Zoology. — "*Experimental Budding in Fungia fungites*". By Dr. H. BOSCHMA. (Communicated by Prof. C. PH. SLUITER).

(Communicated at the meeting of January 27, 1923).

A large number of the Fungiae to be found on coralreefs display anomalies mostly arising from the destruction of part of the living tissue. In many cases the destroyed stretches of living tissue are attacked by small algae, which penetrate to a considerable depth, and gradually spread into the living tissue. Such decaying spots often stimulate the adjacent tissue, which consequently exhibits a more energetic growth-activity than usual. The result then is that something like a raised rim arises on the border between the living and the defunct part. In many cases this greater activity is also manifested even in the formation of buds. In a previous publication I discussed this budding in adult Fungiae [1]). Here I also pointed to the fact that algae-parasitism is one of the chief causes of budding in adult corals. Generally the destruction of only a small part of the living tissue suffices for the vicinity to be stimulated to a more energetic growth-activity.

This induced me to endeavour to develop buds experimentally in *Fungia fungites*. My material for this experiment consisted of specimens of *Fungia fungites* from the reef of the island of Edam near Batavia. The most normal corals devoid of buds or other anomalies were selected. To destroy part of the tissue a small piece of putty was pressed into the central region of the oral surface of some fifty specimens on the 18th and the 19th of August 1921. The putty was held fast on either side of the mouth by the septa. The corals were then restored to their original places.

In this experiment, I expected the destruction of part of the central tissue to extend to the mouth in most of the specimens, as this would most likely bring about a strong reaction to the lesion, so that budding would soon ensue. True, the ingest of food would hereby be slightly impeded. But considering that Fungia feeds only partly on organisms other than zooxanthellae, and considering moreover

[1]) H. BOSCHMA, "On Budding and Coalescence of Buds in Fungia fungites and Fungia actiniformis." Proceedings Kon. Ak. van Wetensch. Amsterdam. Vol. XXIV, 1922.

that the basal portions of the axial groove were not entirely covered, the impediment was not of a serious nature. This experimenting method was most suitable for achieving results in a short time.

After the lapse of nearly four months the putty could still be seen unaltered as to shape, as a hardened substance above the mouth. Some corals had already developed buds. On the 11th of December 1921 five specimens were brought back, one of which (N°. 464) was preserved in formalin and the other four were left dry (N°. 460—463). The changes resulting from the experiment are summarized as follows:

N°. 462. About one fifth of the upper surface is defunct. Beneath it buds have developed on the under surface, smaller ones at the margin, larger ones more towards the centre.

N°. 463. Half of the upper surface is defunct. Only few septa in this destroyed part exhibit in the margin residues of living tissue. Portions of the margin of the under surface, under the defunct part of the upper surface, are also defunct. The rest is still covered with living tissue. On the upper surface some large buds and many small buds at the margin. (Fig. 1—3).

N°. 464. Two opposite quarters of the upper surface devoid of living tissue. The destruction of the soft parts has extended round the margin of the coral, so that here also some portions are defunct. On the under surface a few large buds, a few smaller ones in the margin.

N°. 460. On the upper surface the living tissue was quite lost, on the under surface only in some places at the margin. Here a few small buds are to be recognised, while in the more central part a few larger ones have developed.

N°. 461. Upper surface quite defunct, under surface still covered with living tissue. In the margin of the under surface many small buds, in the centre a few larger ones.

In all specimens a stretch of the tissue nearest to the putty first died away. This process progressed along the septa to the periphery so that the defunct part assumed the form of a sector of a circle. The decay of the living tissue now spread along the margin on the lower surface, the consequence of which was that the environing tissue was stimulated to greater activity and accordingly developed buds.

At the living corals the larger buds, which were located at some distance from the margin, were most conspicuous. (Fig. 3). The diameter of the basal part of these buds varied from 2 to 12 mm. The mouth was invariably small and the height inconsiderable. The spines of the costae of the parent coral were often visible through the thin living portions of the bud. In these large buds the skeleton is still very incomplete. The theca and the first septa are only little developed; on the other hand the columella is already distinguishable in the form of a large number of irregular trabeculae.

In the smaller buds, which were generated principally in the marginal regions of the under surface the development of the skeleton can easily be traced, as the buds differ very much in age. They are of a much more regular structure than the larger ones.

