reproduction is extremely simple. From this group, we pass to the Actinia, in which there is a distinct stomach and a series of fleshy lamellæ around the internal cavity,—the first rudiments of an isolation of the functions of digestion and generation,—but the circulating fluid is only the elaborated chyle, mingled with more or less water from without. A step farther, and we find the developement of separate organs for the functions of the liver and of generation in the Echinoderms, and in some species a circulating system.

Whether the Acalephæ or Zoophyta are highest in the scale, we do not intend to indicate above. The young of some zoophytes are acalephs in form, even to organs of sight, and the young of some acalephs are much like polyps: moreover, the adult acaleph is often quite analogous in its radiately subdividing alimentary channels, to the same in the Fungia.

Through the Bryozoa, the infusoria are connected with the Tunicata and the other Molluscs; and through the Rotifera and Entozoa, they connect with the Articulata, thus passing each way, out of the true Radiate type, into that which characterizes the higher subkingdoms. The Bryozoa, Rotifera, and Entozoa, may be arranged in the sub-kingdom Radiata, or with the Mollusca and Articulata, whose types of structure they exhibit, though under a Radiate form.

The Echinoderms, although so strikingly peculiar in some species, —the Echini,—yet, through the Holothuriæ, bear closely upon the Articulata; while the Acalephs incline toward the Mollusca.

The animal kingdom is throughout a network of affiliations, yet there are main trunks and larger branches, to which the smaller anastomosing ramifications are subordinate. Systems of 3s and 5s, look pretty to the mathematical eye, and have some foundation in nature; yet, in tracing affinities, it is better first actually to ascertain

Crustacea, the same or analogous organs, together with the mouth, become lateral, owing to the developement and projection of the cephalic ganglion—and its accompaniments constituting the head—beyond to one side of the circular series of the natatory plates; these natatory plates, about the Rotifer's mouth, becoming, at the same time, the branchiæ and the attached maxillary organs about the Crustacean's mouth. The transition from the Crustacean to the Radiate type is also shown in the passage of the Caligi into the Epizoa. This subject admits of a long series of illustrations, which are reserved for another place.

relations, and then to map them out, rather than force the devious windings of nature into circles large and small.*

109. *Subdivisions of Zoophytes.* The orders Hydroidea and Actinoidea, have already been laid down as the primary subdivisions of zoophytes. The order Actinoidea has been again divided into the sub-orders Actinaria and Alcyonaria. The Alcyonaria, according to most authors, constitute one of the grand divisions equivalent to Hydroidea and Actinoidea. But the general identity in structure and mode of reproduction, and other coincidences stated in the preceding pages, seem fully to justify the arrangement adopted. In the subordinate groupings, the actual character of the animals has been considered of superior importance to the mere absence or presence of coral secretions. Olivi long ago correctly stated that the consideration of the presence or absence of calcareous secretions was of no more importance in zoophytes, than in the Mollusca.†

110. The farther subdivision of the sub-order Actinaria, into the four tribes Astræacea, Caryophyllacea, Madreporacea, and Antipathacea, is based upon the structure of the polyps and their mode of budding. The fleshy Actiniæ belong to this sub-order, and possibly we may yet find among them representations of all the several tribes. Yet, as they are not budding species, excepting the Zoanthidæ, and their distinctive internal characters have not been laid down, they have all been retained for the present in the same tribe, Astræacea. The Antipathi have been arranged by some with the Gorgoniæ, and by others of late, with the Bryozoa.‡ They have no relation to the latter, and but little to the former; their tentacles are quite similar in appearance to those of the Madrepores, although but six in number. The family Fungidæ has not hitherto been recognised as a distinct

* The Bryozoa, Rotifera, and Entozoa, are by no means the only links between the Protozoa and the other sub-kingdoms; on the contrary, the direct affiliations, and the analogical connexions which arise from parallel gradations of developements in separate and often distant groups, are numerous, and a long series of investigations will be required before they can be fully made out. In the Baccillariæ, and others of the Pseudopoda, we appear to distinguish the Echinoderm and Acaleph form developed in an infusorial structure. The sponges, also, belong here, if animal, as Dujardin urges,[a] and seem, in like manner, to represent the Zoophyta.

† Zoologia Adriatica, Bassano, 1792. See Blainville's Man. d'Actin., p. 30.

‡ Ehrenberg, op. cit., 357; also, M. Perty, Allgemeine Naturgeschichte, as quoted in Oken's Isis, 1841, p. 371.

[a] Annales des Sci. Nat., x., 5, 1838.

group among the Astræacea, yet it rests on characters of striking importance (§§ 43, 78).

111. As the characters laid down for many of the received genera were not drawn from a study of the animals, it has been found necessary to vary their limits, restrict, extend, divide, or unite, according to the facts thus ascertained. These changes have been made cautiously, and no new names introduced, except after long deliberation. On account of the various uses of the same name, by different authors, it has been sometimes extremely difficult to decide on the one to be received and retained. The admirable principles published by the British Association, in 1843, have been followed in such cases. An instance of the difficulty alluded to, will be found illustrated in full under the family Caryophyllidæ, where the authorities for the different names of the genera adopted, are given, and the final reasons for restoring the name Caryophyllia to the Cladocoræ of Ehrenberg.

The genus Explanaria of Ehrenberg, made up in part of certain Astræas, and of some of Lamarck's Explanariæ and Gemmiporæ, has been disbanded, for reasons stated under the genus. The genus Porites, as employed by late authors, contains two distinct genera, or if we include fossil species, so called, *four* distinct genera. Its subdivision, therefore, was unavoidable. The Porites spumosa is the type of one of the recent genera, which I have called Manopora; the species are closely related to the Madrepores. The Porites glomerata and clavata are types of the other genus (Porites), which is so decidedly peculiar in its characters, that it was necessary to establish it as the type of a separate family, Poritidæ (§ 40).

Other remarks, upon the changes that have been found unavoidable, will be made in the course of the following pages containing descriptions of the genera and species. Those genera, whose places in the system are not determined, are placed in an Appendix.

112. A few of the transitions among the genera are pointed out in the following tables:

1. *Transitions of the Astræidæ to the Fungidæ.*

Astræa	Meandrina	Monticularia	Pavonia	Herpetolithus	Fungia,
		Manicina, Tridacophyllia		Agaricia	Zoopilus,
		Merulina			Polyphyllia.
	A. orbicellæ—Echinopora, Phyllastræa . . .				

2. *Transitions of the Astræidæ to the Caryophyllidæ and Madreporacea.*

Astræa
- . . . . Cyathophyllidæ . . — Turbinolia, Caryophyllia,
- Caulastræa — Mussa, Euphyllia — Fungia, Cyclolites — Stephanoph., Desmoph. — Turbinolia, Caryophyllia,
- *A. orbicellæ*
  - *A. rotulosa* . . . . Cyathina — Turbinolia, Caryophyllia,
  - *A. pleiades* . . . . Stylina, Anthoph. — Dendrophyllia, Gemmipora, Astroitis, Astræopora — Madrepora, Goniopora, Porites, Heliopora.
  - *A. microphthalma* ., Echinopora . . . — Oculina — Dendrophyllia, Gemmipora, Astroitis, Astræopora — Madrepora, Goniopora, Porites, Heliopora.

3. *Transitions of the Madreporidæ to the Caryophyllidæ.*

Madrepora
- . . . . Dendrophyllia, Caryophyllia, Turbinolia.
- Manopora
  - Alveop.
    - Siderop.
      - Pocillop., Seriatop. — Millepora — Cyathina, Oculina.
      - Favosites, Heliopora — Catenipora — Stylina, Anthophyllum, Astroitis, Astræopora,
    - Porites . . . . Goniopora — Stylina, Anthophyllum, Astroitis, Astræopora,
- *Mad. labrosa* . . . . Gemmipora, Zoanthidæ.

