Zoology. — *"On Budding and coalescence of Buds in Fungia fungites and Fungia actiniformis."* By H. BOSCHMA. (Communicated by Prof. C. PH. SLUITER).

(Communicated at the meeting of November 26, 1921).

Budding in adult corals of the genus *Fungia* was first described by SEMPER [1]) in a specimen which had most likely been thrust upside down fortuitously. In their further growth the septa had bent round the border and in various places new mouths had arisen on the original underside, round which the later formed septa were arranged more or less radially.

From this SEMPER concludes: "Es geht daraus hervor, dass alle diese Polypen ohne Ausnahme die Fähigkeit besitzen, an ganz beliebigen Stellen ihres Körpers neue Individuen zu erzeugen, wenn durch irgend eine Ursache — physiologisch-chemische oder rein mechanische — ein besonderer Anstoss zum Hervortreiben plastischer Massen gegeben ist." [2])

Judging from the figure (Taf. **XXI**, fig. 3) some at least of these buds are to be considered as calicular buds as they are lying entirely on the curled-up border. Of course, it is within the bounds of probability that they are lateral buds generated through the broadening of a number of spines into septa, a process easily to be watched in the ordinary lateral budding.

Lateral budding (at the underside of the disc, which side corresponds to the lateral side of other corals) is of rather frequent occurrence in *Fungia fungites* (L.). [3]) This mode of asexual reproduction has been described at length by DÖDERLEIN. [4]) However, he does not assign a cause for this budding, probably because DÖDERLEIN did not work with fresh material. In a large number of *Fungia fungites*,

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[1]) C. SEMPER. Ueber Generationswechsel bei Steinkorallen und das M. Edwards'sche Wachsthumsgesetz der Polypen. Zeitschr. f. wiss. Zool. Bd. XXII. 1872.

[2]) l. c. pag. 275.

[3]) SEMPER reports also a case of budding at the underside of a specimen of *Fungia Linnaei* Val. (= *F. repanda* Dana) (l.c. pag. 275, note 1.)

[4]) L. DÖDERLEIN. Die Korallengattung *Fungia*. Abh. der Senckenb. naturf. Ges. Bd. XXVII, 1902.

which I collected near the island of Edam in the Bay of Batavia, we could detect at the underside buds in various stages of development; they are seen nearly always in the immediate vicinity of part of the parent-coral which is overgrown profusely with algae. It frequently happens that a bud appears at the underside, just beneath that portion of the upperside that is grown over with algae. When a *Fungia fungites* is partly attacked by sea-weeds, the latter impart a stimulus to the adjacent tissue, which consequently displays a more energetic growth-activity. This greater activity is also manifested in an increased Skeleton-production, resulting in the formation at the underside of larger spines, which are sometimes branched out, or even in the formation of buds; at the upper side this intensified growth engenders new septa, which are often of an irregular shape, while in some cases buds are formed.

DÖDERLEIN already suspected that calicular budding occurred also in *Fungia fungites* but he could not prove it. In a few specimens of this species found near Edam, rather distinct buds were formed at the upper-side of the disc; one of these specimens was very conspicuous. In this *Fungia* (Fig. 1) part of the disc is grown over with sea weeds of various kinds and with case-worms, which causes the tissues of the polype to be destroyed at this spot.

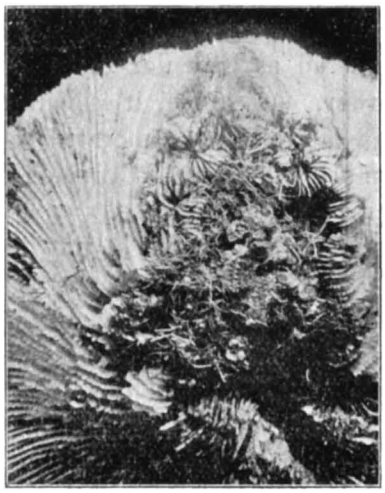

Fig. 1. *Fungia fungites.* Upper-side. Calicular budding around a part grown over with seaweeds and other organisms. 3/5 nat. size.