In the youngest buds, with a diameter of about 0.5 mm., nothing of the skeleton is visible except the theca, which appears as a thin wall, stretching obliquely upward and consequently looks like a truncated cone. (Textfig. *a*).

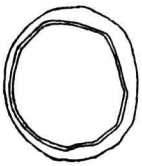

Fig. *a*. × 45.

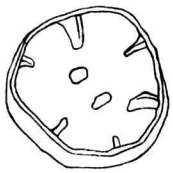

Fig. *b*. × 45.

Fig. *c*. × 45.

The theca has no perforations, which come forth only in much older buds. Soon after this the first cycle of six septa spring up. They proceed from the theca further towards the centre of the bud. (Textfig. *b*). The upper rim of the theca rises above the septa. The columella also develops in this phase as short projections in the basal parts of the bud. In buds of this size there are never more than six septa. They originate almost simultaneously, buds with a smaller number of septa occurring only very seldom. The number of similar buds with less than six septa is too small to ascertain whether the septa arise in a definite order.

The next cycle of septa can only be observed in buds of about 1 m.m. in diameter. In them the septa of the first cycle have already considerably increased in size and in thickness, and are already provided with some dentations. (Textfig. *c*). Likewise the columella has grown larger in this stage. The septa of the second cycle are distinguishable at first sight from those of the first cycle by their being less developed and being shorter. The bud has now attained the length of the youngest stage described by BOURNE[1]),

[1]) G. C. BOURNE, On the Postembryonic Development of Fungia. Transact. Roy. Dublin Soc. Vol. V, 1893.

to which it bears great resemblance. The further development of these buds resembles that of the buds of an anthocormus.

With the exception of the five specimens that were brought back in December 1921, the other Fungiae remained on the reef during nearly nine months. On the 2nd of September, when the experiment had been going on for more than a twelvemonth, the specimens that could still be found, were collected. The putty was still in the central part of the oral surface; in the majority of cases the form was unaltered.

In most corals at least some part of the oral surface had lost its living tissue, in a few cases only the plug of putty had caused little or hardly any change. The aspect of the Fungiae was now as follows:

Nos. 507. 510, 519 and 520. The aspect of the corals was very normal, without defunct parts. No budding.

N⁰. 518. Living tissue normal. The central parts of some septa have risen and have longer dentations. This is owing to the occurrence of new mouths by the side of the old mouth, as was easy to see in the two following specimens.

N⁰. 509. No parts of the living tissue destroyed. The central extremities of many septa have grown higher in those places which were in contact with the putty and new mouths have been developed beside these elevations of the septa. The new mouths are now entirely surrounded by septa; on the one side by long regular ones (the original septa of the parent-coral) on the other side by higher parts of recent origin. These parts are somewhat irregular in shape; also the dentations are longer than those of the original septa.

N⁰. 508. Covered all over with living tissue. On either side of the old mouth-fissure a few young buds had developed, whose mouths lay between the normal longer parts of the septa and the higher irregular parts that originated later on. (Fig. 5). This specimen is very much like N⁰. 509, in which the young septa between the new mouths and the putty are also provided with long dentations.

N⁰. 521. Few alterations. The living tissue has disappeared only from the central parts of some contiguous septa. Budding is absent.

N⁰. 512. Some adjacent septa devoid of living tissue, further no alterations. No budding.

N⁰. 506. Upper surface with two defunct parts, the larger of which covers nearly one fifth of the surface; the smaller part is a narrow streak from the mouth to the margin of the coral. The larger part of destroyed tissue overlaps the margin and covers a small portion of the under surface. At the margin two stemmed young buds have taken origin. The diameter of the disc is respectively 2,5 en 3 m.m. In the defunct part on the under surface there are a few smaller buds.

N⁰ 501. Almost half of the upper surface defunct, just as a smaller part of the under surface, especially the margin under the destroyed portion of the upper surface. On the boundary between the living and the destroyed part of the under surface, five buds have developed still completely encircled by living tissue of the mother-coral. They are very regular and distinctly stemmed. The diameter of the disc, which in all of them is already broader than the stem, amounts to 6, 7.5,

10.5, 8.5 and 6 m.m. In the defunct marginal part of the under surface there are some smaller younger buds (diameter 1 to 3m.m.), which, however, have lost their living parts.