It is impossible in tables, or in any manner *on a plane*, to give a correct and complete idea of all the interlinkings of genera; circles give a regularity to the reticulations, which is not found in nature. The passage of the Madrepores into the Manoporæ (table 3), and from these into the Alveoporæ, is almost a direct line; from the last, the line branches either way into the Porites and the Sideroporæ, and the Sideroporæ pass into a network of species of the family Favositidæ, the Seriatoporæ of which appear to lead the way to the Oculinæ. The Porites, through the Gonioporæ, graduate into the Astræoporæ, and thence to the Astroites on one side and the Gemmiporæ on the other. The Madreporæ also pass into the Gemmiporæ, and likewise into the Dendrophylliæ, which two groups are closely allied though distant in the table; the four lines thus meet in the Caryophyllia family, the genera of which have their principal gradations, as shown above. By a study of the other tables, the relations of the groups will be made out without particular explanation. The Actinaria graduate towards the Alcyonaria, through certain Actiniæ, with four or eight lobed disks.

The following table contains a general view of the Classification of Zoophytes, to which the principles discussed appear to lead, together with the characteristics of the several subdivisions.

CONSPECTUS DISTRIBUTIONIS ZOOPHYTORUM.

ZOOPHYTA.

Animalia Radiata sæpius basi affixa, supernè tentaculis coronata cum ore centrali edentato, et intus, tubo cibario uniforo: androgyna; ovipara et gemmipara: nervis inconspicuis (?): circulatione excorde laxissimâ: sensûs organis specialibus nullis.

Ordo I.—ACTINOIDEA.

Ventriculo stomachum includente lamellis radiatis generativis septato; ovulis ore ejectis.

Sub-ordo I.—ACTINARIA.

Tentaculis 6, 12, aut pluribus, sæpissimè non papillosis et apice perforatis: sæpe coralligena; corallis calcareis, (rarissimè corneis,) cellis radiatis.

Tribus I.—ASTRÆACEA.

Multitentaculata, tentaculis subseriatis aut sparsis; sæpe gemmipara, gemmatione superiore, polypis supernè lateraliter prolatantibus: sæpe coralligena, corallis calcareis, cellis multi-radiatis, lamellis ultra cellas productis, itaque superficie corallorum aggregatorum lamello-striatâ.

Familia I. Actinidæ. Animalia non coralligena, sæpius affixa.

Genera. Actinia, Anthea, Adamsia, Edwardsia, Ilyanthus, Capnea, Actinecta, Epicystis, Actinodendrum, Lucernaria, Metridium, Actineria, Heterodactyla, Epicladia.

Familia II. Astræidæ. Calcareo-coralligena; tentaculis margine disci dispositis, discis interdum seriatim tantummodo confluentibus: corallorum cellis excavatis, stellis circumscriptis, interdum lobatis aut lineatis; lamellis corallorum aggregatorum in medio septo sæpius interruptis.

TABULAR VIEW OF THE CLASSIFICATION OF ZOOPHYTES.

ZOOPHYTES.

Animals of the class Radiata: usually attached at base: having a coronet of tentacles above, and an edentate mouth at the centre: within, an alimentary cavity, to which the mouth is the only opening: androgynous; gemmiparous and oviparous: nerves indistinct (?): circulation very imperfect: no special organs of sense.

Order I.—ACTINOIDEA.

Visceral cavity enclosing the stomach, and divided into compartments by radiated lamellæ, having reproductive functions; ovules ejected through the mouth.

Suborder I.—ACTINARIA.

Tentacles 6, 12, or more, in number, not papillose, (with few exceptions,) and perforate at apex: often coralligenous; coralla calcareous, very rarely corneous, cells radiate with lamellæ.

Tribe I.—ASTRÆACEA.

Tentacles many, in imperfect series or scattered; when gemmiparous, gemmation superior, the polyps widening above: often coralligenous; coralla calcareous, cells multiradiate, lamellæ prolonged outward beyond the cells, and hence the surface in aggregate coralla is lamello-striate.

Family I. Actinidæ. Not coralligenous, usually attached.

Genera. Actinia, Anthea, Adamsia, Edwardsia, Ilyanthus, Capnea, Actinecta, Epicystis, Actinodendrum, Lucernaria, Metridium, Actineria, Heterodactyla, Epicladia.

Family II. Astræidæ. Calcareo-coralligenous; tentacles arranged along the margin of the disks; disks sometimes confluent in simple series; coralla, with excavate cells, stars circumscribed, sometimes lobed or linear; lamellæ, in aggregate coralla, interrupted usually along the middle of the septa.

Genera. Euphyllia, Ctenophyllia, Mussa, Manicina, Caulastræa, Tridacophyllia, Astræa, Meandrina, Monticularia, Phyllastræa, Merulina, Echinopora.

Familia III. Fungidæ. Coralligena; discis non circumscriptis, tentaculis sparsis, brevibus et sæpe obsoletis: simplicissima et aggregato-gemmata; aggregatis, discis, undique confluentibus, interstitiis nullis: corallis superficie lamello-striatis et sæpius stellatis, cellis veris nullis; lamellis, aggregatis, ex uno ad alium centrum productis.

Genera. Fungia, Cyclolites, Herpetolithus, Halomitra, Polyphyllia, Zoopilus, Pavonia, Agaricia, Psammocora.

Tribus II.—CARYOPHYLLACEA.

Multitentaculata; sæpissimè gemmipara, gemmatione inferiore, gemmis lateralibus, raro (sicut in quibusdam Cyathophyllidis) sursum crescentibus, polypis supernè non prolatantibus: sæpe coralligena, corallis calcareis, cellis multiradiatis, superficie interstitiali non lamello-striatâ.

Familia I. Cyathophyllidæ. Coralligena; polyporum singulorum corallo internè ad medium sæpius transversè obliquève septato et celluloso.

Genera. Cyathophyllum, Calophyllum, Amplexus, Caninia, Arachnophyllum, Acervularia, Cystiophyllum, Clisiophyllum, Michelinia, Columnaria, Sarcinula.

Familia II. Caryophyllidæ. Coralligena; tentaculis confertis, elongatis; oribus longè exsertis: corallo internè non transversè septato, cellis multiradiatis (radiis duodecim superantibus), caliculis margine tenuibus; interstitiis nunquam lamello-striatis. (Lamellis fere integris.)

Genera. Ecmesus, Cyathina, Stephanophyllia, Turbinalia, Desmophyllum, Culicia, Caryophyllia, Dendrophyllia, Oculina, Anthophyllum, Stylina, Astroitis.

Familia III. Gemmiporidæ. Coralligena; tentaculis brevibus, marginalibus, 2–3 seriatis, disco lato, paulo convexo; corallis porosis, caliculis margine crassis, lamellis fere æqualibus, non exsertis.

Genera. Gemmipora, Astræopora (?).

Familia IV. Zoanthidæ. Non coralligena, extus subcoriacea; tentaculis brevibus, marginalibus, 2–3 seriatis, disco sæpe convexo, margine radiatè striato et interdum valde reflexo.

Genera. Isaura, Zoantha, Palythoa.

Tribus III.—MADREPORACEA.

Tentaculis uniseriatis, duodecim (raro pluribus), interdum obsoletis; gemmipara, gemmatione laterali: coralligena, corallis calcareis, cellis parvulis, radiis 6–12, aut obsoletis; superficie interstitiali non lamello-striatâ.

Familia I. Madreporidæ. Polypis 12-tentaculatis, basi medio non coralligenis; itaque cellis profundissimis, ad medium corallum usque productis.

Genera. Madrepora, Manopora.

Genera. Euphyllia, Ctenophyllia, Mussa, Manicina, Caulastræa, Tridacophyllia, Astræa, Meandrina, Monticularia, Phyllastræa, Merulina, Echinopora.

FAMILY III. FUNGIDÆ. Coralligenous; disks not circumscribed, tentacles scattered, short, and often obsolete: simple or aggregato-gemmate; when aggregate, the disks every way confluent without interstices: coralla, generally with a stellate surface, and without proper cells; lamellæ, in aggregate species, continuous between adjacent polyp-centres.

Genera. Fungia, Cyclolites, Herpetolithus, Halomitra, Polyphyllia, Zoopilus, Pavonia, Agaricia, Psammocora.

TRIBE II.—CARYOPHYLLACEA.