An abundant growth of algae is also observed over the mouth. Greater growth-activity is shown round the attached part which generates new septa everywhere at the borders of the destroyed

tissue. At the intact side mouths have originated by the side of these new septa, so that ultimately instead of the old lost mouth the *Fungia* possessed about twenty new, small orifices around the algae-covered zone. A few of these mouths are environed by new septa (see the upperside in the figure); these buds therefore present a more regular aspect than the others, in which the mouth is at one side surrounded by a semicircle of new, young septa, which unite at the other side with the unattacked septa of the parent [1]).

Also at the border of the disc of *Fungia fungites* buds may arise by constricting off part of the septa of the parent-polyp and by the formation of a new mouth. This, then, is also a case of calicular budding. In its initial stage it is seen in the specimen which is represented partially in fig. 2.

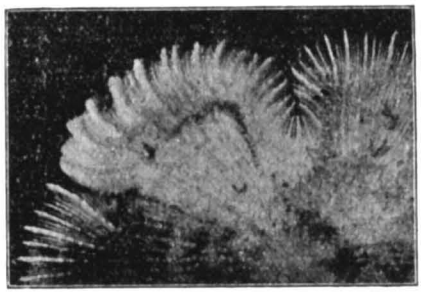

Fig. 2. *Fungia fungites.* Underside. Part of the border is grown out towards the underside. 3/5 nat. size.

At its underside a groove is noticeable at some distance from the border. This may be a scar of an old wound and the border may have been renewed at this spot through regeneration. At the periphery part of the border has curved downwards, the border has, so to speak, doubled up here and parts of the septa are lying at the underside of the disc. For the rest this *Fungia* looks quite normal. Now when this curved portion is cut off, we obtain a bud here also, a calicular one at the underside of the parent-coral.

This budding is seen further developed in another specimen (fig. 3).

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[1]) In this specimen the algae-parasitism has proceeded right across the disc as far as the underside (in *F. fungites* the disc is provided with pores), which also here has given rise to a number of lateral buds, although only a small portion of the tissue of the underside has been destroyed. These buds are rather large (the largest is 32 × 25 mm.), the oldest have already a broadened border, as may be distinctly seen, so that they are attached to the underside by a stem.

Here the border has bent down at one place, just as in the preceding case, but here the septa do not merge into those of the

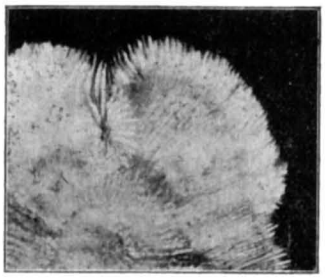

Fig. 3. *Fungia fungites.* Underside. Calicular budding at the border. 3/5 nat. size.

mother-coral, the bud having become more or less independent. A mouth has already been formed, completely encircled by septa, so that a separation of the bud from the parent has already been established. The part belonging to the bud is already easy to distinguish from that belonging to the parental coral, which was not practicable in the case previously described. Now when this separation becomes more evident, the whole aspect is that of a bud at the underside. Such a bud would then be considered as a lateral bud, although ab origine it was a calicular one.

In this way may have arisen some of the buds of SEMPER's specimen alluded to above, since in the figure the septa of the old coral touch those of the buds.

The buds above-described are all either devoid of a stem, or provided with a short stem. In one specimen I found at the underside a bud with a longer stem, such as are generally found at an anthocormus. The upperside of the disc of the *Fungia* under discussion is quite normal, while the underside differs from that of normal specimens (fig. 4). The central part is rather sharply isolated from the border, while part of it is defunct. We are impressed with the idea that when this coral had a diameter of about 3 cM., the tissues of the one moiety died off for some reason or other, while from the other half a regeneration was started, which caused the coral to ultimately grow up to 8 or 9 cm. and after this to present a normal aspect. But the defunct portion maintained itself and leans on the living portion like a scale. Attached to this defunct portion we observe a stemmed young bud 6 mm. in diameter, while the stem itself is 8 mm. in length. The extremity has not yet broadened into a disc.

