Preliminary Account of a Contribution to an Evaluation of the Sea.

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INTRODUCTION.

An investigation of the rate of growth in Marine Invertebrates was begun in 1911, and a large amount of material the age of which is known has now been collected from various sources. The particular objects of this research are: (1) to establish the age of common marine invertebrates, (2) to determine the minimum age at which these forms begin to breed, (3) to examine the rate of growth at different seasons of the year and under different conditions, (4) to investigate the fecundity of different forms so far as possible, and (5) to collect the scattered literature on these subjects.

The investigations have been carried on mainly by immersing various objects in the sea at a known time and subsequently observing and collect-

ing the various kinds of animals growing on them. Other experiments, however, are being carried out with some success with the object of entrapping young or larval free-living animals and observing their rate of growth. The sexual condition of the collected animals has been noticed particularly, and evidence of the maturity of the sexual products obtained either by isolating the animals or by trying artificial fertilisations. As a result of these investigations a good deal of information about members of most of the groups of invertebrate animals has been obtained, and the following statements may be regarded as a sample of the results.

RATE OF GROWTH IN SOME CŒLENTERATA.

Among the Cœlenterata it has been found that various species of Obelia and *Clytia Johnstoni* give off medusæ when not more than a month old. Similarly, *Bougainvillea ramosa* yielded medusæ at once when collected at an age of not more than six weeks and a few days. In all these cases, however, the observations do not cover the whole life-cycle as do the following. The commonest species of Tubularia—almost certainly *T. larynx*—has been found to give off actinulæ larvæ at an age of not more than six weeks, and in one experiment this species had moderately developed gonophores at an age of not more than 26 days. As these Tubularia actinulæ have been found to settle and grow into little polyps within a few days, it follows that this species may pass through its life-cycle within about six weeks and probably actually within four or five under favourable conditions. In the same way Plumularia and Gonothyræa have been found to give off planulæ at an age of not more than three months; thus, as these planulæ may probably settle almost immediately, these hydroids may complete their life-cycle within at least three months, and in both cases in a period probably less than that stated by some few weeks. Hence there can be little doubt that these hydroids pass through several generations—probably three and possibly more—in a year. A species of Syncoryne yielded medusæ at a maximum age of ten weeks, but doubtless the actual age was much less than this.

In all these cases, however, there can be little doubt that the rate of growth—probably apart from the question of food-supply—varies at different times of the year. So far as the investigations have been examined, it would appear that in this group most of the species mentioned above appear to have a maximum rate of growth in the months of August and September.

The most interesting record of the rate of growth obtained so far in Actinians is that of *Sagartia viduata*, which has been found to attain to full size at a maximum age of 14 to 15 months.

RATE OF GROWTH IN SOME PORIFERA AND THE LIFE-HISTORY OF SYCON, GRANTIA, AND LEUCOSOLENIA.

Among Porifera a fairly complete investigation of the life-history and rate of growth of *Sycon coronatum*, *Grantia compressa*, and a species of Leucosolenia has been made. These sponges have been found to be annuals, as they have generally been believed to be. But the interesting fact has been ascertained that there are two breeding seasons, especially well marked in *S. coronatum* and Leucosolenia, one in summer and one in late autumn. Data have, moreover, been obtained supporting the view that the same specimens may breed twice in their life-history, namely, once in late autumn and again in the following summer. Thus, therefore, it would seem that temperature is the main factor governing reproduction in these animals, since continuous rapid growth takes place in the winter, as will be seen from the following observations. Some very fine specimens of *S. coronatum* of known age have been obtained. One exceptionally fine specimen attained a length of more than 28 cms. with an average width of about 2·2 cms. in not more than 10 months 19 days, and growing during the period from July to May. Another specimen 24·8 cms. long grew between June and January in a period not longer than 7 months and 20 days. In another case several specimens measuring between 14 and 16 cms. long grew between May and January in a period not longer than 8 months and one day. It is an interesting fact that none of these specimens yielded embryos when they were isolated in dishes of sea-water, whereas tiny specimens from 3 to about 5 cms. taken in September and October gave off a good number of embryos. These tiny specimens have been obtained from several independent experiments started in early and late spring and in the summer, hence they are the sponges derived from the embryos liberated at the summer breeding period, namely, about the latter end of May or early June. The approximate age of these specimens is therefore about four months ; in one case the actual age of such specimens was not more than 15 weeks. It is highly probable, moreover, that these autumn breeding forms continue to grow through the winter and again give off embryos in the following summer, when they die down. However this may be, there can be no doubt that there are at least two broods of

embryos produced in a year, and from the fact that specimens only 1·5 cms. long have been found to contain fully developed free embryos in the inner flagellated chambers in the autumn I think it very probable that this species might in favourable seasons yield three generations within a year, rushing through two of them in late autumn.