Polyps having numerous tentacles in two or more series: mostly gemmiparous, gemmation inferior, buds lateral; rarely (as in some Cyathophyllidæ) growing upward above the summit of the parent, but summits of polyps (the disks or adjoining margins) not prolate: generally coralligenous; coralla calcareous, cells many-rayed, interstitial surface not lamello-striate.

FAMILY I. CYATHOPHYLLIDÆ. Coralligenous, the corallum of each polyp internally at middle, usually transversely or obliquely cellular.

Genera. Cyathophyllum, Calophyllum, Amplexus, Caninia, Arachnophyllum, Acervularia, Cystiophyllum, Clisiophyllum, Michelinia, Columnaria, Sarcinula.

FAMILY II. CARYOPHYLLIDÆ. Coralligenous; tentacles crowded and long, mouths long exsert; corallum internally not transversely cellular; cells many-rayed (rays more than twelve), margin of calicles thin, interstices not lamello-striate. (Lamellæ nearly or quite entire.)

Genera. Ecmesus, Cyathina, Stephanophyllia, Turbinalia, Desmophyllum, Culicia, Caryophyllia, Dendrophyllia, Oculina, Anthophyllum, Stylina, Astroitis.

FAMILY III. GEMMIPORIDÆ. Coralligenous, tentacles short, marginal, in 2 to 3 series, disk broad and a little convex: coralla porous; calicles with a stout margin, lamellæ even and not exsert.

Genera. Gemmipora, Astræopora (?).

FAMILY IV. ZOANTHIDÆ. Not coralligenous, exterior subcoriaceous; tentacles short, marginal, in 2 or 3 series; disk often convex with the margin radiately striate and sometimes much reflexed.

Genera. Isaura, Zoantha, Palythoa.

TRIBE III.—MADREPORACEA.

Tentacles in a single series, 12 (rarely more), sometimes obsolete; gemmiparous, gemmation lateral: coralligenous, coralla calcareous, cells quite small, rays 6 to 12 or obsolete; interstitial surface not lamello-striate.

FAMILY I. MADREPORIDÆ. Polyps with 12 tentacles, not secreting lime at middle part of base; and hence the cells deep, extending to the centre of the corallum.

Genera. Madrepora, Manopora.

Familia II. Favositidæ. Polypis 12-tentaculatis, basi seriatim coralligenis, itaque cellis fundo calcareis, et medio corallo transversè septatis, raro solidis.

Genera. Alveopora (*Alveoporinæ*); Sideropora, Seriatopora, Pocillopora, Stenopora, Constellaria, Favosites, Catenipora (*Favositinæ*); Heliopora, Heliolites, Millepora (*Helioporinæ*).

Familia III. Poritidæ. Polypis tentaculis interdum duodecim superantibus, totâ basi omnino porosè coralligenis; corallis undique æqualiter porosis, cellis paulo profundis aut superficialibus et medio corallo vix dispiciendis, radiis fere obsoletis.

Genera. Porites, Goniopora.

Tribus IV.—ANTIPATHACEA.

Animalia 6-tentaculata, secretiones corneas basi elaborantia.

Familia I. Antipathidæ. Animalia carnosa, axem corneum spinulosum tegentia.

Subordo II.—ALCYONARIA.

Animalia 8-tentaculata, tentaculis papillosis, papillis apice perforatis: sæpe coralligena, corallis calcareis aut corneis, raro siliceis, cellis nunquam radiatis.

Familia I. Pennatulidæ. Nunquam affixa, aut libera, aut basi defossa.

Genera. Renilla, Pennatula, Veretillum, Funiculina, Virgularia (*Pennatulinæ*); Pavonaria, Umbellularia (*Pavonarinæ*).

Familia II. Alcyonidæ. Carnosa, penitus sæpe calcareo-spiculigera.

Genera. Rhizoxenia, Anthelia, Xenia (*Xeninæ*); Ammothea, Sympodium, Nephthya, Alcyonium (*Alcyoninæ*); Spoggodia (*Spoggodinæ*).

Familia III. Cornularidæ. Corallis tubulatis, corneis.

Genus. Cornularia.

Familia IV. Tubiporidæ. Corallis tubulatis, calcareis.

Genera. Aulopora, Telesto, Tubipora, Syringopora.

Familia V. Gorgonidæ. Secretiones epidermicas basi elaborantia, et sæpissimè alias quoque calcareas internas.

Genera. Corallium (*Coralliinæ*); Hyalonema, Briareum, Gorgonia, Primnoa, Bebryce (*Gorgoninæ*); Isis, Mopsea, Melitæa (*Isinæ*).

Ordo II.—HYDROIDEA.

Ventriculo tubuliformi, simplicissimo; ovulis e lateribus externè enascentibus.

Familia I. Hydridæ. Ovulis singulis; gemmis lateralibus, et pullis maturis deciduis: corallis nullis.

Genus. Hydra.

Family II. Favositidæ. Polyps with 12 tentacles, secreting lime periodically at base, and hence the cells have a calcareous bottom and in the interior of the corallum are transversely septate, rarely solid.

Genera. Alveopora (*Alveoporinæ*); Sideropora, Seriatopora, Pocillopora, Stenopora, Constellaria, Favosites, Catenipora (*Favositinæ*); Heliopora, Heliolites, Millepora, (*Helioporinæ*).

Family III. Poritidæ. Polyps with rarely more than 12 tentacles, forming porous calcareous secretions continuously at base; coralla every where equally fine-porous, cells shallow or superficial and scarcely traceable within the corallum, rays indistinct.

Genera. Porites, Goniopora.

Tribe IV.—ANTIPATHACEA.

Animals with 6 tentacles, forming at base corneous secretions.

Family I. Antipathidæ. Animals fleshy, enveloping a corneous spinulous axis.

Suborder II.—ALCYONARIA.

Animals with 8 tentacles; tentacles papillose, papillæ perforate at apex: often coralligenous; coralla calcareous or corneous, rarely siliceous, cells never radiate within.

Family I. Pennatulidæ. Never attached, but either free or with the base buried in the mud.

Genera. Renilla, Pennatula, Veretillum, Funiculina, Virgularia (*Pennatulinæ*); Pavonaria, Umbellularia (*Pavonarinæ*).

Family II. Alcyonidæ. Fleshy, usually containing disseminated calcareous granules.

Genera. Rhizoxenia, Anthelia, Xenia (*Xeninæ*); Ammothea, Sympodium, Nephthya, Alcyonium (*Alcyoninæ*); Spoggodia (*Spoggodinæ*).

Family III. Cornularidæ. Forming corneous tubular coralla.

Genus. Cornularia.

Family IV. Tubiporidæ. Forming calcareous tubular coralla.

Genera. Aulopora, Telesto, Tubipora, Syringopora (?).

Family V. Gorgonidæ. Forming basal epidermic secretions, and often, also, other tissue secretions, the latter separable from the former.

Genera. Corallium (*Coralliinæ*); Hyalonema, Briareum, Gorgonia, Primnoa, Bebryce (*Gorgoninæ*); Isis, Mopsea, Melitæa (*Isinæ*).

Order II.—HYDROIDEA.

Animals with the internal cavity tubular and quite simple: ovules growing outward from the sides.

Family I. Hydridæ. Ovules single; buds lateral, young falling off when full grown: not coralligenous.

Genus. Hydra.

FAMILIA II. SERTULARIDÆ. Ovulis in vesiculo inclusis, gemmis lateralibus persistentibus: corallis corneis, caliculis sessilibus.

Genera. Antennularia, Plumularia, Sertularia, Thuiaria, Thoa, Pasythea.

FAMILIA III. CAMPANULARIDÆ. Ovulis in vesiculo inclusis, gemmis lateralibus persistentibus; corallis corneis, caliculis pedicellatis.

Genera. Laomedea, Campanularia.

FAMILIA IV. TUBULARIDÆ. Gemmulis nudis caducis, juxta tentaculos enascentibus; animalia sæpe coralligena, corallis corneis, tubulatis.

Genera. Pennaria, Tubularia, Syncoryna, Corydendrium, Eudendrium, Coryna, Hydractinia.