This case slightly reminds us of the aspect (in *F. agariciformis* = *F. fungites*) of a number of young stemmed Fungiae on the

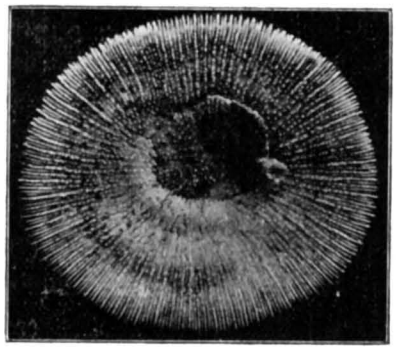

Fig. 4. *Fungia fungites.* Underside. Stemmed bud at a defunct part in the middle. 1/2 nat. size.

defunct disc of a coral of the same species, as described by STUTCHBURY. [1]) The same aspect was presented by some of the Fungiae I found near the island of Edam. At the underside of one of them residues of living tissue were distinguishable, but all the softer parts of these corals were vanished and here and there seaweeds and *serpulids* had settled. At the border of all the specimens there are a large number of buds, while in a few of them buds have also been formed near the central part of the underside. Of the latter the stem has a uniform breadth everywhere, in contradistinction to many at the border, whose stem has broadened at the upperside into a disc-shaped young Fungia. The stem of many buds adhering to the border of the underside, has bent round, so that the disc of the young Fungia is seen at the upperside of the border of the old coral. Some of these young corals are overgrown with algae, most of them are fully alive and look quite normal.

STUTCHBURY [2]) considers the occurrence of young corals on a defunct disc of the same species to be something accidental. ("I consider the cases in which young Fungiae are found fixed to the underside of others of the same species, to arise from the accidental attachment of the young polype"), whereas SEMPER holds that these young corals have arisen in situ through budding of the coral; the

[1]) S. STUTCHBURY, An Account of the Mode of Growth of Young Corals of the Genus Fungia. Trans. Linn. Soc. London, Vol. XVI, 1833.

[2]) l. c. p. 497.

genesis of the budding has then to be looked for in an alteration of the natural position.

MOSELEY [1]) in studying *Fungia fungites* [2]), found a portion of a very large defunct Fungia quite covered with numerous young colonies of various ages. According to MOSELEY they arose from larvae which had attached themselves to the expired Fungiae.

SAVILLE KENT also describes these Fungiae with young stemmed specimens (in *F. discus* = *F. fungites*) and gives us a picture of one of these with 13 stemmed young corals at the upper-side (Plate XXIV, fig. 1).

Although he does not dictate either the one or the other conception, he deems it most probable that we have to do here with a case of budding: ("It is a moot point whether this luxuriant colony of Nursestocks arose fortuitously from different sources, or in a single embryonic swarm from some more distant corallum, or whether they may not represent the product of the expiring vital energy of the defunct adult corallum to which they are united. The latter interpretation appears to be the most reasonable" [3]).

According to DÖDERLEIN the occurrence of colonies of young Fungiae on defunct corals of the same species has nothing to do with budding; these young corals he believes to have arisen from extraneous larvae.

The specimens I collected near Edam all lay in a normal position, orifice upwards. They exhibit some peculiarities which point to true budding. The specimens alluded to (cf. fig. 5) deviate from those described by STUTCHBURY, MOSELEY and SAVILLE KENT, in that young polypes occur only at the border of the upperside of the disc and not in the centre. Nor do these buds attain the size of those of the Fungia illustrated by SAVILLE KENT.

Each specimen is provided with a great number of these young corals, one of them with as many as 73 buds. We deem it highly probable that this is a case of true budding. The following arguments lend support to our view:

1. The rest of the parent-coral is quite defunct or nearly so. Budding is considerably promoted by algae-parasitism, as has been pointed out above. Here it arose most likely as the final manifestation of vitality of a doomed individual.

2. These stemmed buds are found only at the border, and not

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[1]) H. N. MOSELEY, Notes by a Naturalist on the Challenger. London, 1872.

[2]) Determined by QUELCH as *Fungia discus* (= *F. fungites*). (J. J. QUELCH, Report on the Reef-Corals. Challenger Exp. Zoology, Vol. XVI, 1886).

