## XII.—*On the Geographical Distribution and Classification of Zoophytes**. By James D. Dana.

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 it is nearly true of 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 which man has explored, affording traces of life.

*Order Hydroidea.*—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.*—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 *Actiniæ,* 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

* From Silliman's American Journal for March and May 1847.

region included mostly 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 66° or 68° F., this being the winter temperature of the ocean on the outskirts of the reef-growing seas. The waters may sometimes sink to 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 of the ocean 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 tropical life. A range from the above temperature to 72° does not appear to be too great 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.

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 100 fathoms. Light and pressure, the latter affecting the amount of air for aëration, are probably the principal causes. The waves, moreover, seldom reaching to a greater depth than thirty 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

* *Lobophyllia* of Blainville, *Mussa* of Oken.

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

‡ The exceptions belong mostly to the genus *Euphyllia*, which includes the genus *Flabellum*, some *Turbinaliæ* and the *Lobophyllia*, having entire lamellæ.

§ The *Caryophylliæ* of Blainville, with the *Dendrophylliæ*, *Oculinæ*, &c.

equator to the frigid zone, and some species occur at a depth of 200 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.

Besides the above-mentioned limiting causes, there are others of importance, one of which may be alluded to in this place; the remaining, belonging more properly to the Geological Report on Coral Reefs and Islands, will be particularly considered in the forthcoming volume by the author. 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 recognized. 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 will undoubtedly 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.

| | 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 |

* The *Pocilloporæ*, *Sideroporæ*, *Milleporæ*, *Favosites*, and other genera of Madreporacea, in which the cells are internally divided by horizontal septa.

† Part of the *Porites* of authors, the species having shallow cells closed

From this table, it appears that only twenty-seven species out of 306 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 are but two,—the *Meandrina labyrinthica* and *Astrea galaxea*,—about which much doubt remains.

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 two osculant species, are confined to the subgenus *Mycedia*, exclusively West Indian, which contains very firm compact corals, often 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 *Gonioporæ*.

*General Remarks on Classification.*—It has often been justly said, that there can be but one strictly natural classification in either of the organic kingdoms. Yet if we look upon any system presented in the usual order on paper, as correctly and completely *the* natural system, we greatly mistake nature; for the various affinities cannot be fully expressed on a plane surface. The lines are so many, and so interlaced, that to be understood, they must be conceived of as ramifying in space. The mind, proceeding properly to its work, determines first upon those qualities which are physiologically of the most fundamental importance: it follows out the variations of structure under the grand divisions thus ascertained, fixing its attention successively upon qualities of a less and less general character; it traces the species through the various modifications in these several particulars, marking out the lines of gradation in affinities,—observing, some it may be,

at bottom (*Porites clavaria* and the allied). The other *Porites*, with a few exceptions, belong to the genus *Manopora* of the author, and are true Madrepores in their cells, but with imperfect calicles or none: the *P. spumosa* of Lamarck, and the allied, are here included, besides the *Montipora* of Blainville.

* *Sarcinula* in part of Blainville, *Caryophyllia* in part of Lamarck; *Anthophyllum* of Schweigger, who introduces the name, but not of writers on fossil corals.

partly isolated and terminating abruptly, others graduating into the different series by frequent blendings or anastomosings, and often between different lines detecting a serial parallelism: in this way the network is finally completed to the mind's eye.

When the relations are fully understood, we are ready to divide off into classes, orders, and the smaller subdivisions, cutting the threads here and there, as shall best exhibit the general character of the whole, remembering to make the corresponding divisions of equivalent importance and character. The institution of these various groups is not properly classifying; for the classification is completed when the branchings and interlinkings of affinities are made out. Subdivisions with appropriate names are however necessary, to aid the memory and convey this knowledge in words. Genera are convenient artificial sections, based on natural affinities; and very commonly they shade almost imperceptibly into one another. Whoever has attempted to lay out classes and their families and genera, has perceived the interlinkings, and felt the perplexity they produced. It may often have seemed vexatious to the systematist to have had a *well-characterized* family or genus spoiled in its characteristic, and *exceptions* introduced, by the discovery of new species which blend it with another group, before considered quite distinct. But such perplexities will not be perceived, if we follow nature with docility, and make it our aim to bring out prominently the various shadings between subdivisions. The true object of classification is not to dissect the departments of life into as many distinct parts as possible for display like anatomical preparations; but to illustrate the system of nature in its unity, and exhibit the myriad parts blended in one concordant whole.

