exhibited in *L. selaginoides*, where it must be possible to find a great many stages at one time on a single spike, as so many oophoridia occur on it. They must be also very easy to prepare for examination here,—a matter of exceeding difficulty in *L. denticulatum*.

In conclusion to these remarks on the oophoridium, two words on the affinities of *Isoëtes* and *Lycopodium*. It appears to me that this question involves the import which must be attributed to the large spore-sporangia of *Isoëtes*. Are these metamorphosed branches or not? In the latter case the affinity would be merely apparent, only inasmuch that both, *Isoëtes* and *Lycopodium*, exhibit two kinds of spores. In the former case, however, the affinity would be perfectly proved. The compressed, concentrated stem of the *Isoëteæ* would not be any great evidence against the affinity, since we have become, through Kunze, acquainted with the genus *Phylloglossum*. This is apparently a connecting link between *Isoëtes* and *Lycopodium*; and if A. Braun's opinion be correct, that *Phylloglossum* is to be regarded as a *Lycopodium acaule*, *Isoëtes* would also have to be regarded as a *planta acaulis* of the *Lycopodiaceæ*. It is readily conceivable that the term stemless plant is not to be taken here in its strictest sense, but rather to be understood as indicating a plant with an abbreviated stem.

Lastly, in reference to the import of the germinative spore of the oophoridium, Bischoff (Krypt. Gew. 126) has called them spore-bulbels (*tubercula sporoidea*), and compared them to the bulbels of *Arum ternatum* and *Dentaria bulbifera*. It is evident that this has no meaning till we know the whole course of development. The same applies to the expression *receptaculum tuberculiferum*, which he applied to the oophoridium. I have preferred the latter name because it is the more simple.

[To be continued.]

XV.—*An Outline of an Arrangement of Stony Corals.*

By J. E. Gray, F.R.S. &c.

About ten years ago, when I arranged the Corals in the British Museum, I was struck with the difficulty of determining with precision the proper situation in the system either of Lamarck or De Blainville, of a large number of the specimens we then possessed, and in the 'Synopsis' I made some remarks on the variation which accidental circumstances, such as localities, &c., appeared to have on specimens of the same species. Since that period I have examined the collections of corals which have come in my way, and selected for the Museum collection the

specimens which showed any variation or peculiarity of structure. Being now called, by the increased space which I have at my disposal, to re-arrange the collection, I intend in the following paper to embody the result of my experience in the study of these interesting beings.

Pallas divided the Madrepores into seven groups, according to their general forms (Zooph. 275). Lamarck gave names to these groups, and extended their number, taking for the characters of his genera the form of the cell, the position of the mouth of the cell, and the distribution of the cells with regard to each other in the mass, and also if they were distributed on both or confined to the upper surface of the mass, and if the mass was fixed or free.

Forskal figured the animal of several species, Savigny in the great work on Egypt figured another, and arranged them with the harder *Actiniæ*; and subsequently Lesueur in three papers published in the Mémoires of the Museum and Philadelphia Journal, figured the animal of some other genera. Blainville with these materials and with the original drawing made by MM. Quoy and Gaimard in their 'Circumnavigation,' in his article Zoophytes in the 'Dictionnaire des Sciences Naturelles' (afterwards published separately as a Manual) attempted to characterize the genera by the conjoint consideration of the animal and its coral, paying more attention to the form of the cells than to the form of the coral and the distribution of the cells in the mass, and certainly he succeeded in much improving Lamarck's arrangement; and having Lamarck's original specimens within reach, he has referred them to their proper genera according to his view, and produced one of the best works on these animals which has yet appeared. Unfortunately, like Lamarck, having only isolated specimens, and often only fragments to examine, M. de Blainville has placed too much reliance on the general form of the corals: thus he divides his genus *Gemmipora* into arborescent, explaniform and crustiform; the *Montipora* into crateriform and explaniform species; the *Porites* into incrusting, conglomerate and branching species; when the same species of these genera may be found in each of these forms, and the species founded on these characters depend only on some accidental and often local peculiarity of the specimens, or may even have been broken from the same specimen.