A BRIEF REVIEW OF THE PRINCIPAL SYSTEMS OF CLASSIFICATION OF FORMER AUTHORS.—The principal systems of classification in this department of Zoology, are those of Lamarck, Lamouroux, Schweigger, Blainville, Ehrenberg, and Milne Edwards.

LAMARCK.—This author included under the head of Polyps, the Infusoria and Rotifera, together with the Corallinæ (Algæ) and Sponges. The following are his subdivisions, as given in the second edition of his work on Invertebrate Animals, with their equivalents, where there are such, in the system adopted.

ORDO I. POLYPI CILIATI. Includes the Infusoria and Rotifera.

ORDO II. POLYPI DENUDATI, or naked polyps. A group of unrelated genera, comprising the Hydræ, part of the Zoanthidæ, and part of the Tubularidæ.

ORDO III. POLYPI VAGINATI, or coralligenous polyps, subdivided as follows:

1. "*Polypiers fluviatiles*," some *fresh-water* Bryozoa with the Spongillæ.

2. "*Polypiers vaginiformes*." The Hydroidea, excepting the Hydræ, together with some Bryozoa and Coralline Algæ.

3. "*Polypiers à reseau*." Mostly Bryozoa.

4. "*Polypiers foraminés*;" compact calcareous corals with small cells, without rays. The Tubiporæ of the Alcyonaria, and the Favosites, Cateniporæ and Milleporæ of the Madrepore tribe, with some others.

5. "*Polypiers lamellifères*." Calcareous with rayed cells. The coralligenous Astræacea, Caryophyllacea, and the Madreporacea, excepting the Favosites, Cateniporæ, and Milleporæ.

6. "*Polypiers corticifères*." The Antipathi and Gorgonidæ, with many of the Coralline Algæ.

7. "*Polypiers empâtés*." The Sponges, with some of the Coralline Algæ.

ORDO IV. POLYPI TUBIFERI. The family Alcyonidæ.

ORDO V. POLYPI NATANTES. The Pennatulidæ from among the Alcyonaria, together with the family of Encrinites, which belong with Echinoderms.

LAMOUROUX.—Lamouroux, excluding the first order of Lamarck, arranges Zoophytes in three groups. 1. *Those that are flexible or not entirely stony*; 2. *Those that are stony and not flexible; and* 3. *Those that are fleshy* (*sarcoid*) *without a central axis.* He included in the first division, the Hydroidea, part of the Bryozoa, the Corallinæ, Sponges, and Gorgonidæ; in the 2d. The remainder of the Bryozoa, the Caryophyllia, Astræa, and Madrepore tribes, together with the "Foraminés" of Lamarck; and in the 3d. The Alcyonia, Zoanthidæ, and other unallied species.

SCHWEIGGER.—Schweigger divides Zoophytes into Z. MONOHYLA, and Z. HETERO-

Family II. Sertularidæ. Ovules enclosed in ovarian vesicles; buds lateral, persistent: coralla corneous, calicles sessile.

Genera. Antennularia, Plumularia, Sertularia, Thuiaria, Thoa, Pasythea.

Family III. Campanularidæ. Ovules enclosed in ovarian vesicles; buds lateral, persistent; coralla corneous, calicles pedicellate.

Genera. Laomedea, Campanularia.

Family IV. Tubularidæ. Caducous gemmules growing from near the base of the tentacles, and naked; often coralligenous, coralla corneous, tubular.

Genera. Pennaria, Tubularia, Syncoryna, Corydendrium, Eudendrium, Coryna, Hydractinia.

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hyla, separating thus the fleshy species from the others; the former including Lamarck's orders, I., II., IV., and the latter, the remainder of his orders. The Zoophyta Heterohyla are subdivided as follows:

1. *Lithophyta nullipora.* Nullipores, lately shown to be of vegetable nature, secreting lime.

2. *Lithophyta porosa.* The Madrepore tribe, excluding the Favosites and Catenipora.

3. *Lithophyta lamellosa.* The coralligenous Astræacea and Caryophyllacea.

4. *Lithophyta fistulosa.* Lamarck's "Polypiers foraminés."

5. *Ceratophyta spongiosa.* Sponges, and some Alcyonidæ.

6. *Ceratophyta tubulosa.* The Hydroidea (excluding the Hydridæ), the Tubularidæ in part, and some of the Bryozoa.

7. *Ceratophyta foliacea.* Bryozoa.

8. *Ceratophyta corticosa.* The Antipathi and Gorgonidæ.

9. *Pennæ marinæ.* The Pennatulidæ.

Blainville.—Blainville includes under the name Zoophytes, the fleshy Actiniæ as well as the coralligenous species, and also the Echinoderms, Acalephæ, and Sponges. The Sponges constitute his "*Amorphozoaires*," and the other species, the "*Actinozoaires*." The "Actinozoaires" are distributed as follows:

Class I. "Cirrhodermaires," including the Echinoderms.

Class II. "Arachnodermaires." The Acalephæ.

Class III. "Zoanthaires." The Actinidæ, Zoanthidæ, together with the coralligenous Astræacea, Caryophyllacea, and Madreporacea, excluding from the last the Antipathi, Milleporæ, and Favosites, nearly as was done by Lamarck.

Class IV. "Polypiaires." Includes the Milleporæ, under which name Blainville follows Lamouroux in comprising various unallied genera, characterized by the small non-radiate cells of the corallum; and in other divisions, the Bryozoa and Hydroidea.

Class V. "Zoophytaires." Corresponding to the Alcyonaria.

We perceive in this classification a great advance beyond those preceding it. The Alcyonaria, before widely distributed, are here united in a single group: the Actinidæ are arranged with the coral polyps; the Bryozoa are mostly grouped together, and the Hydroidea are brought into close association, although still the Hydra forms a sub-class next to the Sertularidæ, instead of being united with them.

Ehrenberg.—Ehrenberg divides Zoophytes—his Anthozoa—into the two orders, Zoocorallia and Phytocorallia. The former, "*Animal Zoophytes*," contains the fleshy species and unattached coralligenous species; and the latter, "*Plant Zoophytes*," the attached coralligenous species.[a]

The order ZOOCORALLIA includes the following subdivisions:

TRIBE I. ZOOCORALLIA POLYACTINIA. Comprises his families Actinina, Zoanthina, and Fungina, corresponding respectively to the families Actinidæ, Zoanthidæ, and the free Fungidæ, along with the genus Turbinalia of the Caryophyllia tribe.

TRIBE II. ZOOCORALLIA OCTACTINIA, or species with 8 rays to the polyps. Comprises his families Xenina, Tubiporina, Halcyonina, and Pennatulina, or all the Alcyonaria but the Gorgonidæ, which fall into his second order.

TRIBE III. ZOOCORALLIA OLIGACTINIA, corresponding to Hydroidea, and including his families Hydrina, Tubularina, and Sertularina.

The order PHYTOCORALLIA, is subdivided as follows:

TRIBE IV. PHYTOCORALLIA POLYACTINIA. Includes the families Ocellina, and Dedalina; the former corresponding to the Caryophyllidæ and Cyathophyllidæ, except that the Turbinaliæ are excluded by Ehrenberg, and some Astræas are introduced under the genus Explanaria; and the latter corresponding nearly to the Astræidæ and Fungidæ, except that the free Fungidæ are separated.

TRIBE V. PHYTOCORALLIA DODECACTINIA. Comprises the families Madreporina and Milleporina, the first including the Poritidæ and part of the Madreporidæ, and the second, the remainder of the Madreporidæ of the system adopted.

TRIBE VI. PHYTOCORALLIA OCTACTINIA, including the families Isidea and Gorgonina, corresponding to the Gorgonidæ.

TRIBE VII. PHYTOCORALLIA OLIGACTINIA, including the single genus Allopora.

This system removes the free Fungidæ far from the attached species, and the same principle carried out should place in different families the free and attached Cyathophylla, Euphylliæ, and others. The natural group Alcyonaria is divided, and the parts are widely separated. Notwithstanding these singularities arising from the undue importance allowed to the characters of his Orders, the system exhibits throughout the comprehensive acumen of its distinguished author, and was the first that rested its distinctions solely on the structure of the animals, or the *living* zoophytes.