The modifications of structure in living beings evidently proceed, to a great extent, from the nature of the world we inhabit, and the general laws and necessities of life. There are air, earth, and water, and these have their varieties of condition. Plants and animals offer other sites for living beings. The same circumstances may be said to call for the variety of size which exists in nature, for otherwise there would be possible conditions for existence unoccupied. The general nature of life and its modes of exhibition, with the primary systems of structure, being determined upon in infinite wisdom, we need attribute no other plan to creative power than that of the simple adaptation of life, as thus constituted, to the conditions the world affords. Circles and numerical relations may amuse the imagination; but we have no evidence that the Hand which made was confined by such prescribed courses. We cannot fail to see, however, that in the primary plan of structure in living beings, certain organs or their parts, through extended groups, have been limited by fixed

numbers: and this is so distinct in some classes, that it becomes an interesting study to trace out the sources of variations from the typical number*. We see the boundless resources of nature's Author displayed with greater force, the fewer the types from which an infinite variety might proceed; but not in any limiting of the number of species constituting groups.

Among the organs upon which the range of characters in the animal kingdom depends, the nervous system takes necessarily the precedence, for, as has been said with much propriety, this system is itself *the species*; since upon its characters, in connexion with the general laws of organic growth, depends in a very great degree the nature of the individual. Next to this, come those organs which are intimately connected with the sustaining of life, *primarily*, those pertaining to respiration and circulation, and *secondarily*, those adapted to the receiving and digesting of food; and next, or of parallel value with the last, the provision for the continuation of the species. The means of locomotion and the associated structure, constitute a characteristic intimately connected with the causes just mentioned. Under the several grand divisions to which we are led by the above considerations, there are subordinate variations arising from the adaptation of life to minor differences in the conditions of existence around us:—such as minor differences of soil (if we may extend this word to all those varieties of sites, afforded by the air, earth, water, vegetable and animal structures, variously modified by temperature, light and pressure); differences in the modes of taking prey or food of whatever kind, and in some peculiarities of the organs of digestion; certain differences depending on the sexual relations, and the means of preserving and developing the young, varying with the modes of existence alluded to; modifications of the provisions for self-preservation against enemies. These minor differences are exhibited in two ways: either particular organs retaining the *same* functions, undergo modifications in form and structure; or with other modifications, they subserve the purposes of *different* functions. When adaptations to different circumstances or pur-

* Milne Edwards has well illustrated the fact, that *seven* is a normal number in Crustacea, the cephalic, thoracic and abdominal parts each consisting normally of this number of segments, and variations taking place by a union of two or more segments, or by subdivisions; and this same law extends even to the joints of the legs and antennæ. The prevalence of such a law through so large a class affords a sufficient ground for belief that specific numbers have not been entirely disregarded in any branch of nature, though the actual exhibition of them has been obscured in ways not understood. We cannot disbelieve, therefore, that numerical relations were involved in the plan of creation; yet, while admitting them as regards the *nature* of organic structures, we do not admit that the *number* of structures made on any particular type had reference to any similar ratio.

poses take place by variations in corresponding sets of organs or parts of organs, the relations produced are termed *homological*; and the relations are *analogical* when they depend on a similarity of function, however produced*.

As the several families or classes of animals are exposed, in some respects more or less general, to the same circumstances, they would naturally undergo, in many instances, either *homological* or *analogical* modifications, occasioning that serial parallelism alluded to on a preceding page. And again, as the animals of the same class may be fitted to many different circumstances in nature, other parallelisms should exist, of a wider character.