M. Ehrenberg in 1834 proposed an arrangement of Zoophytes, which, though it has much the external appearance of novelty, made very little addition to the real knowledge of the stony corals; for his generic characters differ very little from those given by Lamarck and De Blainville, though they are expressed in a very different manner, and made chiefly to depend on the mode in which the buds are developed; and as this circum-

stance is in almost every instance only to be derived from the study of the result in the perfect coral, and not from the development of the buds of the animals themselves, I think it is better to state, as Lamarck and De Blainville have done, the description of the coral as found in the collection, than to give a theoretical account of the development of the buds, leaving one to divine what kind of coral must result from the development of the buds described. As was to be expected, the development which appears from the study of the *Polyphylliæ*, for example, in the different stages of growth in the same specimens, does not appear to agree with the theoretical development described by the author; for in the young state this coral has a single star with regular rays, and looks like an attached Fungia, but is rather more solid; new mouths, indicated by smaller stars, are gradually developed near the centre, the number increasing as the coral increases in size, and at length the mass becomes free and assumes the oblong shape. It appears to be one of the great defects of this arrangement, that the stony corals which are free in the adult state, as *Fungia*, *Haliglossa* and *Polyphyllia*, are separated from the others by *Pennatula* and its allied genera, because the author believes these *corals* to be internal and hence free; for we now know that these genera (which belong to two very different groups) are all in their young state attached like other corals. M. Ehrenberg compared these free internal corals to the bones of cuttlefish, and the plant-like or external corals, as he calls the other genera, to the shells of the oyster: he can only mean this as a resemblance as regards their position, for neither the internal *Fungia* nor the external *Cladocora* are deposited or formed like a shell, but merely consist of the hardening of the cellular substance of the animal itself by the deposition of cretaceous matter in the cavities of its cellular substance; and the *Fungia* is not truly internal, but placed in exactly the same situation as regards the coral as the other genera, and only covered with a reflexed part of the edge of the body. M. Ehrenberg divides the plant or external corals into two sections, those which have many and those which have twelve tentacles, but these divisions exactly agree with the sections named *Madrephylles* and *Madrepores* established by M. de Blainville.

M. Ehrenberg in the paper above referred to has described many new species; they have not been figured, and unfortunately his characters are not very clear and are difficult to understand, so that I am not able to refer to them with certainty, more especially as he places great reliance on the size of the coral and on the size of the cells. Now experience has taught me that both are very liable to variation even in different parts of the same specimen or group. In the 'Synopsis of the British

Museum' for 1842 I observe, "the form of the masses (of coral) appears to be greatly influenced by the position in which they have grown, and the size of the individuals (cells) greatly depends on the quantity of nourishment they are able to procure. This is proved by the fact, that if all the individuals of the same mass are equally exposed they are of equal size, but if the surface of the coral is waved as in *Explanaria*, the individuals on the convex part of the mass which could procure the most food are large, while those on the concave or sunken parts are small," p. 131. Continued experience and the examination of many hundred specimens have only extended and confirmed these opinions; consequently I expect that many of M. Ehrenberg's new species are what are only regarded in this paper as varieties: for example, he has described six species of *Seriatopora*; I have examined many specimens from different localities presenting differences of size and of comparative thickness and length of the branches, but am inclined to consider them as all varieties of the same species*.

It is a common error to regard the whole mass of a Brainstone, for example, as a living mass; this is by no means the case; it is only a very shallow coat on its outer surface, which is alive at one time; for as the animal increases in size above, the deposition of calcareous matter continues advancing below, and when that is completely deposited it is of no further use to the animal but as a support, and has no longer any organic life, for this part is in fact buried in its own secretion. This is the case with most of the coral animals, it is only the end of the *Caryophyllæ* or *Dendrophyllæ*, about as deep as the cavity of the cell, that is alive; the other part being merely a peduncle to support the animal. This is well seen in the *Oculina virginea*, where the older branches of the coral often become tubular.