N⁰. 500. Along the shorter diameter of the corallum a broad band of the upper surface has lost its living tissue. In the living part some septa exhibit a more energetic growth of the central part; however, new mouths could not be distinguished as yet. The parts of the margin of the under surface contiguous to the defunct part of the upper surface had lost their soft portions. In their vicinity buds had developed in the living tissue, five on one side and two on the other (Fig. 4). These buds are less regular in form than those of N⁰. 501. Their stages of development differ. The dimensions are: 13 × 8, 7.5 × 7, 4.5 × 4, 6 × 5.5, 5 × 4, 13.5 × 8.5, and 10 × 7 m.m. They are fixed to the parent coral by a broad base, The septa of the youngest buds, which are still little developed, are distinguishable from the spines of the costae of the mother-coral by their flattened shape. In the basal parts of most of these buds the spines of the mother-coral are still unaltered. In the destroyed part of the margin, with the five buds, a stemmed bud has developed (diameter of the disc 4.5 m.m., of the stem 3.5 m.m., height 3.5 m.m.). Besides these there are still remains of a number of smaller ones, whose living tissue has, however, disappeared.

N⁰. 511. Only one third of the coral was covered by living tissue on the upper surface as well as on the lower surface. In the defunct portion of the lower surface a great many buds had arisen, most of which were still alive. The diameter of these buds ranges from 1 to 3 m.m.

N⁰. 502. Of the upper surface only a small part of the margin was still covered with living tissue; of the under surface almost one fourth was still alive. In this part there are in the vinicity of the defunct region four large buds, only two of which possess well-developed septa. The dimensions are 10 × 7, 7 × 6.5, 9.5 × 7.5. and 10 × 9 m.m. The buds are not yet stemmed, so that the basal parts of the septa are still fixed over their whole length to the skeleton of the mother-coral. The septa of the youngest buds are distinguishable from the spines of the costae of the mother-coral only by their flattened shape. Besides these large buds there are at the margin, now surrounded by the destroyed region, two stemmed buds with a disc, 3 and 2.5 m.m. in breadth. Moreover a few smaller ones are also visible in the marginal part

N⁰. 514. Upper surface without living parts. However, the tissues of a fourth part had died off quite recently, the skeleton of this part still being little overgrown with algae and other organisms, in contradistinction to the remaining part. At the margin of the part that died off long ago some few young, stemmed buds have developed, which however, have likewise lost their living tissue. The under surface still possessed rests of living tissue beneath that portion of the upper surface, which kept alive longest. Then follows a broad edge from which nearly all soft parts had disappeared. Here some large buds have developed (diameter up to 6.5 m.m.). Little is to be seen as yet of the skeleton In the remaining part of the under surface, which had been defunct longer, the remains of many small buds are visible, none of which were alive any more.

N⁰. 516. Upper surface devoid of living tissues in the margin a few short-stemmed young buds. Under surface still covered with living tissue. In the margin a few young buds of small dimensions, still completely encircled by living tissue of the parent-coral.

N⁰. 513. Living tissues entirely disappeared from the upper surface; on the under

surface about one third defunct. In the marginal stretches, where the soft parts have disappeared, a few young buds, most of which are stemmed. Diameter of the disc of these buds up to 3 m.m. In the part of the under surface, which is still covered with living tissue, there occur a large number of buds in all stages of development. The size ranges between 0.5 and 3.5 m.m. The stages represented in the textfigures are also perceptible in many buds.

N°. 505. The upper surface as well as the under surface without living tissue. At the margin some buds occur; the disc of the largest bud has a diameter of 7 m.m. On the under surface of the coral many young buds in different stages of development.

N°. 517. This specimen happened to lie upside down. It had lost its living tissue on both sides. On the aboral surface (now the upper surface) no buds had formed, on the oral surface there are eight buds, some of which are already stemmed. The diameter of the disc of these buds varies from 2.5 to 5.5 m.m.

It appears from the foregoing that the results are very different. In some cases the destruction of part of the living tissues had an influence only on the immediate vicinity, where the tissue was consequently brought to greater activity. This appeared from the formation of new mouths beside the old one which had got lost, and of small septa between the new mouths and the defunct part.