The order in which the above sources of distinctions in the animal kingdom are mentioned, may be in the main nearly that of their relative importance. Yet it is well known that a set of characters valuable in one group is worth nothing in another: and this holds true in some cases even with those characteristics that are in general fundamental. It seems at first a violation of all propriety, to arrange together animals having gills, and those that have none; those that have a heart, and those that are destitute of even a vestige of one beyond a distant valve or two in the circulating system; those that have distinct arteries, and those whose arteries are only the lacunal passages among the muscles and other organs. Still this may be in accordance with a philosophical classification. The class Crustacea actually illustrates each of the three anomalies just stated. If the singular Amphioxus is truly a fish, as many ichthyologists affirm, we may have a vertebrate animal without a brain, and without a sense to

* Prof. R. Owen, the eminent comparative anatomist of England, mentions three kinds of homology, viz. "general," "serial," and "special." "General homology is the relation in which a part or series of parts stands to the ideal or fundamental type; and thus, when the basilar process of the occipital bone in Anthropotomy is said to be the 'centrum' or 'body of the last cranial vertebra,' its *general* homology is enunciated. When it is said to repeat, in its vertebra or natural segment of the skeleton, the body of the sphenoid bone, the body of the atlas, and the succeeding vertebral bodies or centrums, its *serial* homology is indicated. When the essential correspondence of the basilar process of the occipital bone in Man with the distinct bone called 'basi-occipital' in a crocodile or a fish is shown, its *special* homology is determined."—*Phil. Mag.* xxviii. 3rd ser. 526, June Supp. 1846.

We refer the reader also to a very excellent paper "on the Structural Relations of Organized Beings," by H. E. Strickland, F.G.S., Phil. Mag. xxviii. 3rd ser. 354, in which the subject of affinities in organic beings is presented in a clear and philosophical light. In addition to the terms *homology* and *analogy*, Mr. Strickland proposes the word *iconism*, to express *resemblance of form without a similarity of structure or function*; for example, the resemblance of the flower of the pea to a butterfly, or the shell Haliotis to an ear; and it includes also resemblances between species arising from accidental coincidence of colour; while *analogy* includes such resemblances as depend upon a similarity of function.

raise it above the Polyp. In such cases, the system of structure typical of a group is ascertained by a general study of the species, and then an acquaintance with this structure assists in tracing out transitions, and determining how far one and another organ may fail without requiring an entire separation of an individual from the group.

To classify requires therefore the widest possible range of knowledge of organic beings, and the nicest balancing of affinities: and we remark again, that it consists rather in expressing the various chains of affinities or homologies direct and parallel, with their shadings and blendings, than in searching for certain inviolable characteristics for distinguishing groups of species.

*Classification of Zoophytes.*—In view of the foregoing principles, any classification of Zoophytes made out without reference to the structure of the animals must necessarily be faulty. There have been several of this kind in the department of Corals; and as the subject has been little understood till within a few years past, errors were to be expected. They subserved, for the time, the purpose of systematizing the facts known, and afforded a means of characterizing species: so far they were good. But at the present day, to make out a classification based on the corals alone and the easiest method of distinguishing them, would partake of times of past ignorance: they can no more be properly arranged without reference to their animals, than shells without regard to their mollusks. The zoological relations of the species should be first studied, and afterwards such characters laid down for the corals as belong to the orders and families thus deduced.

The first classification of Zoophytes in which the animals received attention was offered by Blainville*. Lamarck had led the way with a discriminating study of the corals. Blainville availed himself of the observations of Quoy and Gaimard, besides the few investigations of older authors, and with great acumen made out an arrangement, which in its general features was highly natural. He divided Zoophytes, *including the Actiniæ*, into the groups *Zoantharia*, *Polypiaria*, and *Zoophytaria*; and if we strike out from Polypiaria a few species that belong to the first division, and others that are Bryozoa, we have the groups Zoantharia and Zoophytaria corresponding to the groups *Actinaria* and *Alcyonaria* of the classification by the writer, and Polypiaria nearly to the *Hydroidea*. The only other change of importance which the writer has proposed in these primary subdivisions is

* Manuel d'Actinologie ou de Zoophytologie, par H. M. D. de Blainville. 644 pp. 8vo, with an atlas of 100 plates. Paris, 1834. (The printing began in 1830.)

the union of the Actinaria and Alcyonaria into a single group, Actinoidea, equivalent in importance to Hydroidea. Blainville was the first author who actually introduced coral zoophytes fairly into the animal kingdom by his mode of describing and arranging them. He did not call the department a branch of zoology, and then describe corals as if they were *porous, stelligerous stones,* which is even now in many instances the case*. Still he speaks of the cells as *containing* the polyps, which is the reverse of the fact.