This structure is further exhibited by the fact, that when any part of a massive coral is injured and the animal destroyed, the injured part is healed over by the lateral development of a thin layer of coral, which is not to be distinguished in appearance from the normal structure of the coral.

In general the edge of the cell and the laminæ within it are calcareous nearly to the surface of the animal, and in many of

* Since this paper has been in type, Mr. Forbes has kindly lent me a volume by Mr. Dana on the Structure and Classification of Zoophytes (Philadelphia, 1846), containing some very interesting observations on these animals made during the United States' exploring expedition. Mr. Dana's classification of the stony corals is only a slight modification of that proposed by M. Ehrenberg. The three works I have quoted have each a very different character;—the French clear, calm and minute; the German theoretical, almost mystical, and difficult; the American oratorical and high-flown.

these animals each individual is distinctly divided, and hence each cell has distinct parietes; but on the contrary in the *Porites* the separate animals do not secrete any calcareous matter between themselves, hence there are no distinct cells on the surface of the coral, and the coral is very porous, being pierced in every direction, and what are laminæ in other corals in this genus are only calcareous spicula.

The animals of the stony corals, besides being reproduced by eggs, which are developed between the septa of the stomach and emitted by the mouth, as in soft coralless *Actiniæ* or the coriaceous *Zoanthi*, and form new individuals or masses, also have the power of developing buds from their sides, or of increasing themselves by the spontaneous division of their stomachs, and it is by these means that the masses of coral are enlarged and continued; and the forms which the various kinds of coral assume in their growth, which gives the most prominent differences between their genera, depend on the manner in which these buds are developed, or the body of the animal spontaneously divided, each cell or branch being either the growth of a separate bud or resulting from this spontaneous division.

Before the spontaneous division of the animals takes place, the stomach enlarges and a new mouth opens near the original one in the disc, and from the mouth new radiating lamellæ arrange themselves, forming new centres, and this process is again and again repeated. Now as the laminæ of the coral represent the plates in the stomachs, and the centre of the plates the mouth, this kind of development may be observed in the coral nearly as well as if the animal was present.

The effect of this kind of spontaneous division on coral is very different in the two forms which the animals assume during their growth; and as these forms gradually pass into each other, so their peculiarities become less apparent. If the animal grows in height, raising itself on the gradually solidified part of the former coral, as in the branched *Caryophyllia fastigiata*, Lam., where the cells are round, they at length become oblong, then separate in the middle, the separation becomes more complete, and at length two complete similar cells are formed*, each placed on the end of a branch divided by a fork, and this process is repeated, forming a forked coral. The same kind of separation takes place in *Caryophyllia sinuosa*, Lam., but here the divided portions sometimes form separate stars, and at others only form new centres in the enlarged old star, which remains surrounded by the same edge. It is this latter kind of division which forms the elongated compressed cells of the *Meandrinæ* and the sinuous con-

* See Synopsis Brit. Mus. 1842, 130.

tinued cells of *Monticulariæ*; these forms gradually pass into the next form.

On the other hand, if the animal chiefly extends its size by spreading out laterally, forming a thin foliaceous expanded coral, the cell of the young animal has simple rays, as is shown in the young *Fungia Talpa*, Lam., in the British Museum; and as the animal expands, new mouths forming new centres are developed in the disc of the star. This is the mode of growth of the *Agariciæ*, *Pavoninæ*, &c., the animals being continually expanded towards the margins of the corals; and when the cavities of the stomach, separated by the septa which form the plates on the surface, are sufficiently expanded (or perhaps too much expanded for the food conveniently to reach them), then new mouths are opened; hence the mouths, and the stars indicating these mouths, are generally placed in concentric lines parallel with the edge of the corals. The foliaceous corals which are thus developed are easily known from those which are produced by buds, for in the latter instance (as the *Gemmipora*) the edge of the coral is formed by the last-formed buds or stars, while in these the edges are formed by the extended side of the stomach, and are thin and marked above with the laminæ of the stomach, the stars being some distance within the margin.