Owing to the experiment a smaller or a greater part of the remaining living tissue of the *Fungia* had been destroyed. This process began invariably at central parts of one or more septa, i.e. beside the putty. When the central part of a septum has lost its living tissue, this process progresses towards the periphery and farther along the margin to the under surface of the coral. Of the decaying tissue some isolated parts keep alive and buds issue from them. At the margin of the mother coral these buds are small and of a regular shape; they develop like buds of an anthocormus.

Regarding the development of the skeleton a few remarks may follow here. According to BOURNE[1]) the twelve first septa of Fungia originate simultaneously, as is also the case with *Astroides*. In the former, however, the six septa of the first cycle come first and then those of the second. Since the development of the buds is so very regular and the older stages are quite similar to those of the buds of an anthocormus, it may be expected that the first stage of development of the skeleton of the young Fungiae, which arise from planulae, is similar to that of the youngest buds here described.

Moreover the youngest stages of *Fungia patella* described by GARDINER[2]) possess no more than six septa, while the older stages

[1]) loc. cit.

[2]) J. STANLEY GARDINER, On the Postembryonic Development of Cycloseris. Willey's Zoological Results. Pt. II, 1899.

bear a striking likeness to the young Fungiae, described by BOURNE. VAUGHAN[1]) also points out that it has not yet been proved that the first twelve septa of Fungia appear simultaneously.

In the development of *Caryophyllia*[2]) there is one stage in which the skeleton agrees very much with the stage illustrated in Textfig. *b*. However, the preceding processes differ in the two corals; whereas in *Caryophyllia* the septa are formed prior to the theca, the reverse takes place in *Fungia*. In *Caryophyllia*, therefore, the septa have outgrown the theca much sooner than in *Fungia*.

So while a great number of small buds appear at the margin, and several large ones on the under surface, the tissue is dying off by slow degrees. The result is a defunct specimen with a large number of living buds of different age. Many authors[3]) look upon such buds on defunct specimens of the same species as having originated from larvae.

In a previous paper I advocated my view that these young Fungiae must be considered as buds[4]). My experiment yielded all sorts of intermediate stages between normal specimens and defunct ones with buds. The large buds that may arise on the aboral surface, are in their earliest phase so large already (up to 12 mm. in diameter) that it is a priori highly improbable that they should have been formed from larvae. Besides the lateral tissues of the bud are connected with those of the parent, while the basal living parts of the bud overlie the skeleton of the old coral, which results from the way in which the columella is formed in these buds. The trabeculae of their columella namely are generated between and on the unaltered spines of the costae of the parent coral.

In the above description the young individuals, which resulted

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[1]) T. WAYLAND VAUGHAN, Recent Madreporaria of the Hawaiian Islands and Laysan. Smithsonian Institution, U. S. Nat. Museum, Bull. 59. 1907.

[2]) G. VON KOCH, Entwicklung von Caryophyllia cyathus. Mitt. Zool. Stat. Neapel, Bd. XII, 1897. (The stage alluded to is reproduced in Fig. 14).

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

H. N. MOSELEY, Notes by a Naturalist on the Challenger. London, 1872.

L. DÖDERLEIN, Die Korallengattung Fungia. Abh. der Senckenb. naturf. Ges. Bd. XXVII, 1902.

Also the youngest stages of *Fungia patella*, described by GARDINER (loc. cit.) are probably buds of a specimen, of which the remaining part of the living tissue had been destroyed.

[4]) loc. cit. SAVILLE KENT (The Great Barrier Reef of Australia. London, 1893) also deems it most probable that these young Fungia are buds, originating from the remains of the living tissue.

from the destruction of stretches of living tissue, have been called buds. Theoretically however, none of these individuals can be considered as buds. In budding the parent remains intact, the buds are generated through a local intensified growth at the body of the parent (DEEGENER [1])). The animal, on which the young individuals grow, is now only a remnant of what it was before. The process of development of the young individuals under consideration, is rather to be defined as a fragmentation, as it has been termed by KORSCHELT and HEIDER [2]). Small portions of the tissue of the body are apt to develop into new independent individuals. That these portions are not detached from the parent coral but remain fixed to the skeleton does not take away from the theoretical significance of separation.