Ehrenberg in 1834†, after a more thorough acquaintance with coral animals obtained by investigations in the Red Sea, made some important improvements in the minor subdivisions; but his grand divisions were unfortunate. He separated in many cases the attached from the unattached species, and again, the simple from the compound, and thus broke up the natural assemblages which Blainville had made out. Even the natural group Alcyonaria (Blainville's Zoophytaria) is subdivided by him, and the parts widely separated. His system, notwithstanding some anomalies, exhibits great reach of mind and searching investigation. He removed correctly the Bryozoa from other Zoophytes, and first suggested the relation of the Millepores and Favosites to the Madreporacea. He pointed out the true nature of coral secretions, and described the mode of reproduction by spontaneous subdivision, which had not before been noticed. The modes of growth were also to a considerable extent described by him, and important use made of them, though not always correctly, in the classification of Zoophytes.

Milne Edwards, whose acquaintance with Zoophytes had been extended by a personal examination of many species, and by a thorough study of the labours of others, besides a comprehensive knowledge of nature, proposed, in 1837, a brief outline of a classification, which, as far as detailed, exceeded those preceding it in philosophical character. The Hydroidea ("Sertulariens"), the Actinaria ("Zoanthaires"), and the Alcyonaria ("Alcyoniens"), are laid down as the grand divisions, and without the striking violations of affinities which appear in Blainville's order Polypiaria. We only observe that the Favosites are separated from the Madreporacea, with which group they were placed by Ehrenberg, and where they beyond doubt belong.

* In descriptions of corals (the *internal* or *basal* secretions of Zoophytes), those characters which belong to the Zoophyte ought to be first stated, such as the general form, mode of growth, &c.; and afterwards, separately, whatever, not already stated, may require mention with respect to the coral itself.

† Abhandl. der Königl. Akad. der Wissensch. zu Berlin for 1832, pp. 225–438.

These are the principal authors since Lamarck who have undertaken a general arrangement of the class of Zoophytes. The "Stony Corals" have quite recently been arranged mostly from the corals alone by Mr. J. E. Gray of London*. We may express the belief, without entering into any criticisms on his classification, that with a more extended study of the animals and their corals, he would not have separated the *Milleporæ* and *Helioporæ* so widely from the *Pocilloporæ*; the *Stylastridæ* from the *Sideroporæ*; the *Montiporæ* from a part of Lamarck's *Porites*; the *Fungiæ* from the *Pavoniæ*; nor united into a single group the *Pavoniæ* and many *Astrææ*; nor the *Fungiæ*, *Flabella* and *Meandrinæ*:—in the last case giving an unreal importance to the oblong shape of the Flabella, and implying a relation which is wholly without foundation between the oblong cell of the *Meandrinæ*, *Flabella* and *Fungiæ*; for in the *first*, the form arises from budding; in the *second*, it is the shape of the polyp's disc; and in the *third*, the cell is only a depression *at the centre of the disc*, and the form has not even generic importance.

Before giving a general view of the classification of Zoophytes, to which the writer has been led by the study of coral animals†, the importance of different characters as a basis of classification may be briefly considered.

Owing to the simplicity of polyps, there are few organs or functions to afford distinctive characters. They are as follows: I. The digestive system. II. The ovarian. III. The modes of budding and growth. IV. The tentacles and general character of the exterior. V. The secretion of coral and its nature.

I. *The Digestive System.*—In this system the stomach varies (1) in length as compared with the internal or visceral cavity below, and (2) in the character of the parts below and around it. In the *first* particular, the difference is one of less general importance than has been allowed; the relative length in the *Actiniæ* and most Actinoid corals is between *four-fifths* and *one-third*; in the *Zoanthidæ* it is between *one-third* and *one-sixth*; in the Alcyonaria, between *one-third* and *one-twentieth*; in the Hydroidea the stomach is sometimes much shorter in proportion than in many Alcyonaria, though often far longer. In the *second* particular the difference is wide, the Actinoidea having the sto-

* "An Outline of an Arrangement of Stony Corals," by J. E. Gray, F.R.S. &c.: Annals and Magazine of Natural History, xix. 120, Feb. 1847.