In these corals the animals form a common mass, the cell of the stomach of the different mouths having a more or less complete communication with each other, which is not the case with those which enlarge by buds, the polypes and their stomach being separate from each other, and the animal only united by their cellular integuments.

The manner in which the buds are developed also greatly modifies the form of the coral; thus if they are developed from the expansions of the base, the coral formed is crustiform or rounded, as in some *Astrææ*; and if from the upper part of the cell, then the coral is generally arborescent and branched. It may be observed that it is the marginal or terminal that is the last developed bud, which shows plainly the manner in which the buds are developed, as the after-development of the coral obliterates the separation between them; and further, when branches of different stems meet or cross they are frequently united together in a single network, as is the case with the horizontally expanded *Madrepores* and *Oculina virginea*, and if the branches are arranged parallel and by their growth become near each other, they by the development of the animal are united into a single expanded mass, as in *Madrepora palmata*, where the separate spike-like branches which are gradually united together to form the fronds are to be seen on its edges.

As in the coral animals which enlarge by the spontaneous di-

vision of their digestive cavity, so in these, there are all kinds of intermediate gradations between the two modes of development above described; indeed in some corals, as the *Madrepores*, in the early stages of the animal, the buds appear to be developed from the base of the sides forming a crust, and then one of the animals which is larger and stronger than the rest, ascends above the level, throws off buds from its upper part, and the coral becomes arborescent.

The buds are developed in various manners from the surface of the body; in the *Oculina axillaris*, Lam., they are emitted from each edge of the cells, and the coral becomes forked with the stars in the axilla; in *O. prolifera*, Lam., one or two buds are produced from one side of the animal; and hence a kind of secund arrangement of the cell. In *O. flabelliformis* a single bud is developed on one side of the animal, and then this developes another on the opposite side; so that the young cells form a kind of zigzag stem, and the whole coral assumes a fan-like shape; while in *O. virginea* and *hirtella* the buds are so developed, that the animal assumes a somewhat spiral direction, the cell at the tip being the one last developed.

In other corals, as the *Seriatopores*, the buds are developed in pairs on the alternate side of the branch, hence the cells appear in longitudinal series; and lastly, in the *Porites*, *Pocillopora* and *Sideropora*, each of the animals at the end of the compressed branches developes a bud on the upper side, and the branches are prolonged.

In other corals a single animal continues to ascend, and as it grows developes from its sides a succession of buds which form lateral cells; some of these being produced form branches emitting buds like the original stem. This is well seen in *Caryophyllia ramea*, Lam., where the lateral cells and branches are smaller than the main stem; sometimes, as in *C. flexuosa*, Lam., where the whole coral assumes a subglobular shape, the branches are nearly as large as the stem. In the genus *Madrepora* the original animal as it elongates gives out a succession of buds on all sides, forming subspiral whorls of cells round its base; some of these cells in their turn becoming the parent of a similar set of buds. It is this original cell which forms the "*apex perforatus*" in Lamarck's description of these corals.

There is extreme difficulty with regard to the authority that can be placed in the figures hitherto published of the animal of these corals. Donati (Mer Adriat. 50. t. 7) figures the animal of *Madrepora ramea*, and M. Milne Edwards, who has seen the animal on the coast of Africa, assures us it has nothing resembling the hooked appendages figured by Donati (*Lam. H.* edit. 2. ii. 354). MM. Quoy and Gaimard figure in the Voy. of the Ura-

nia, t. 96, the animal of *Mad. cærulea,* but in the Voyage of the Astrolabe they found that what they had taken for the animals must be parasites, which must have been lodged between the cells, and not what they then regarded as the true animals of the corals. M. Lesueur figures the animal of several species of *Meandrinæ,* but they all differ from the animal which MM. Quoy and Gaimard (Voy. Astrolabe) figure as being the animal of that genus, and both differ from M. Ehrenberg's account of the animal. Lesueur describes *Astræa ananas* as having no tentacles, and Quoy described under the same name a coral that has small rounded tubercle-like tentacles!