[3]) W. SAVILLE KENT, The Great Barrier Reef of Australia. London 1893, p. 38.

farther on, at the upperside. If larvae had given origin to these young corals, they would not have been disposed so regularly in one row along the border.

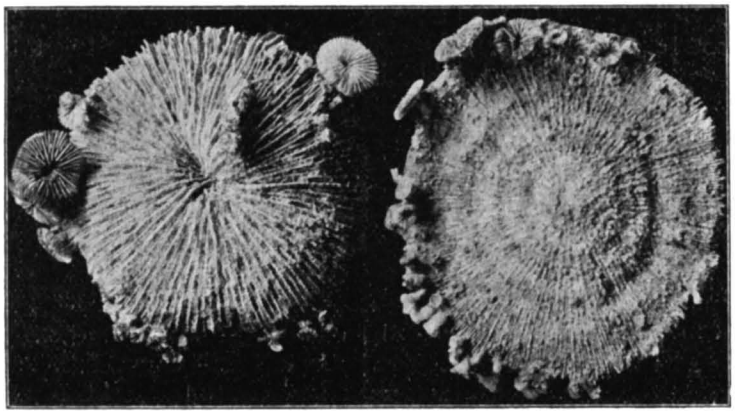

Fig. 5. *Fungia fungites.* The left specimen seen from above, the right one from below. Budding at the border of individuals almost entirely overgrown by parasites. 3/8 nat. size.

3. Also at the underside some buds are noticeable, rather removed from the border. When a Fungia is attacked by algae, the tissue of the underside keeps intact longer than any other part, because the weeds have to force their way through the disc in order to attack it also.

This is why the tissue at the upperside may be entirely destroyed by algae, while rests of soft parts may still exist at the underside, which may induce the growth of buds.

These buds do not develop so well as those at the border, their extremity is not broadened into a disc, which is probably due to the absence of light. The development of these very buds goes against the hypothesis that they should have originated from larvae which had attached themselves here. The old Fungia lies flat at the bottom, even the borders are still covered with sediment [1]. Owing to this the underside is isolated from the environment, so that no larvae can settle there, putting aside the very unpropitious position occupied by these buds with respect to the light.

[1]) A living Fungia continually removes the sediment that falls on the upperside, by enclosing it in a layer of mucus, which is removed from the centre onward over the border.

4. I found these stemmed young Fungiae only on the disc of the defunct Fungia and not on the defunct coralfragments in the neighbourhood. If these young polypes had arisen from a swarm of larvae, which had settled down at the same time or at different epochs, a few would no doubt have found a base of attachment in the neighbourhood.

Colonies of fixed young Fungiae (Anthocormus) are especially known of *Fungia fungites*. Of *Fungia actiniformis* Q. et G. fixed young corals have been described by STUDER [1]). Afterwards no more mention is made of anthocormus-formation in this species. Still, it seems to occur occasionally; as I found on the reef round Edam about 24 young colonies of Fungia actiniformis. The number of buds at every anthocormus differs largely. One of these specimens possesses 48 buds or stems from which the young coral has detached itself. Upon a number of these stems, a new bud is already developing. The largest young Fungia, found fixed to an anthocormus, has a diameter of 5 cM.

Besides the budding at the anthocormus, also lateral budding occurs in *Fungia actiniformis*. The method of lateral budding, occurring so frequently with *F. fungites* when the tissues of this species are partially destroyed by algae, seems to be very rare in *F. actiniformis*. I found only one specimen, exhibiting this mode of budding. Three fourths of this Fungia was defunct. Only the remaining fourth was covered with living tissue and bore tentacles. There is a bud about midway between the border and the centre at the underside on the boundary between the defunct and the living part, still in the latter. The septa of the bud, arranged radially, are modified spines, but much larger than those of the environment and distinctly flattened. The septa are over their full length attached to the underside of the parent-coral, a stem has not yet been formed.

Another very peculiar mode of budding seems to occur rather frequently in *F. actiniformis*; I found near Edam 10 specimens which exhibited it.