† As it may be of some importance to those interested in the department of Zoophytes, the writer here states that the animals of more than sixty species of coral animals, exclusive of Alcyonaria and Hydroidea, and pertaining nearly to every genus, have been figured by him, from living specimens obtained in the Pacific and East Indies, and these figures will appear, along with others of different corals whose animals were not obtained, in the forthcoming Atlas to accompany the Report on Zoophytes.

mach suspended within the visceral cavity, and attached to the sides of the polyp by a radiating series of vertical fleshy lamellæ, which are wanting in the Hydroidea. The visceral cavity is a simple tube in the latter, and is radiated with vertical lamellæ in the former; but these peculiarities are also connected with the modes of reproduction. We omit other less obvious points of difference.

II. *Ovarian System.*—In this system, ranking in importance with the digestive, the absence of special organs with spermatic and ovarian functions distinguishes the Hydroidea, and the existence of such organs the Actinoidea. No character can be of higher value, or more marked in its attending peculiarities.

Among the Actinoidea, there is a great variation in the number of genital lamellæ, and in the relative position of the two kinds, the spermatic and ovarian. In the Alcyonaria there are uniformly *eight* in all; in the Actinaria, either *six*, *twelve*, or *more**. In many of the latter division, if not in all, the two kinds of lamellæ (spermatic and ovarian) are distinct: in some of the former, the same lamella is ovarian above and spermatic below, or two are spermatic and the rest ovarian; or perhaps other conditions may exist. There is good reason for separating the Alcyonaria from the Actinaria, but not for making each division equivalent in rank to that of Hydroidea.

III. *Process of Budding and Growth.*—1. We find that the fact of species *budding* or *not budding*, is not connected in Zoophytes with any peculiarity of structure that can be detected, and farther, the transitions are gradual and frequent. This character therefore, as it indicates no difference of concentration in the nervous system, is entitled to little consideration as a means of distinction in the classification of these animals:—it is no more important here than in botany, where a plant consisting of a single individual bud may be placed alongside of one which consists of several. It may sometimes however be used to distinguish genera: yet in the genus *Fungia* there are a few species

* A passage of the *Actiniæ* into the Alcyonaria may perhaps be observed in the *Lucernariæ*, which have a four- or eight-lobed summit; and other *Actiniæ* approximate to this lobed character. These lobes bear a number of tentacles, or correspond to a number; and hence analogy suggests that possibly in the Alcyonaria each tentacle properly corresponds to two tentacles or more, or to a lobe in the *Actiniæ* alluded to. This view is borne out by finding in the larger Alcyonaria the tentacles having a size wholly incompatible with the structure of the Actinaria; for the writer has shown in another place that in the Actinaria there are limits to the relation between the number of tentacles, as well as the width of interval between the genital lamellæ, and the size of the animal. Whether the analogy holds or not, the facts show striking differences between the Actinaria and Alcyonaria. See further, 'Report on Zoophytes,' pp. 34, 123.

that increase until they consist of two or three individuals; and there is thence a passage to the *Herpetolithi*, Eschsch. (Haliglossæ, *Ehr.*) and *Polyphylliæ*, Q. and G. The simple and compound *Cyathophylla* are other examples of the difficulty of this separation.

2. But the *modes of budding and growth* are of higher character; especially the distinction of *superior* and *inferior* gemmation, in the former the buds being terminal or at the summit, and in the latter lateral or basal. It is of little importance whether the summit-widening, which accompanies superior gemmation, takes place in the discs, or just exterior to the discs. In either case, the visceral lamellæ are prolonged at top beneath the upper surface by the process of growth, and hence such species have the upper surface of the corallum lamello-striate.