Similar breeding phenomena to those described in *S. coronatum* are presented by *G. compressa* and Leucosolenia. Tiny specimens of *G. compressa* 1·3 cms. long taken in October at an age not greater than 7 months and of an actual age of less than 4 or 5 months have been found to be crammed full of embryos, while large specimens 8 cms. long with an average width of 3·5 cms. taken in March and April have been found to contain only immature ova. In the following June, however, specimens similar to the latter have yielded crowds of embryos. Corresponding results to these have been obtained with Leucosolenia. Thus the summer and winter breeding periods appear to be general in our calcareous sponges. The life-cycle of Grantia has been carefully followed round the year, and it was observed that in one situation where this sponge was extremely common of a large size in June they gradually disintegrated during July, so that by August it was impossible to find any but the tiniest specimens, which were doubtless the first comers of the new summer crop. The same difficulty in finding any but small specimens was also met with on other grounds in the district where these sponges can generally be obtained at any other time of the year.

The summer crop continues to grow during the autumn, and by about December may attain to an area in side view, i.e. on one flat side, of about 10 sq. cms. By the following March specimens may be found with an area of from 25 to 30 sq. cms.,* and at the end of a year's growth in the following June specimens of average size may attain to an area of at least 30 sq. cms.* in side view, or in other words, the whole "body-wall" would have an area of more than 60 sq. cms. After delivering their summer embryos these specimens, as we have already seen, die down and a fresh crop arises.

Of siliceous sponges few records of much value have so far been obtained, but a colony of *Halichondria panicea* grew on a flat surface between June and the following January to an area of about 45 sq. cms. and of about the usual thickness of this sponge.

* More exact measurements will be given later.

RATE OF GROWTH IN SOME PLATYHELMINTHES.

Among the Platyhelmia strong indications have been obtained that Cycloporus, Leptoplana, and their allies pass through a generation within a few months, but no certain evidence has been obtained with regard to these animals. The results will be more fully discussed later.

RATE OF GROWTH IN SOME ANNELIDA.

A good deal of information has been obtained of various members of the Annelid group, and especially of the sedentary Polychætes. *Pomatoceros trigueter* and *Hydroides norvegica* grow to nearly full size in about 4 months, and at this age the former has yielded in many cases practically 100 per cent of embryos on being artificially fertilized, while a specimen of Hydroides of the same age shed ripe eggs, but unfortunately no male of the same age was available for a fertilization. The common species of Filograna has been obtained, carrying ripe eggs and trochospheres at an age probably less than four months, having grown through the summer. About the same time another experiment yielded specimens with fully developed eggs at an age not greater than 10 weeks and 4 days. Later in the year full-sized specimens with buds had an age not greater than 4 weeks and 2 days. There can be little doubt, therefore, that in this species there is an alternation of generations, the summer forms producing eggs and sperm and the autumn and winter ones producing buds.

Polymnia, Dasychone, and many others have been found to attain a good size in much less than a year. Ripe *Serpula vermicularis* not more than about 10 months old yielded an excellent result on being fertilized. Dinophilus has been reared through at least one generation in the Laboratory within a period of 7 weeks, and Ophryotrocha to a medium size in 8 weeks, but with more attention doubtless the rate of growth in these two forms might easily be found to be twice as great. Chætopterus at an age less than 13 months grew a tube 14 cms. long and had developing ova in its gonad, and *Sabella pavonina* a tube 12·6 cms. long in less than 31 weeks, and at this age contained well-developed but not quite mature ova. Similar results have been obtained with many free-living Polychætes, but these will be discussed later.

RATE OF GROWTH IN SOME POLYZOA.