KORSCHELT and HEIDER point to the fact that fragmentation is originally not a phenomenon of itself, but the effect of processes of fission or budding.

The processes in Fungia, dealt with in this paper are undoubtedly related to budding. Sometimes daughter-individuals are found on the aboral surface of specimens, whose oral surface presents no anomalies. These daughter individuals are true buds. They have the same outward appearance and are attached to the parent-coral in the same way as the buds which were developed experimentally. Daughter-individuals can also be developed from that part of the living tissue of a mother-coral, which is contiguous to a small region of the margin of which the living tissue has been destroyed. The mother-coral will then remain alive, although it is slightly injured, and the young individuals, derived from a portion of the living tissues, are buds also in this case.

The evidence produced shows that any part of the tissue may develop into a complete animal. This, however, occurs only when the interconnection between the living parts of the original animal ceases to exist in consequence of destruction of part of the tissue.

The place where the young individuals develop is very different. They may arise at the top of the costae or between two costae or, when they are larger, on several costae together (Fig. 1). In corals that were inverted while the tissue was being destroyed, young individuals may develop between the septa and in the vicinity of the mouth, i.e. on the oral surface.

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[1]) P. DEEGENER, Versuch zu einem System der Monogonie im Thierreiche. Zeitschrift f. Wiss. Zoologie. Bd. 113, 1915.

[2]) E. KORSCHELT und K. HEIDER, Lehrbuch der vergleichenden Entwicklungsgeschichte der wirbellosen Thiere. 1 u. 2 Aufl. Allgemeiner Theil. 4 Lief. 2 Hälfte. 1910.

Some of the experimental animals could have survived in a slightly altered form. They are the corals, in which new mouths had been formed round the destroyed central part of the oral surface. Most specimens however had altered their shape completely: the ultimate result would ever have been a defunct disc with a number of young living individuals, chiefly on the under surface and at the margin. The young individuals on the under surface were in unfavourable conditions for further development, although some were already rather large (Fig. 4). The young Fungiae at the marginal regions, would have developed into a stemmed specimen if the corals had remained on the reef, When their disc has grown to a certain size, it falls off and at the upper extremity of the stem a new disc forms. These young Fungiae, originated from the last living residues of a defunct specimen, develop further in the same way as young individuals do, which are generated from fertilized ova.

Leyden, Jan. 1923.

Zoological Laboratory of the University.

Plate I.

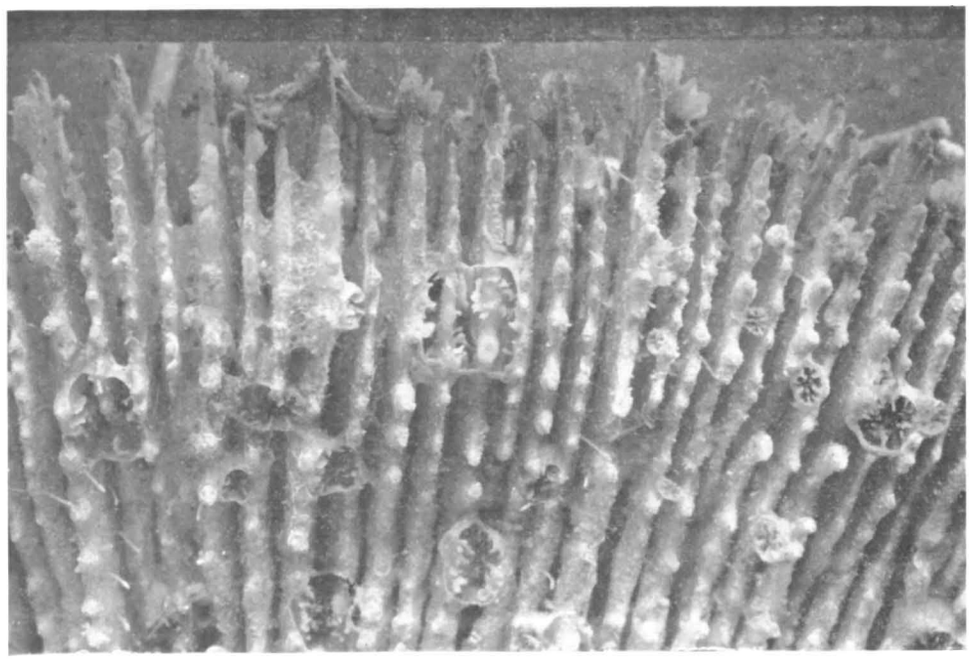

Fig. 1. Part of the margin of the aboral surface of *Fungia fungites* No. 463. Living parts removed. Many small buds and a few larger, less regular ones. Magnified $\times 5^1/_2$.