MILNE EDWARDS.—In the philosophical system of Milne Edwards, the Bryozoa constitute the order *Polypes tuniciens;* and other Zoophytes (our Zoophyta), his *Polypes parenchymatés.* This second order he subdivides as follows:

1. "*Sertulariens.*" Corresponding to the Hydroidea.
2. "*Zoanthaires.*" Corresponding to the Actinaria.
3. "*Alcyoniens.*" Corresponding to the Alcyonaria.

The Alcyonia group, which is bound together by important characters, is thus kept united; and the other groups are equally well defined in their limits and characteristics. The "Zoanthaires" and "Alcyoniens," constitute together our Actinoidea, a group which is equivalent, as a whole, rather than its parts, to the "Sertulariens" (Hydroidea).

[a] These orders are characterized by Ehrenberg as follows (op. cit., pp. 255, and 299):

ZOOCORALLIA. Corpore aut omnino molli, aut Cephalopodum more intus lapidem generante (secernente nec excernente) hinc sæpe omnino libera et, præter formam, animalium characteres omnes perfectius servantia. PHYTOCORALLIA, Corpore aut lapideam aut corneam materiam agglutinantem secernente ac dorso (solea) excernente ejusque ope semper adnato (Ostrearum more).

APPENDIX.

ADDENDA AND ANNOTATIONS.

Reproduction in the Hydroidea.—p. 22.

The observations of Van Beneden, on the Tubularidæ, but lately published, have brought out many new facts with regard to the structure and modes of reproduction characterizing this division of the Hydroidea.* His investigations have led him to distinguish the following modes of reproduction :

1. By persistent buds, by which, as in the Sertulariæ, and in zoophytes generally, compound groups are formed.

2. By caducous ovule-like buds or gemmules. These are produced about the bases of the tentacles, and have been considered true ova (pp. 22, 23), to which they are closely analogous. Van Beneden describes them as presenting within, when complete, a distinct cellule, which he considers as corresponding to the germinant vesicle of the true egg. This cellule enlarges, and shortly a membrane forms across, which is in contact below with the circulating fluids of the axis; from this membrane the new polyp proceeds. He traces out the changes in progress from this state to the developement of the medusa-like young, a Beroe in form,—a floating pellucid disk, fringed around with delicate tentacles, and furnished with eight eyes.

3. By a single ovule, thus approaching in character the Actinoidea.

Besides the above modes, he mentions also two others.

4. Compound ova, resulting in each instance from a production of numerous ovules from the yolk of what at first appears to be a simple ovum, each ovule having its own germinal vesicle, and producing separate young.

5. Ovules formed within the caducous gemmules. This mode corresponds nearly to known instances of ova in larvæ or undeveloped young. These develope and take the form of a Planaria, and are the *Planules* of Sir J. G. Dalyell. (Fourth Rep. Brit. Assoc., 1834, p. 602.) From the Planule, a kind of larve, the perfect animal afterwards proceeds.

* Van Beneden's very elaborate Memoir is just published in the Transactions of the Royal Society of Brussels. A short abstract of it is given in a late number of L'Institut, and also in the Annals and Magazine of Natural History, vol. xv., p. 346 ; and these are the only sources of information with regard to it which the author has had.

The condition of a forming bud, that is, the nutrition present and forces at work, seem to render it liable to this abnormal developement in animals of the lower grades, in which the formation of an ovule is little more than the reproduction of any other cellule in the body. The ovigerous portion of any animal must be that best fitted in these respects for the developements required ; and in these inferior organizations, the powers of reproduction are more generally distributed, as less concentration is needed.

Van Beneden has observed, that in the Corynæ and Hydractiniæ the stomachs of the several polyps in a compound zoophyte are isolated, instead of communicating with one another along an axial tubular cavity ; and that consequently there is no circulation in these animals like that of other Hydroidea. This fact decides the unimportance of the character upon which the Alcyonaria have been hitherto so widely separated from the Actinaria. See note to page 45.

Reproduction in the Alcyonaria.—p. 43.

Milne Edwards, by his dissections of the Veretillum cynomorium, illustrated by excellent figures in the late edition of Cuvier's Règne Animal (Paris, 1837, pl. 91, fig. 1), shows that both spermatic cords and ovarian clusters sometimes occur attached to the same lamellæ. The figures represent the upper part of the lamellæ as spermatic and the lower part ovarian. It is interesting to observe the close analogy here exhibited to a *gynandrous* plant. Two of the lamellæ, however, as in the Tubipora described in the text, were without spermatic cords.

Structure of Coralla.—p. 51.

Under a microscope of moderate power, animal fibres may be readily detected in a thin slice of coral, ramifying irregularly throughout it. But beyond this, even with an instrument magnifying three hundred diameters, I have been unable to discover any regular structure that can be traced with certainty to the pre-existence of separate animal cellules. In the lamellæ of the Euphyllia gracilis and Astræa dipsacea, polished down and examined with the power above specified, only a minutely clouded appearance was made out, too indefinite in character to be represented. By rubbing a crayon over a piece of paper a little rough, as good a figure of it would be had, as a more laboured sketch could give. There were parallel bands of light and shade corresponding in direction with the margin of the plate, and with all its dentations, which indicated what other observations had shown, that these plates gradually enlarge by the extension of the edge; and this was the only evidence made out of regularity of structure. Examined with a polarising attachment to the microscope, the thin slices permitted the polarised light to pass, but no colours were exhibited, except in points which were extremely minute when magnified one hundred and fifty diameters, the power used in making the observation. This fact indicated that the coral plates were composed of minute granules, confusedly aggregated, as if each had been the result of independent formation, or the secretion of a separate animal cellule. There was no reason whatever to infer that the particles of the plate had been secreted and accumulated by superposition under crystallogenic forces; on the contrary, the structure was completely amorphous, and such as could have resulted only from a mere aggregation of extremely minute granules, themselves crystalline. Although there seemed to be nothing of the tessellated structure, which has been detected in the shells of many molluscs, yet the observations may point to a similarity of formation; and it is possible that with more skilful manipulation and higher lenses, something more satisfactory might be ascertained. It should be observed, however, that the beautiful results obtained by Mr. Carpenter, in his investigations into the structure of shells, were generally distinct when a power of only fifty diameters was used.

The structure of the spicula in the Alcyonia appears to be somewhat different. These spicula are commonly five or six times as long as their greatest breadth, and are more or less pointed at each extremity. The surface is usually rough with minute prominences, so that a profile, seen in any direction, gives nearly the appearance in the figures on page 54, though often still more irregular. In the Spoggodia florida of Lesson, their length is equal to full twenty diameters, and the spicula are mostly a little curved. They lie in every position in the thin integuments which constitute these zoophytes (figure 4 *c*, plate 59), and are exsert about the small clusters of polyps. But in the Alcyonia they are generally much shorter, and often lie nearly parallel, through much of their texture; and near the bases of the tentacles, there are two oblique divergent series, corresponding apparently with the lines of tissue.

One of the spicula of the Spoggodia is figured, enlarged, on plate 59, fig. 4 *d*. Although unusual in length, the knobby character of its surface is the prevailing one in the Alcyonaria. When polished down very thin, the appearance in figure 4 *e*, is presented. Faint lines varying in distinctness are seen to run parallel with the edge, through all its uneven outline; that is, there is evidence of a concentric structure, evincing that the spicula are formed by successive superpositions over the irregular surface. About the central portions of the figure there are a few oblong dark spots, each of which pertained to one of the surface knobs that had been polished off. The concentric layers in these transsected knobs, have their edges towards the observer, and consequently they are not as transparent as the flat parts between. It is also seen that these prominences, traced inward, become a little oblique at the centre, from which they appear to radiate, showing that the spicula, as they were formed, increased most rapidly towards one extremity. In polarised light the spicula exhibit brilliant colours; and the same magnifying power which gave scarcely visible points of colour with the lamellæ of the Astræa, here afforded sheets half an inch or more in breadth, of rich green and flame tints. The spicula appeared therefore to be the result of a simple crystalline superposition of the calcareous material from the depositing secretions. With a power magnifying three hundred diameters, no trace of animal cellules was distinguished, and no regular texture apart from the evidences of a concentric structure above stated.