One interesting result has been obtained among the Polyzoa. By continued experiments and observations *Bugula flabellata** was found

* Including *Bugula calathus*, Norman, for the purpose of the present paper.

to grow to a good-sized colony and give off larvæ within a period of not more than 8 weeks. From the observations made there is no doubt that this species passes through several generations during the summer and autumn, and indications were given that the most rapid growth occurs during August and September. In one case more than 100 zooids were counted in a colony not more than a fortnight old. Another species of Bugula has been found to grow colonies 4 cms. high and 2·5 cms. wide in 15 weeks. Very large colonies of a Bowerbankia species of an age not more than 9 months gave off a great number of larvæ, and in another experiment a colony 4·5 cms. high and 2·5 cms. wide was obtained at an age not greater than 15 weeks. *Scrupocellaria reptans* formed good-sized colonies in less than 7 months ; *Membranipora membranacea* grew to a circular colony 6 cms. in diameter within 12 weeks, *Lepralia pallasiana* circular colonies 1·1 cms. in diameter within 8 weeks, and 3·1 cms. in diameter within 23 weeks. *Cellularia neritina* grows into huge colonies in the inner basin at the Great Western Docks in a year.

RATE OF GROWTH IN SOME CRUSTACEA.

A few observations have been made on members of the Crustacea, mostly of the sedentary forms.

Balanus balanoides attains to full size in a year and gives off large numbers of nauplii at this age, but there does not appear to be more than one breeding season, namely, in the late winter months. Other species of Balanus, however, have been found to grow to a large size in less than a year. Especially interesting results have been obtained in this group by examining the bottoms of ships in dry dock and obtaining information from the captain of the ship as to when the ship was last scraped and painted. From the information obtained in this way it has been found from independent data that *Conchoderma virgata* grows to a good size and gives off nauplii within from 4 to 5 summer months, and *Lepas anatifera* and *L. hilli* within the same period. *Conchoderma aurita* grows to a large size, namely, 7 cms. long, within 5 months, but was not found with embryos or nauplii when examined. This rapid growth of Cirripedes is well known to some captains of sailing vessels, who are constantly sailing the high seas in relatively slow-moving boats, for there is apparently a limit to the speed of the boat on which Lepas and Conchoderma will grow. The vessel on which the specimens mentioned above were obtained had travelled mostly at 6 to 8 knots I was told, hence the limit of speed for their growth must be something greater than this.

In this group a special experiment has been tried with success, with the object of entrapping young forms in a wire basket of a small mesh inside which, as the animals grow, they become imprisoned. Food is obtained by the animals from the natural growth on the wire basket and the surrounding parts. The wire basket was placed in a large floating wooden raft in Cawsand Bay adjacent to Plymouth Sound. From this cage put out in the sea on the 28th May, 1913, and taken in on 26th February, 1914, were obtained *Palæmon serratus* measuring on the average about 5·6 cms. long from the tip of the rostrum to the end of the tail, and two *Portunus puber*, one a male with a carapace width of 3·5 cms. and one female whose carapace measured 3·3 cms. wide. As the greatest width of the mesh of the wire cage at the close of the experiment was 14·5 mms., by 9 mms., it follows that the specimens of Portunus were in all probability samples of the young for the season of 1913, since the breeding season of this species of Portunus falls in about the spring of the year. (See "Plymouth Marine Invertebrate Fauna," p. 257, *J.M.B.A.*, N.S., Vol. VII, No. 2, 1904.) It is highly probable that the specimens of *Palæmon serratus* entrapped in the cage were also examples of last year's crop of this species, and as specimens about the size they attained occur in berry there would appear to be little doubt that this species becomes mature and bears young within a year. Some specimens are being kept alive in the tanks with a view to watching their subsequent growth.

An experiment conducted on similar lines on the Essex coast (see pp. 320 and 322) with a wire cage, the *greatest* width of any mesh of which at the end of the experiment was less than 2 cms., yielded four specimens of *Carcinus mœnas*, three males and one female. The width of the carapace of the three males was respectively 3·6, 3·4, and 3·2 cms., and that of the female 3·1 cms. This experiment extended over a period of 15 weeks between the 18th June and the 3rd October. Hence there can be little doubt that the common crab also attains to maturity within a year. Further experiments will be made with cages of wire having a smaller mesh in the hope of following the rate of growth more fully in these and other species of Crustacea.

RATE OF GROWTH IN SOME MOLLUSCA.