These buds occur at the underside, attached to the scar by which the coral had been fixed in its young state to the stem of the anthocormus (fig. 6). This scar is covered with living tissue, which proceeds into the tissue of the bud. Tentacles are distinctly noticeable

[1]) TH. STUDER, Uebersicht der Steinkorallen aus der Familie der *Madreporaria aporosa, Eupsammina* und *Turbinaria*, welche auf der Reise S. M. S. Gazelle um die Erde gesammelt wurden. Monatsber. K. Preuss. Ak. der Wiss. Berlin 1877.

in the buds, which for the rest produce a normal impression, only the soft parts are of a lighter colour than those of the upper side

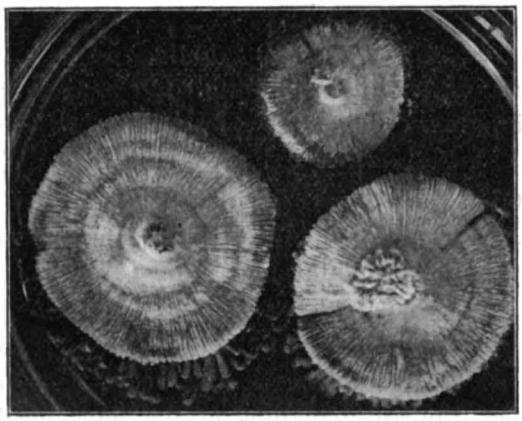

Fig. 6. *Fungia actiniformis.* Underside of three living specimens with budding at the scar.

of the parent. Since the buds occur at the underside, they are shut off from the light, to which the lighter colour of their tissue is perhaps to be ascribed. This budding generally presents one bud at the scar, sometimes two. With the older buds of this kind the upperside is already distinctly broadened into a disc, so that they have short stems. The structure of the skeleton is regular like that of the young buds of anthocormus, but it is very thin and fragile. It is difficult to account for the origin of these buds; the specimens in which they occur are already mature, with a transverse diameter of more than 5 cm. and for the rest look quite normal. Neither have they suffered from algae-parasitism, which consequently cannot have given rise to this budding. Maybe these buds are loosened later on, and are located under the disc of the parent-coral, which brings about a very unfavourable condition.

Excepting the formation of buds at the anthocormus budding in *Fungia fungites* and *F. actiniformis* is ever an abnormal phenomenon. In nearly every case in which buds could be observed, they could be shown to originate from an increased growth of the tissue owing to seaweeds or other organisms which established themselves here. Only one category of buds forms an exception viz. the buds on the scar of *F. actiniformis*.

This scar, in fact, is the place of an old wound, but even very young Fungiae, recently dropped from the stem, have covered this cicatrice again with living tissue. It is, therefore, difficult to account

for the origin of this renewed activity of growth at the scar, which induces the formation of these buds. Though their aspect is normal and regular, they are in unfavourable conditions for further development.

The most successful mode of budding in adult Fungiae is no doubt that from the remains of the living tissue of a disc of *F. fungites* that is almost entirely overgrown with seaweeds or other organisms.

Here the buds have been formed as normally as those of an anthocormus. On this account many researchers consider these buds to have directly arisen from larvae.

At an anthocormus a large number of buds are massed together within a short time. Most of them form new buds laterally to their stem. Now when the anthocyathus of the buds gradually enlarges, this broadened extremity often leans against the disc of a neighbouring young Fungia, which inhibits further broadening in those places. In this way originate anomalous young Fungiae, as may be seen from many colonies. Hereby the anthocyathus is elongated in many cases in one direction or is angular with many flattened sides.

This close contiguity may also cause the undersides of two young Fungiae to coalesce, the buds then drop simultaneously and remain twinned. At an anthocormus of *Fungia actiniformis* I found two of these young buds, the underside of one of which was at one place grown together with the other. The septa of the one anthocyatus are still separated from those of the other. During the transport these buds got loose from their stems but they were not severed from each other.

Not unfrequently do we find old Fungiae, which clearly show their origin through coalescence of two buds as is evident from two scars at the underside of such twin-specimens. When these twins have arisen from the intergrowth of two Fungiae of about the same age two mouths with the surrounding septa are to be observed at the upperside, the septa being grown together anomalously at the plane coalescence between the two individuals.