The hardness of these coral secretions, which is much above that of common carbonate of lime, as stated by Mr. Silliman on a following page, is not fully explained by the peculiar chemical composition detected by this chemist. We suggest, as one cause, that the calcareous portion may have, in its intimate texture, the structure of Arragonite, or prismatic carbonate of lime, instead of that of common rhombohedral calc spar. The Arragonite structure has been shown to be due to crystallization at a higher temperature than that which is required for calc spar, the two minerals being identical in composition: in consequence of this higher temperature, a different crystalline form is assumed; and, moreover, the material has a higher degree of hardness, that of Arragonite being designated by $3\frac{1}{2}$ to 4, while common calc spar or rhombohedral carbonate of lime is 3. These remarks, it will be perceived, bear upon the internal calcareous secretions of other animals. In connexion, it should be observed, however, that distinct rhombohedrons of *calc spar* have been detected by Carpenter in the shells of some molluscs.

With regard to the structure of the horny axis of the Gorgoniæ, we have nothing to add to what is stated in the text. In structure, growth, and vitality, they appear to correspond to the horny secretions of other animals.

Much yet remains to be done in investigating the microscopic structure of corals, and we may express the hope that one who has been so successful in his examinations of molluscs, may extend his researches to this department of science.

Composition of Coralla.—p. 56.

It has been stated that the chemical analyses of corals were undertaken for this work by Mr. B. Silliman, jr. The following pages contain the results of his researches, which will be found to be highly important, both in a physiological and geological point of view.

"No extended researches on the chemical constitution of corals have been made, it is believed, since Mr. Hatchett's, already quoted in this work. This chemist did not operate *quantitively* on any of the species examined by him ; and his investigation tended to show that the calcareous corals, as well as the coverings of most of the molluscs, experimented upon, consisted merely of carbonate of lime. Such was the opinion with which these chemical examinations were commenced. But while it has been found that carbonate of lime is the principal ingredient, other elements have been detected, showing that coral is far from being the simple calcareous material supposed.

"The following is a list of the species examined, which are here numbered for the convenience of reference :

1. Porites favosa, Sandwich Islands.
2. Porites nigrescens, Feejees.
3. Porites limosa, Feejees.
4. Porites cylindrica, Feejees.
5. Porites fragosa, Feejees.
6. Porites,* Paumotu.
7. Porites,* Wakes Island.
8. Porites,* Wakes Island.
9. Madrepora palmata, West Indies.
10. Mad. spicifera, Ceylon.
11. Mad. prolifera, Bermuda.
12. Mad. plantaginea, Ceylon.
13. Mad. cytherea, Tahiti.
14. Madrepora, Feejees.
15. Madrepora, Feejees.
16. Madrepora, Feejees.
17. Madrepora, Feejees.
18. Mad. cyclopea, Wakes Island.
19. Pocillopora damicornis, Sooloo.
20. P. elongata, Ceylon.
21. P. grandis, Feejees.
22. P. ligulata, Sandwich Islands.
23. P. cespitosa, Sandwich Islands.
24. Millepora tortuosa, Feejees.
25. Heliopora cærulea, East Indies.
26. Gemmipora brassica, Feejees.
27. Dendrophyllia nigrescens, Feejees.
28. Meandrina phrygia, Ceylon.
29. Astræa orion, Ceylon.
30. Astræa (pl. 13, fig. 15).

* Worn specimens, not identified.

31. Astræa, Wakes Island.
32. Astræa, Wakes Island.
33. Astræa, Feejees.
34. Astræa, Feejees.
35. Astræa, Feejees.
36. Shell of Chama.

"Nine of the above species, of which there was the largest quantity on hand, were selected for a minute determination of each ingredient, while of the others, only the proportion of carbonate of lime and animal matter to the other ingredients, was determined. The following are the nine selected :

I. Porites favosa (No. 1), Sandwich Islands.
II. Madrepora palmatum (No. 9), West Indies.
III. Madrepora spicifera (No. 10), Ceylon.
IV. Madrepora prolifera (No. 11), Bermudas.
V. Madrepora plantaginea (No. 12), Ceylon.
VI. Pocillopora ligulata (No. 22), Sandwich Islands.
VII. Meandrina phrygia (No. 28), Ceylon.
VIII. Astræa orion (No. 29), Ceylon.
IX. Astræa (No. 30, p. 721, pl. 13, fig. 15).

"A few remarks are added upon some of their physical characters, before giving the mode and results of analysis.

"*Hardness.*—All the various corals examined were superior in hardness to calcareous spar or common marble, and not inferior to Arragonite; while some were as hard as Apatite or crystallized phosphate of lime; or according to the scale used by mineralogists, the usual hardness will be expressed by 4, though in a few instances as high as 5. Using an iron mortar in the earlier trials, the iron pestle was roughened and cut under the resistance of the angular masses of coral, to a degree quite remarkable considering the nature of the substance operated on. So much iron was communicated to the powder from this source, that recourse was had to a mortar of porcelain, and even this was not proof against wear, the porcelain pestle being pitted by the repeated blows. The more porous species, of course, were crushed with less difficulty; and this was especially the case with the species of Porites.

"*Specific Gravity.*—The specimens were reduced to fine powder before trying the specific gravity, as the porous character of the coral would otherwise interfere with obtaining correct results. Considerable variation will be observed in the following table. The numbers correspond to the catalogue on the preceding page.

Specimens.	Sp. Grav.	Specimens.	Sp. Grav.	Specimens.	Sp. Grav.
No. 1	2·817	No. 20	2·217	No. 31	2·688
3	2·732	22	2·564	33	2·500
4	2·564	23	2·353	34	2·500
9	2·421	25	2·578	Meand. rustica	2·571
10	2·105	26	2·584	Shell of Chama.	2·857
12	2·427	27	2·740		

"The average from the sixteen species of corals is 2·523.

"*Colour.*—In general the colour of the specimens examined was white, or nearly so; but some of them, as Dendrophyllia nigrescens, and the blue Heliopora (H. cerulea) were highly coloured. The colouring matter, in all cases, proved to be organic, and was generally due to some trace of the animal tissues. The highly-coloured ones, when powdered, burned white, giving out, at a red heat, the odour of animal matter. The Heliopora dissolved in chlorohydric acid, without having its colour altered, and gave a light indigo-blue solution. A drop of nitric acid, however, discharged this colour, and ammonia threw it down as a brown precipitate. Heat immediately destroys it. It is, therefore, evident that the colouring matter is entirely organic, and is in no way connected with the mineral constitution of the coral. However, some corals have a slight ferruginous tint, from the presence of a little peroxyd of iron, which will be seen to be an almost constant constituent, although in exceedingly small quantity.

"*Behaviour with reagents.*—All corals are rapidly dissolved in dilute chlorohydric, nitric, or acetic acids, with brisk effervescence and escape of carbonic acid. The solution is frequently coloured by organic matter, which sometimes renders it turbid. When the powdered coral is treated with pure water, more or less of common salt and other soluble saline matters, derived from the evaporation of sea water, are washed out, and this precaution was found necessary to insure accurate results.

"The solution of a coral in nitric acid is very soon blackened by a solution of *nitrate of silver*, from the presence of organic matter. Ammonia, added to a solution in nitric or chlorohydric acid, with the least possible excess of acid, will generally produce an immediate precipitate of granular ammonio-phosphate of magnesia, thus indicating the presence of both magnesia and phosphoric acid.

"Chloride of barium produces, with a chlorohydric solution, a granular, white precipitate, which is nearly all redissolved in an excess of chlorohydric acid. (A small portion of sulphate of barytes is generally formed in using this test, owing to the almost constant presence of a small quantity of sulphate of lime in the corals.)