In the Mollusca group the age at which several species begin to breed has been determined. The common mussel, *Mytilus edulis*, has been found to spawn naturally at an age of one year. From eggs spawned in this way a fertilization made by adding sperm from a male of the same

age yielded 100 per cent of fertilized eggs. At this age the commonest sizes are from 3·5 to rather more than 4 cms. A good deal of material of this species has been obtained continuously during a period of two years, so that it will be possible to work out the rate of growth in this important mollusc fairly thoroughly. From several independent experiments it has been found that *M. edulis* may grow in this district to a size of from 3·5 to 4 cms. within the period between April and November, i.e. in about 30 weeks. During the winter it would appear that relatively little growth takes place. By the following April, however, specimens may attain to the size of upwards to 5 cms., and at the end of the summer following that in which the animals were spawned, i.e. at an age of about 18 months, the average length of specimens is about 5 cms. with a corresponding increase in width and depth, while one specimen of this age attained a length of 6·8 cms. and a width of 3·4 cms. The variations in size at different ages will be given later. An interesting comparison has been made between mussels 3·5 cms. long and about 10 months old and thick-shelled mussels from 1·3 to 1·6 cms. long from the exposed shore at Whitsand Bay. The latter were quite ripe and gave good fertilizations, whereas at the same time the former were not ripe. Thus it would seem that the Whitsand Bay specimens really were dwarfed individuals of an age of at least two years.

Continuous observations have also been made on the rate of growth in a few individuals of the common limpet, *Patella vulgata*. It has been found that specimens may attain a size of 4 cms. in less than 15 months, and at this age are ripe. An artificial fertilization made from these specimens gave ultimately a fair percentage of trochospheres. During 31 weeks between the 27th January and the 2nd September, 1913, two specimens grew on a flat surface, respectively, from (*a*) 2·1 cms. long by 1·6 cms. wide to 4·1 cms. long by 3·3 cms. wide, and (*b*) 3·8 cms. long by 3·2 cms. wide to 5·3 cms. long to 4·5 cms. wide. Thus the smaller specimen increased 2 cms. in length and the other 1·5 cms. in length. The age of the latter specimen when 5·3 cms. long was not more than two years. Another specimen grew between April 4th and September 2nd in the same year from 2·25 cms. long by 1·7 cms. wide to 3·3 cms. long by 2·85 cms. wide, thus increasing in length 1 cm. within 20 weeks. Thus the rate of growth of *P. vulgata* in this district is much greater—as indeed might be expected—than that found by Russell* in Scotland. These observations are, however, being continued, and the results in

* E. S. Russell, "The Growth of the Shell of *Patella vulgata*," *Proc. Zool. Soc.*, 1909, p. 235, I.

relation to those obtained by Russell will be discussed later when more data are available.

Anomia aculeata has in several independent experiments been found to attain to an average size for this species and to give larvæ on being fertilized at an age of less than four months. Specimens of this age have been taken at various times of the year with the same result, hence this species undoubtedly passes through two and probably three generations within a year. Next to the common mussel this is probably the commonest mollusc on our shores.

The boring mollusc, *Teredo navalis*, has been found to grow to a length of 19·8 cms. in 31 weeks, and made borings in soft wood 28 cms. long with an average width of about 1 cm. It was also found that the gill was alive in specimens obtained a fortnight after the wood in which they were living was taken out of the sea. Thus these animals would be able to live easily during the period during which most vessels would be in dry dock for scraping and painting, hence, as is well known but not always fully realized, it is highly important that wooden vessels should be constantly cleaned to prevent the attacks of this destructive mollusc.

THE RATE OF GROWTH OF *CREPIDULA FORNICATA*.

By means of a grant from the Royal Society a number of special experiments were carried out during the year of 1913 off the Essex coast with the object of determining the rate of growth in Crepidula. For this purpose a floating raft containing shells and tiles was moored at the mouth of the River Blackwater in the expectation of catching the spat. In putting out the raft and taking it in again in the autumn the Directors of the Tollesbury and West Mersea Oyster Company very kindly placed at my service the valuable help of their fishermen and their boats, and I wish here to express my thanks to them for the facilities they gave me in carrying out the experiment. The design of the experiment succeeded, and Crepidula spat was obtained on the raft and on the material placed in the raft, but unfortunately this success was marred by the fact that the raft had probably been touching the bottom of the river a few days when I went to examine it. It is therefore possible but not probable that some of the spat obtained on the raft may have crept on to it. Hence it is hoped to try the experiment again this year. From the position of some of the spat on the raft and on the tiles in it there was no doubt that they had been settled there some time, and therefore before the raft touched the bottom, and as the specimens obtained were all of sizes similar to the smallest sizes obtainable on the grounds in the

district, and, further, since the size of the spat is what might be expected from the following experiment and other observations, there can be little doubt that they had settled on the raft and had grown in position, and are therefore examples of the spat for that season. The spat obtained varied in length from 4·5 mms. to 14 mms., and altogether 15 specimens were obtained. Their average length was 8·1 mms. and their average breadth 6·4 mms. Since they had grown during the time the raft was in the sea, namely, from June 16th to October 2nd, their greatest possible age is 15 weeks.