3. In superior gemmation, when the discs widen and bud, they sometimes subdivide as each new mouth opens, and sometimes not till several mouths have opened. This difference (distinguishing the genera *Astræa* and *Meandrina*) is of small importance. There are *Astrææ* in which the discs become 2- or 3-compound before they subdivide; and thus the two genera graduate into one another. There are simple and meandrine *Mussæ*, Oken (Lobophylliæ, *Bl.*), between which no line of separation can be drawn, and they have been always retained in the same genus. The *Monticulariæ*, in the same manner, are related to the *Meandrinæ**.

4. There is a group of species having superior gemmation, in which the discs have no proper limits; and in the compound species the surface is a single disc with many mouths and scattered tentacles (the latter often obsolescent). The *Fungiæ* are examples of simple species of this kind; and the *Polyphylliæ*, *Pavoniæ*, &c. (including the *Astræa siderea*) are compound species. The coralla of compound species are characterized by the continuation of the lamellæ of the stars from centre to centre, without interruption along a medial line; and they have no cells except it arise from a prominence of the intervals between the polyp-mouths. They thus differ from the *Astrææ*; for the cells in the *Astrææ* correspond to the visceral cavities of the polyps.

5. Growing *free* or *attached* is a character of minor importance. It is sometimes a convenient *generic* distinction, as with the *Fungidæ*, but in other cases cannot be appealed to. All species, as is well-known, are attached in the young state; and the time of becoming free varies with the species, some earlier and some later. The *Flabella* thus pass so gradually to attached species, and the animals in the two cases are so completely iden-

* See on this subject Report on Zoophytes, pp. 76, 77.

tical, that the separation can be sustained only on the ground of convenience in a distribution. We add, that in this last-mentioned case the simple species pass as gradually into the compound, and they are closely connected with the group *Euphyllia*, D. (a part of *Lobophyllia*, Bl., having entire lamellæ).

6. Growing *massive*, or *calicularly branched* (aggregate or segregate), is sometimes a good generic distinction. But polyps in contact grow together so readily that it can be of importance only when supported by other characters. In the group *Manicina* no line can be drawn between the segregate and coalescing species; and the *Cyathophylla* are other examples. Difficulties in the way of characterizing groups thus arise, which must be fairly met and not denied nor overlooked.

7. The *forms of growth*, whether branching, massive or explanate, afford good distinctions for species, but seldom generic characters. We find *explanate* and *massive* Gemmiporæ and Porites; *explanate*, *massive* and *branching* Porites and Manoporæ; and *explanate* and *branching* Merulinæ and Echinoporæ. No more unfortunate generic character can be laid down than one drawn from this source: it may, however, be occasionally used when sustained by other characters. The genus *Explanaria* of Lamarck is an agglomerate of species of several genera.

We have elsewhere shown that the sizes of branches, the frequency of branching, and the width of intervals in groups between branches, are good trivial characters within certain limits. But in all cases in instituting species, the specimens examined should be good and full-grown, and not fragments.

8. Growth by budding from an apical polyp, or from serial budding, are points that may afford good generic distinctions.

IV. *Tentacles and General Character of the Exterior.*—In many genera the tentacles are too short to take any part in the prehension of food, and apparently subserve only the purpose of aëration. As the whole body takes part in this function, the size of the tentacles must necessarily be unimportant as a family character. Hence we find, even in the same genus (*Fungia*, *Porites*), species with comparatively long tentacles, and others in which they are almost obsolete. The species of the genus *Actinia* are almost as various in the sizes of the tentacles. Among the *Astrææ*, one species was observed by the writer in which the place of tentacles was supplied by numerous spine-like processes over the surface between the discs; and the same is true of the *Echinoporæ*, or at least partly so, for the writer observed no tentacles in the two species he examined. The same reason shows that the moss-like subdivision of tentacles, observed in some *Actinidæ*, is a character only of generic importance, for it takes place generally in such species as live more or less buried in the sand

or mud, which fact seems to require an extension of the aërating surface, such as this delicate branching affords.