Synopsis of the Families.

1. *Animal* 12- *or fewer rayed, with* 12 *or fewer tentacles placed in a single series; coral cells gemmiferous, circumscribed, simple, with* 12 *or fewer longitudinal ridges, and sometimes furnished with a central style.* Les Madrepores, *Blainv.* Phytocorallia dodeactinia, *Ehr.*

Fam. 1. Pocilloporidæ, *Gray, Syn. B. M.* 1842, 130.

Coral hard, solid, brittle, spinulose or granulated; cells 6-sided, simple, shallow, ciliated or spinulose.

Seriatopora, *Lam.* Pocillopora, *Lam.* Stylopora, *Schw.* (Sideropora, *Bl.*, and Anthopora, *Gray.*)

Fam. 2. Stylasteridæ.

Coral minutely porous; cells deep, cylindrical, with six grooves, each ending in a pore and a central style.

Stylaster, *Gray.*

Fam. 3. Madreporidæ, *Gray.*

Coral porous, spongy and rough; cells deep, circular, with six or twelve longitudinal folds, immersed or produced, subcylindrical, and without any central style.

Madrepora, *Lam.* Heliopora, *Bl.* Asteriopora, *Bl.* Montipora, *Bl.* Millepora, *Linn.* (Palmipora, *Bl.*)

Fam. 4. Poritidæ, *Gray.*

Coral very porous, spongy and rough; cells many-sided, with granulose edges, more or less incomplete filamentose or spinulose lamellæ, surrounded by pierced or netted parietes.

Porites, *Lam.* Alveopora, *Bl.*

2. *Animal many-rayed, and with many tentacles, placed in two or more series; coral cells with* 12 *or more radiating plates.* Les Madrepores, *Blainv.* Zoocorallia and Phytocorallia Polyactinia, *Ehrenb.*

a. *Coral cell circumscribed, with only a single centre; laminæ smooth or very slightly serrated; animal gemmiferous.* Ocellina, *Ehr.*

DENDROPHYLLIDÆ.

Coral moderately hard, porous; surface minutely longitudinally striated; cells truncated, concave, generally with a convex centre.

Tubastrea, Dendrophyllia, *Bl.* (Cladocora, *Ehr.*) Explanaria, *Lam.* (Gemmipora, *Bl.*)

OCULINIDÆ.

Coral hard, covered with an enamel surface; cells concave, with radia extended over the edges, or with the outer edge radiately grooved.

Cyathina, *Ehr.* Oculina, *Lam.* Anthophyllum, *Schw.* (A. fasciculatum.)

b. *Coral cells circumscribed or not defined, confluent, with many centres; laminæ serrated and extended, reflexed over the outer surface of the coral, or extended from centre to centre; coral hard, with a hard enamel surface; animal growing by spontaneous division.* Dædalina, *Ehr.*

CARYOPHYLLIADÆ.

Cells deep, round (or sinuous with many centres); laminæ torn, serrated, with a sinuous twisted centre, and often with intermediate smaller plates not reaching the centre; animal continuing to grow upwards and gradually to expand in diameter.

Caryophyllia, *Lam.* (Lobophyllia, *Bl.*) Tridacophyllia, *Bl.* Manicina, *Ehr.* Dipastrea, *Bl.*

MEANDRINIDÆ.

Cells deep, elongate, compressed, with a single series of equal laminæ forming a single linear impressed line in the centre; animal continuing to grow upwards and gradually to expand in diameter.

? Fungia, *Lam.* Flabellum, *Lesson.* Meandrina, *Lam.* Monticularia, *Lam.*

AGARICIADÆ.

Cells shallow, not circumscribed, but scattered and united to one another by laminæ on the star-bearing surface of the coral; animal expanding out laterally, forming a leaf-like frondose coral.

***Agaricia and Pavonia, *Lam.* Stephanocora, *Ehr.* Echinastrea, *Blainv.* ? Astræa, *Lam.*