At the same time as the experiment described above was begun another experiment suggested by Mr. J. Bean, of West Mersea, was started for the purpose of observing the rate of growth in the sea of young specimens which were considered almost certainly a year old. For this experiment Mr. Bean very kindly gave me the use of two of his oyster trays—which are shallow wooden trays with one side covered with perforated zinc and the other with small-meshed wire-netting—and also provided new wooden posts, which are driven into the mud to carry the trays. The trays were filled with shells and tiles secured to one side of the tray and a number of young Crepidula were put on to the shells. A few older specimens were marked and the shells on which they were sitting secured to the tray. The total number of young specimens put in the tray was 131, and their average length 10·7 mms. They varied in size from 5 to 15 mms., but the commonest sizes were about 9 to 12 mms. These young ones were put in the trays on June 18th and examined again on the 3rd of the following October. When examined at the latter date a number of them were found dead in the bottom of the tray and only 28 could be found alive. These remaining specimens varied in length from 1·4 cms. to 2·65 cms., and their average length was 2·1 cms., but 17 of them were more than 2 cms. long. It is quite clear, however, that within the period of the experiment, namely, 15 summer weeks, Crepidulas about 1 cm. long grow to a length of two centimetres. Hence the spat obtained in the former experiment may be regarded as a fair sample of the spat for the season of 1913. Thus during the summer Crepidula spat grows to a size of about a centimetre and appears to grow little during the winter, as indeed was found by examining batches of the tiniest specimens procurable on the grounds in the autumn and in the following late winter. During the next summer the young slipper-limpets may grow to a length of about an inch. This experiment is being continued and it is hoped to follow the rate of growth further. Of the few larger marked Crepidula put in this tray only two specimens showed an increase in size. One

specimen grew from a length of 25 mms. and a width of 17 mms. to a length of 29 mms. and a width of 20·5 mms.; the other one grew from a length of 28 mms. and a width of 13 mms. to a length of 33·5 mms. and a width of 26 mms. It is thus seen that *C. fornicata* may grow to a length of at least 3 cms. within $2\frac{1}{2}$ years, but it is desirable that the rate of growth should be observed in a larger number of individuals than was possible under the conditions of these experiments.

THE AGE OF SEX-CHANGE IN *CREPIDULA FORNICATA*.

In the tray experiment just described it was found that some of the small Crepidula had formed chains of two individuals, and in one case two specimens had put themselves in chain with one of the larger marked Crepidula to form a chain of three. When measuring these slipper-limpets their sex condition was also recorded and the singular fact established that while the individuals in chain were quite vigorous males, those which were leading a solitary life were changing from males into females. This phenomenon had indeed been suspected from the extensive examinations which have been made from time to time during the last few years on batches of Crepidula. The condition of these small Crepidulas may be gathered from the following records in which the abbreviations used in an earlier paper* are again adopted. The solitary specimens were recorded as follows: 8 specimens ♂ p.sm.; 3 ♂ p.tr.; one p.r.ut.r.; 2 ♀ ut.sm.p.tr.; 4 or 5 ♂. In the chains formed by the small specimens (one year old forms) the sexes were recorded as follows: (1) A ♀ p.r., B ♂; (2) A ♀ ut.r.? p.r., B ♂. The chains formed by the small specimens with the larger marked specimens, which in all cases are the A's in the chain, were recorded as follows: A I sex not recorded, B ♂, C ♂; A II ♀ p.tr., B ♂; A IV ♀ p.tr., B ♂. Thus in all cases where the young Crepidula had formed chains they retained their characters as males, whilst 14 out of 19 that remained solitary had begun to change their sex. Thus the absence of association with their fellows in chains undoubtedly results in a more rapid change from the male condition to the female condition than in the cases where the Crepidulas are able to form chains. Sex-change in Crepidula therefore may take place in the second year of the life of isolated individuals.

* J. H. Orton, "On the Occurrence of Protandric Hermaphroditism in *Crepidula fornicata*," *Proc. Roy. Soc. B.*, Vol. 81, 1909.

The meaning of the abbreviations used above is as follows:—

p.sm. = penis small; p.tr. = trace of penis; p.r. = penis rudimentary.

ut.sm. = uterus small; ut.r. = uterus rudimentary.

THE RATE OF GROWTH OF OYSTER SPAT IN THE FIRST SUMMER.