Now the occurrence of two or more mouths at the upperside of a Fungia would not warrant the conclusion that such a coral has arisen from several individuals, for when, for some reason or other, a stronger growth appears in one part of the border than in the other part, folds will make their appearance which may extend upwards over a pretty long distance, as a doubled up border. If this folding process continues up to the mouth, it often results in a

splitting of the primary mouth into smaller ones, while the septa formed afterwards then arrange themselves radially round these new mouths. Near Edam I found similar specimens of *F. fungites*

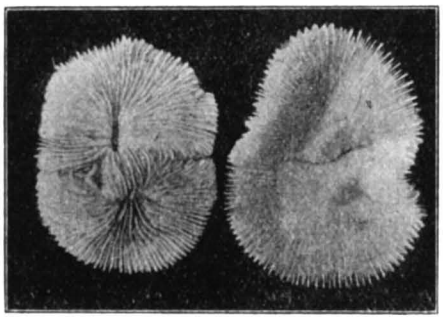

Fig. 7. *Fungia fungites.* Twins, the result of coalescence of two buds of an anthocormus. To the left a specimen seen from above; to the right a specimen seen from below. 2/5 natural size.

as well as of *F. actiniformis*, but when examining the underside we clearly see that only one individual is concerned here, as only one scar is observable. [1])

Rather considerable divergencies in the size of the intergrowing buds may produce formations which remind us of budding at the underside of an adult individual, as is very beautifully typified in a specimen of *F. actiniformis* that I found near Edam. At the underside of this Fungia of 10 cm. diameter a young coral of the same species of 4 cm. diameter is partially grown together with it.[2])

The septa of the smaller Fungia, facing the centre of the larger one, are ill-developed as they touched the ground. The other side possesses well-developed septa and in a living state, bore long tentacles, so that the mouth is rather remote from the centre. The larger Fungia has developed into a normal individual, the smaller one was covered by it entirely and was moreover partly overgrown with sea weed, which also blunted the sharp edges of the scar.

In *Fungia actiniformis* there is generally at the underside in the centre a truncated conical platform, of which the flattened surface constitutes the most often sharply outlined scar of attachment to

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[1]) QUELCH (l. c. page 131) also records the occurrence of similar abnormal individuals.

[2]) The ribs of the smaller Fungia are grown together at the indicated place with those of the larger one: if this were a case of budding, these ribs would grow by themselves.

the anthocaulus. Now we sometimes observe a specimen with stemmed buds by the side of this coniform part. I found one of 43 mm. in diameter; which bore laterally to the platform, at the underside, two buds respectively 3,5 and 3 mm. in diameter; the peripheral portion of the stem had not yet broadened into a disc. From the basis to the septa these buds measured respectivily 6 and 5 mm. These buds completely resemble young Fungiae of an anthocormus; they usually occur at the stem of an older bud as lateral branches. In normal cases they are seen below the spot where afterwards the young Fungia will drop from the stem, so that they can develop further, when this takes place. The instance described goes to show that sometimes the tissue above the preformed cicatrix also engenders buds, which however, stick to the underside of the young Fungia, when the final bud drops from the anthocaulus and which are hereby impeded in their further development. The above interpretation seems to me more plausible than the hypothesis which represents the problem as a lateral budding, arisen after the young Fungia has detached itself from the anthocormis. The size of this coral points to its having only just dropped from the stem.

In *F. actiniformis* the scar has a sharp edge, the boundary between the scar and rest of the underside remains sharp also with older specimens of this species. In *F. acitiniformis* this facilitates the decision whether an apparently coalesced specimen has originated from two buds or through abnormal growth of one specimen. The scar of *F. fungites* becomes obscured in older specimens, in little ones it is mostly easy to distinguish. In the specimens of Fig. 7 the scars could easily be noted, so that this is an indubitable case of coalescence on the anthocormus. Fixed, stemmed coalescent anthocyathi of *F. fungites* I have not been able to discover.

From the Treub Laboratory Buitenzorg, Aug. 1921.