The *number* of tentacles appears to have a relation to two distinct series; in one the number is *six, twelve,* or *more,* with the alternate usually unequal when exceeding six (and always so when over twelve); in the other, *eight* simply, and all equal. The *character* of the tentacles is different in the two series: the former (the Actinaria) having them naked, the latter (Alcyonaria) having them fringed with perforate papillæ. A large number of species of Actinaria are characterized by *twelve* tentacles, and have been separated to form the group Madreporacea; but notwithstanding this point of resemblance, the several genera are as closely related to species having a greater number of tentacles.

The occurrence of suctorial vesicles on the lateral surface or disc is a character of only generic importance.

*Colour* is seldom of much importance, even for trivial distinctions; yet the mode of arrangement of colours may be characteristic of species. A mutual dependence or relation of certain colours may possibly be hereafter ascertained, by which a knowledge of one will determine the others that may be possible in a species; and in such a case, the character may have a value which cannot now be allowed it.

V. *Secretion of Coral.*—1. The *secretion* or *non-secretion of coral internally* is at the best no more than a family distinction; and among the Alcyonaria it is only generic. This is an admitted truth with regard to calcareous secretions among Mollusks; and Olivi and Blainville long since acknowledged it with reference to zoophytes.

2. The *secretion of coral at base, distinct from internal secretions,* is a characteristic of much value; it produces the structure of the *Gorgoniæ* and allied zoophytes, and also of the *Antipathi.*

3. The *nature of coral secretions* sometimes affords generic distinctions, and with other characters, in some instances, distinguishes the higher divisions of zoophytes. The Hydroidea, as far as known, never form any but membranous or horny coralla. The Astræacea, Caryophyllacea and Madreporacea secrete only calcareous coralla, excepting a few marine *Actinidæ* (*Actinectæ*) which form a cellular membranous float at base to keep them at the surface. The *Antipathi* form only basal horny secretions, and therefore have a horny axis. The Alcyonaria are more various in this character, the different genera having their peculiarities: the *internal* secretions are always calcareous and in *grains* or *spiculæ,* and in this last particular they differ from the calcareous of the Actinaria; these grains are sometimes so abundant as to unite into solid tubes (*Tubiporæ*). The *basal* secretions are either horny (*Gorgoninæ*), calcareous (*Corallium*), or siliceous

(*Hyalonema*); and in some instances, from a mixture of membranous tissue with the earthy matter, they resemble cork.

4. Among the calcareous corals the texture or density of the coral is often of little importance, as it may vary in different parts of the same specimen, according to their full exposure to the free ocean waters or not.

In species with stellate cells there is always a definite number of rays to the *adult* cell, excepting among those that bud in the discs, and this number is some multiple of four or six, and usually of both. The characters of the cells—whether immersed or occupying a prominent calicle; and, *internally*, deep and open at bottom, or transversely septate, or spongy cellular or solid,—are important; also the peculiarities of the lamellæ, whether entire or not, equal or irregular, exsert or included.

In transverse sections of the stellate cells, the number of rays (when adult), the diameter, and the character of the centre and of the interstices, are generally good characteristics for species.

The corals of Alcyonaria never have rays to their cells or tubes; the Madreporacea have never more than *twelve* rays; the Caryophyllacea and Astræacea have always more than twelve; and the last order is distinguished by having the interval between the cells lamello-striate (see p. 109, III. 2) *internally*, with few exceptions, as well as *externally*.

This brief review of the characteristics of zoophytes has prepared the way for an exposition of the classification into which the species naturally fall.

[To be continued.]

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## XIII.—*On the Circulation in Insects.* By Emile Blanchard*.

The celebrated author of the 'Anatomie Comparée,' finding no other vessels in insects than the dorsal one, believed that no true circulation existed in these articulated animals. According to Cuvier, the tracheæ ramifying throughout the entire body of the animal, the air in them must proceed in search of the blood, just as, in animals having a pulmonary or bronchial respiration, the blood is conveyed to the air.

Since his time, many anatomists have studied the circulation in insects. They have usually selected transparent larvæ which have allowed them to distinguish, through the tegumentary envelope by the aid of the microscope, currents of liquid blood. In this manner Carus observed a circulatory movement in the larvæ of the Ephemeridæ and Agrions. Wagner, Bowerbank, Newport, and others have verified these facts. According to these observers,

* Translated from the Comptes Rendus for May 17, 1847.