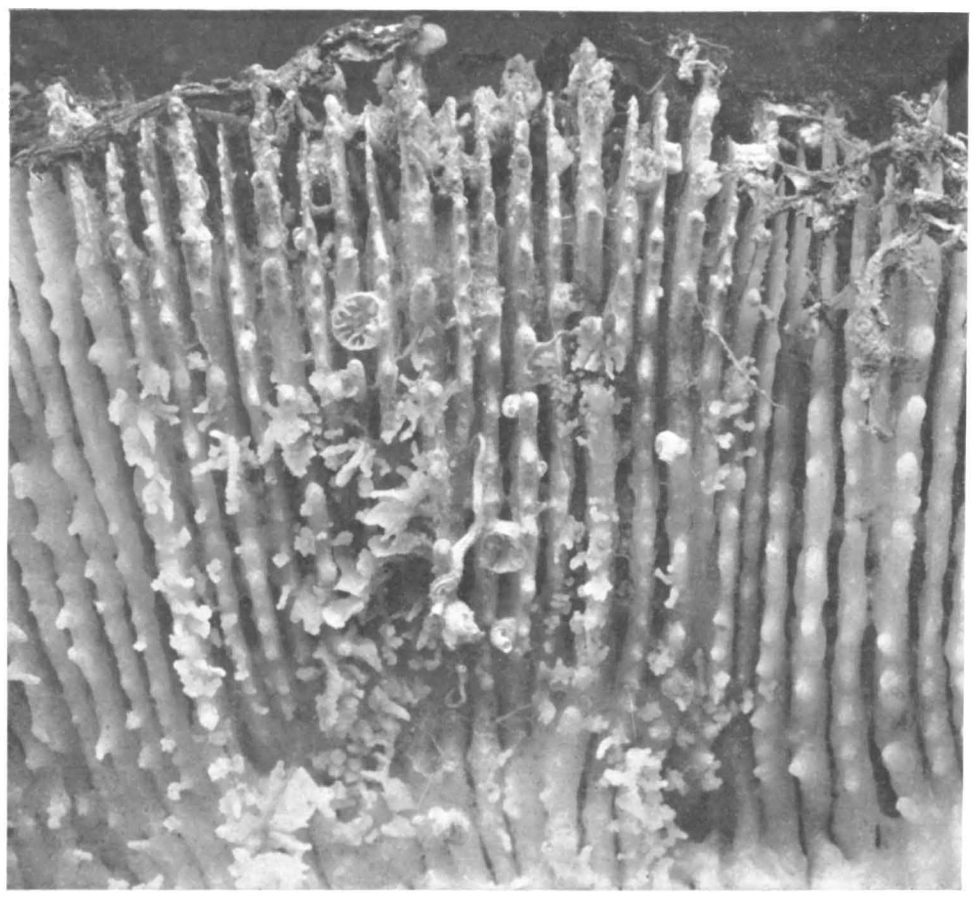

Fig. 2. Other part of the margin of the aboral surface of the same specimen. Besides a few smaller buds also a large number of irregular elements of the skeleton, especially of the columella of larger buds, are observable. Magnified $5^1/_2$.

The photographs for figs 1 and 2 have been taken by Mr. G. F. J. Bley of Batutulis near Buitenzorg.

Plate II.