"A portion, dissolved in nitric acid, and carefully neutralized, when treated with nitrate of silver, will, on standing, deposit a considerable yellowish precipitate of phosphate of silver, which is redissolved in ammonia and nitric acid.

"Acetate of lead, added to a chlorohydric solution, produces a copious precipitate of chloride of lead, which is not wholly redissolved by an excess of acetic acid, but is taken up by nitric acid. These facts are a sufficient proof of the presence of phosphoric acid.

"Lime-water, added to a solution of coral, either neutral or slightly acid, will produce an immediate gelatinous precipitate of all the bases and acids which the coral can contain, except, of course, the lime and solvent acid. Great care is needed in this operation to prevent the formation of a carbonate of lime: the solution should have been recently boiled, and the test applied while it is yet hot, the air being excluded; and the precipitate should be immediately collected on a filter and washed. If the precipitate by lime-water be fused in a platinum capsule, with carbonate of soda, or carbonate of potassa in excess, the phosphoric acid is all transferred to an equivalent portion of alkaline base, while the lime or magnesia, or the base with which it was before united, will remain as a carbonate. The usual tests, which have already been enumerated, will show the presence of the phosphoric acid.

"The *lime-water* test offers far the best means of separating from the lime (which exists as a carbonate), all the other constituents of a coral, as these various substances are in very small quantity compared with the entire mass of the coral. Some easy means of completely separating them all, is an indispensable preliminary step in their examination and estimation.

"I am indebted to my friend Dr. J. L. Smith, of Charleston, South Carolina, for suggesting to me the use of this test in the analysis of the corals.

"As the several elements whose presence our researches have determined in corals, have been enumerated in the body of the work (p. 57), it is not necessary to repeat them here; but we may state, in a summary manner, an outline of the general course of analysis pursued in determining the constitution of the *lime-water precipitate*, which, it will be allowed, contains several elements, whose association has always been considered as offering some of the most difficult problems in the whole range of inorganic analysis. The following plan of analysish as been contrived in part, from the late researches of Von Rammelsberg, on the estimation of phosphoric acid, and partly from the labours of Rose and Berzelius, adapting the method to the requirements of the particular problem before us.

"A. The lime-water precipitate, after ignition, is weighed and then digested in fine powder in cold chlorohydric acid; it slowly dissolves, leaving a white flocculent powder. This collected and washed, will be found to be *silica*. It is harsh and gritty between the teeth, is not taken up by long digestion in strong acids, dissolves in a solution of caustic potassa, and before the blow-pipe forms a hard colourless glass with carbonate of soda, dissolving in this reagent with effervescence.

"B. The solution in chlorohydric acid is supersaturated with caustic ammonia, and boiled; a gelatinous precipitate separates, which is usually coloured by iron, and by its characters indicates the presence of alumina. This precipitate contains the phosphoric and other acids and the bases therewith combined. It is collected and the filtrate therefrom (C) is examined for *lime and magnesia*, both of which are usually present.

"D. The precipitate by ammonia (B) is next made into a thick paste with strong sulphuric acid, in a small vessel of platina. A plate of glass, coated with wax and written on, is placed over the crucible; and heat being applied, *hydrofluoric acid* escapes, and attacking the glass, leaves a permanent record of its presence. I have never failed to obtain evidence of the presence of fluorine in any coral which has been subjected to the test. Generally, exposure for one minute will etch the glass most decidedly; and one experiment will suffice to mark distinctly several pieces of glass. By this plan of analysis the quantity of fluorine cannot be estimated, and it must be judged of either by the loss or by the deficiency of acids to satisfy all the bases formed. The constant association of phosphoric acid and fluorine, renders it advisable, in compounds in nature, where one of these elements is found, to search for the other.

"E. After the sulphuric acid has been digested on (D), long enough to convert all the bases present into sulphates, a portion of bisulphate of potash or caustic potash is added, and a little water, to dissolve it; to this, a very large quantity of alcohol of a specific gravity about ·860, is added, and the whole is allowed to stand for some hours; during which the double sulphates of potassa, alumina, and iron, crystallize out, while any lime previously combined is separated as sulphate, and in the solution we must look for the phosphoric acid and magnesia, together with a little persalt of iron, held up by the alcohol.

"F. The mixture (E) being filtered and the precipitate washed quite clean with alcohol, the filtrate is evaporated until all the alcohol is expelled, and then supersaturated with ammonia; a little trace of alumina and iron separates, which may be added to that to be obtained from the other portion (H). We may now either add an excess of pure chloride of calcium to the filtrate (F), or a portion of perchloride of iron. The object in either case, is to separate the phosphoric acid in combination with a base, from whose weight its quantity may be directly estimated, which is an indispensable step, since the fluorine, according to this plan of analysis, can be estimated only by the amount required to saturate the excess of bases. In case the chloride of calcium is employed, we have all the phosphoric acid in the form of phosphate of lime, mixed with a large quantity of sulphate of lime, derived from the sulphuric acid and sulphate of potassa previously employed. This mixture of phosphate and sulphate of lime is collected, washed, and redissolved in chlorohydric acid. The sulphate of lime is separated by alcohol, and the phosphoric acid remains in solution, which, after the excess of alcohol has been expelled, may be thrown down by ammonia, ignited and weighed, or preferably, may be estimated by a magnesian salt. If we employ the method by perchloride of iron, we form in the acid solution containing the phosphoric acid, a basic perphosphate of iron, on supersaturating the solution with ammonia. This compound is mixed with a bulky mass of peroxide of iron, which being thrown on a filter and thoroughly washed, is subsequently decomposed completely by hydrosulphuret of ammonia, into sulphuret of iron and phosphate of ammonia. Care must be taken to use a sufficient quantity of perchloride of iron, otherwise a white precipitate of neutral perphosphate of iron is formed, which is soluble in an excess of ammonia. In either case (the employment of the chloride of calcium, or the perchloride of iron), the phosphoric acid eliminated may be finally best estimated by a magnesian salt and ammonia, as the ammonio-phosphate of magnesia, from whose known constitution the phosphoric acid is easily calculated. We have employed both of these methods; but on many accounts prefer that by the perchloride of iron.

"G. The alcoholic filtrate from (H), containing magnesia and lime, is treated by the well-known methods of analysis for the estimation of those substances. The lime in all cases in these researches, was converted into sulphate and precipitated by alcohol. The magnesia was estimated as phosphate.

"H. The crystalline precipitate from (F), which was collected on the filter, contained the alumina and iron, previously in combination with phosphoric acid or fluorine. This precipitate is boiled in a capsule with a strong solution of carbonate of soda, to decompose the sulphate of lime; it is then filtered, the insoluble residue washed thoroughly and treated with chlorohydric acid, the precipitate by ammonia from (F) being added, and the whole treated with excess of ammonia. Alumina and iron fall, which may be afterward separated in the usual way; but this was generally not deemed requisite, the quantity of iron being very small in most cases.

"I. The filtrate from (H) is treated for lime by oxalate of ammonia, and the oxalate converted into sulphate and weighed: this dose of lime had been previously united to phosphoric acid or fluorine.

"J. Magnesia is next separated from the filtrate of (I), by ammonia and phosphate of soda.

"K. The alkaline liquor from (H) contains another portion of magnesia, which is separated in like manner as the ammonio-phosphate. Much labour is saved if we take care to reserve the several portions, from which magnesia has been thrown down, and unite them in one filtration and weighing, instead of treating them as so many separate portions.

"The minute determination of all the constituents of the lime-water precipitate, was attempted only on those specimens of which we had a large quantity at command; for a solution of half a pound or more of the coral in nitric or chlorohydric acid was necessary to afford sufficient precipitate for analysis. The carbonate of lime, by far the most abundant constituent, was separately determined on one gramme, as sulphate of lime, and from this the carbonate was calculated. The ratio of phosphates and fluorides of the several bases to the entire mass, was also determined from a distinct portion of coral, two grammes by weight; and from the data thus furnished, we have the means of safely estimating the organic matter by the loss.