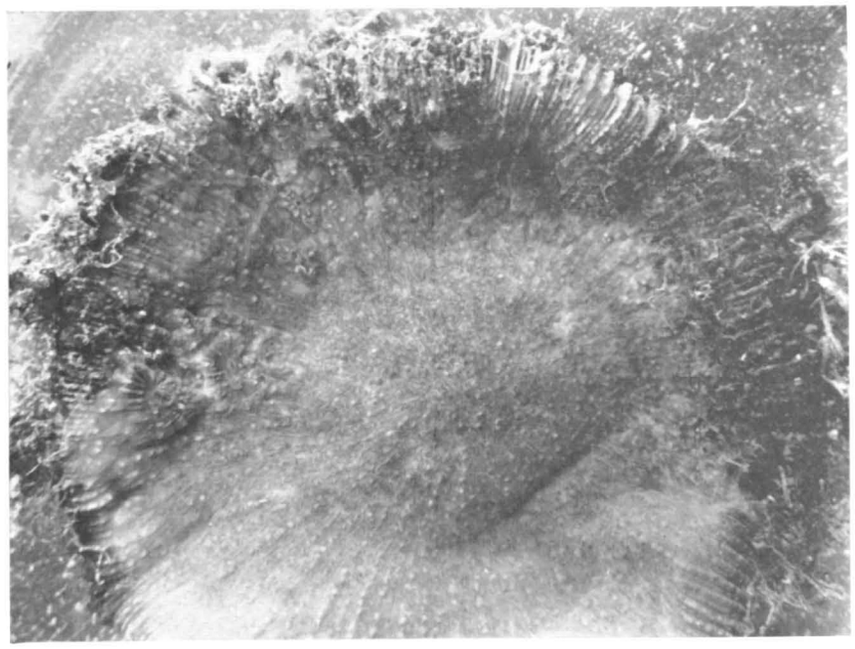

Fig. 3. Lower surface of *Fungia fungites* No. 463 living. A number of large buds, whose living parts are connected with the unaltered tissue of the lower surface. Natural size.

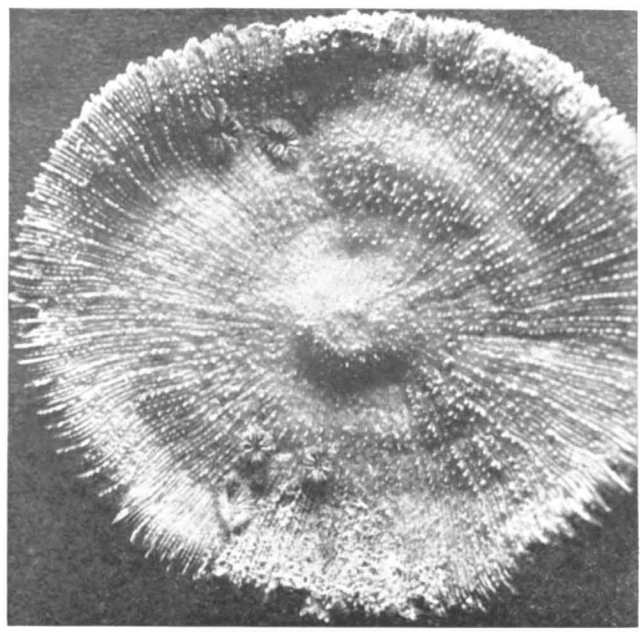

Fig. 4. Lower surface of *Fungia fungites* No. 500. Buds in the living part adjacent to a portion of the margin where the soft parts have died off. $^3/_4$ nat. size.

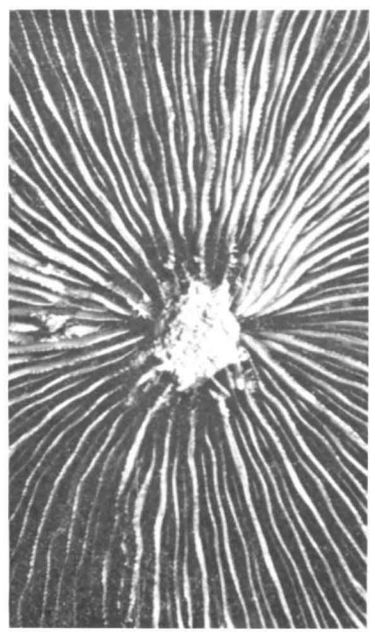

Fig. 5. The central portion of the oral surface of *Fungia fungites* No. 508. By the side of the plug of putty new mouths had been generated, which, towards the central part of the parent-coral, are encircled by raised portions of the old septa with larger dentations. $^2/_3$ nat. size.