"*Organic Matter.*—This constituent of the corals deserves particular notice. Some remarks have already been made on it, when speaking of the colouring matter of corals. This organic matter is so intimately united, throughout the whole structure of the corals, amounting to 4–8 per cent., that it cannot be separated by any method resorted to, except by repeated deflagrations with the nitrate of ammonia. When reduced to the finest impalpable powder, it may be digested in repeated doses of boiling water, until no trace of organic matter is longer found in the water, and yet a careful analysis, by falling short of the amount required to complete the 100 parts, will invariably show its presence. The oxalate of lime obtained in their analysis, if ignited (as in the usual manner directed for the estimation of lime), will always have a dark carbonaceous hue, derived from the organic matter of the coral.

"During the solution of considerable quantities of several corals, whose analyses are given beyond (particularly in No. IV., but more or less in all), a large quantity of fatty (?) matter separated, of a yellow colour and disagreeable penetrating odour, though not fetid. It was easily seen floating on the surface of the solution, in transparent jelly-like masses of a yellowish colour. It was insoluble in alcohol, but readily so in cold ether, and the evaporation of its etherial solution yielded a yellow solid, resembling wax. It fuses below 200° F. A pungent irritating odour arose from the evaporation of the etherial solution near its close, which acted powerfully on the eyes and nostrils. This volatile principle may be analogous to that known to proceed from the decomposition of fat (acrolein ?). It deserves more attention than I have been able to give it, particularly as it may perhaps be the source of the disagreeable odour of some limestones of coral origin.

"*Analyses.*—The following tables exhibit a comprehensive view of the results of the several analyses. The relative proportions of organic matter, carbonate of lime, and the complex precipitate of phosphates and fluorides thrown down by lime-water, are first given; and afterwards the definite composition of this precipitate in the nine species more minutely investigated.

	Porites. No. 1 (I.)	Porites. No. 3.	Porites. No. 4.	Porites. No. 5.	Porites. No. 6.
Carbonate of lime,	95·84	94·412	94·807	93·875	89·864
Phosphates and fluorides,	2·05	0·900	0·950	1·561	0·700
Organic matter,	2·11	4·688	4·243	4·564	9·431

	Porites. No. 7.	Porites. No. 8.	Madrepora. No. 9 (II.)	Madrepora. No. 10 (III.)	Madrepora. No. 11 (IV.)
Carbonate of lime,	94·438	95·000	94·807	92·815	95·086
Phosphates and fluorides,	2·100	1·650	0·745	0·600	0·300
Organic matter,	3·462	3·350	4·448	6·585	4·614

	Madrepora. No. 12 (V.)	Madrepora. No. 14.	Madrepora. No. 15.	Madrepora. No. 16.	Madrepora. No. 17.
Carbonate of lime,	94·881	93·297	94·143	94·239	93·59
Phosphates and fluorides,	0·710	2·450	0·900	0·500	0·500
Organic matter,	4·409	4·253	4·957	5·261	5·91
	Pocillopora. No. 19.	**Pocillopora. No. 20.**	**Pocillopora. No. 21.**	**Pocillopora. No. 22 (VI.)**	**Pocillopora. No. 23.**
Carbonate of lime,	94·659	93·60	95·001	93·848	94·583
Phosphates and fluorides,	0·550	1·90	1·450	0·550	1·050
Organic matter,	4·791	4·50	3·549	5·602	4·397
	Millepora. No. 24.	**Heliopora. No. 25.**	**Gemmipora. No. 26.**	**Meandrina. No. 28 (VII.)**	**Astræa. No. 29 (VIII.)**
Carbonate of lime,	94·226	95·545	92·751	93·559	96·471
Phosphates and fluorides,	1·200	1·000	1·500	0·910	0·802
Organic matter,	4·574	3·455	5·749	5·536	2·727
	Astræa. No. 30 (IX.)	**Astræa. No. 31.**	**Astræa. No. 33.**	**Astræa. No. 34.**	**Astræa. No. 35.**
Carbonate of lime,	96·551	94·810	91·782	93·923	91·112
Phosphates and fluorides,	0·262	0·900	2·100	0·500	·550
Organic matter,	3·187	4·290	6·118	5·577	8·338

"A portion of the massive shell of a large Chama, treated in a similar manner, afforded for 100 parts the following result:

Carbonate of lime, ...	97·007
Precipitate by lime-water, ...	2·600
Organic matter, ...	0·398

"The amount of organic matter is here very small; while the precipitate by lime-water is large. The examination of other shells with reference to this point, would have been highly interesting, and had it fallen within the scope of these researches, the subject would have been farther investigated.

"The per-centage of phosphates and fluorides in the above analyses, after excluding the organic matter, is as follows:

Specimens.	Phosphates and Fluorides.	Specimens.	Phosphates and Fluorides.	Specimens.	Phosphates and Fluorides.
No. 1 (I.)	2·095	12 (V.)	0·743	No. 24	1·258
3	0·945	14	2·562	25	1·036
4	0·992	15	0·947	26	1·593
5	1·637	16	0·528	28 (VII.)	0·964
6	0·774	17	0·537	29 (VIII.)	0·825
7	2·177	19	0·578	30 (IX.)	0·270
8	1·710	20	1·990	31	1·040
9 (II.)	0·780	21	1·504	33	2·114
10 (III.)	0·642	22 (VI.)	0·583	34	0·529
111 (V.)	0·314	23	1·099	35	0·600

"It now remains to give the constitution of the precipitate of fluorides and phosphates. The results annexed are calculated for a hundred parts of the precipitate.

	I.	II.	III.	IV.	V.
Silica,	22·00	12·5	13·50	10·32	23·74
Lime,	13·03	7·5	10·40	15·57	35·01
Magnesia,	7·66	4·2	1·63	38·49	1·35
Fluoride of calcium,	7·83	26·34	34·85	7·50	8·88
Fluoride of magnesium,	12·48	26·62	19·06	2·62	20·44
Phosphate of magnesia,	2·70	8·00	5·87	0·25	3·46
Alumina (and iron),	16·00	14·84	14·69	25·25	7·12
Oxide of iron,	18·30				

	VI.	VII.	VIII.	IX.
Silica,	5·35	11·0	30·01	8·70
Lime,	7·17	25·9	17·45	16·74
Magnesia,	0·49	0·3	24·57	45·19
Fluoride of calcium,	4·05	15·0	0·85	0·71
Fluoride of magnesium,	Phosphate of lime. 4·25	Fluoride of mag. 23·2	4·31	2·34
Phosphate of magnesia,	16·30	4·7	0·32	0·34
Alumina (and iron),	35·00	19·4	22·49	25·97
Oxide of iron,	27·39			

"The foregoing results show that, contrary to the expectation when the research was commenced, fluorine is present in much larger proportion than phosphoric acid. The silica exists in the coral in its soluble modification, and probably is united to the lime. The free magnesia existed as carbonate, and was thrown down as caustic magnesia by the lime-water. Some small portion of lime was probably thrown down as carbonate, in spite of every precaution to the contrary. Only in two or three instances, however, was there any effervescence on the addition of chlorohydric acid to redissolve it.

"It need hardly be said, that the existence of all the matters noted in these analyses in sea water, is a just inference; but this subject, as well as the important geological inferences, which may be drawn from the results now presented, will be fully discussed on another occasion.

"My warmest acknowledgments are due to my friends and pupils, Messrs. D. Olmsted, Jr., and T. S. Hunt, who have zealously aided me in the laborious parts of these investigations.

"B. Silliman, Jr.

"Yale College Laboratory, Dec. 16th, 1845."

Radiated Structure of the Lower Animals.—p. 107.

In the remark that a radiated structure characterizes the simplest forms of animal life, we do not intend to imply, that it is apparent in all these forms. As stated, in connexion, the vegetable kingdom affords us examples of the great variety of structures, which may result from simple cellule developement. The cellules may grow in simple lines or spreading plates, and endless shapes may proceed from them under all their possible modifications. When several lines proceed together in growth, their mutual influence appears to result in a radiated structure. But whether this be so or not, this structure is the highest to which cellule developement alone can attain. The unsymmetrical forms which are exhibited in certain flowers, may all come under the general laws stated on page 99, and be owing to a more rapid reproduction on one side than the opposite.

THE END.