Besides the two experiments described above two other independent ones were carried out, but without success, for the purpose of catching Crepidula spat. These experiments, however, were successful in catching a large amount of oyster spat and other marine invertebrates, and in one case a few spat of the common cockle, *Cardium edule*, which are of much interest, were obtained. Measurements of the oyster spat have been made and a growth curve will be given to show the variation in size in spat of all ages up to 10 and 15 weeks. The limits of size of the 10-weeks' spat—as determined by the area of one valve—are from about 2 sq. mms. to 175 sq. mms., and the commonest size appears to be about 75 sq. mms. The largest specimens of 15-week spat have an area of about 250 sq. mms., i.e. about a square inch. Samples of these oysters are still being kept under observation with the object of observing their subsequent rate of growth and the age at which they begin to spawn.

The spat of the *C. edule* mentioned above varied in their greatest breadth between 2·4 mms. and 8·4 mms. and their greatest age is 15 weeks. Other observations on this mollusc, however, are being carried out with the object of following more fully the rate of growth, and particulars will be given later.

A large collection of various molluscs has also been made with a view to investigating their age from the periodicity of the main lines of growth. Some success has already been obtained with *Patella vulgata*, *C. fornicata*, *C. edule*, and the fresh-water mussel, *Anodonta cygnea*, in all of which the periodicity of growth is well marked. In all these cases, however, it is important to establish the rate of growth during the first season, and, as has already been noted above, valuable information in this respect has been obtained for Crepidula, Patella, Mytilus, Cardium, and Ostrea.

THE LIFE-HISTORY OF *GALVINA PICTA*.

Some remarkable facts relating to the life-history of the Nudibranch Molluscs have been obtained, and the following case may be taken as an example. The raft moored in Cawsand Bay—mentioned above—was visited six weeks after it was put out in the sea. It was found to be covered with a large scattered growth of the hydroid *Obelia geniculata*, on which the adult Nudibranchs, *Galvina picta*, *G. exigua*, *Tergipes despectus*, *G. farrani*, and young *Facelina drummondi* and *Doto coronata* were feeding.

G. picta was the dominant Nudibranch, and 53 specimens were brought in and measured. Their average length from tip of head to end of tail was 11 mms., and they varied in length from 7 to 17 mms. Masses of spawn of both *G. picta* and *exigua* were present on the hydroids, and from these masses free-swimming veligers were being given off. Thus these Nudibranchs had undoubtedly peopled the raft as veligers, rushed through their development at the expense of the hydroid, and were giving off veligers again to populate hydroids elsewhere within a period not longer than 6 weeks and 2 days. Such a rapid growth is very probably a necessity for hydroid-feeding organisms, since the hydroids themselves attain maturity very quickly. In this respect it is also of great importance to the race that some Nudibranchs are protandric hermaphrodites,* for by this means a few individuals are able to multiply rapidly where food is abundant, and thus the race by means of its free-swimming larvæ is frequently able to utilize an abundant food-supply wherever such is available.

THE LIFE-HISTORY OF CIONA, CLAVELLINA, AND ASCIDIELLA.

In the group of Tunicata the rate of growth in many species has been thoroughly worked out. *Ciona intestinalis*, *Ascidiella aspersa*, *Molgula ampulloides ?* have all been found to be ripe and yield embryos on being artificially fertilized at an age of not more than $3\frac{1}{2}$ months, and in some cases have themselves extruded fertilized eggs. Better fertilizations of these forms are, however, obtained from specimens about $4\frac{1}{4}$ months old. At an age of less than 15 weeks *Ascidia conchilega* from the Essex coast also gave 100 per cent of tadpoles on being artificially fertilized. Large numbers of successful artificial fertilizations were made in this group in running down the minimum age at which tadpoles can be obtained, and it was generally noticed that cross-fertilizations gave better results than self-fertilizations. All these species, however, grow at a much greater rate in the summer and autumn than at any other time of the year, and in the months of August and September *Clavellina lepadiformis* and *Leptoclinum* (*Diplosoma*) *gelatinosum* grew from the tadpole to a tadpole-bearing adult within 8 weeks. In one remarkable case *L. gelatinosum* was found to have raced through the whole life-cycle from the tadpole to an adult form giving off tadpoles at an age not greater than 3 weeks and 5 days. And indeed about this time of the year, August, this compound Ascidian is to be found overgrowing almost everything, both about and below low-water mark.

* As has been found by the writer in researches in this group.

The life-history of *C. intestinalis* is very similar to that of the Sycons described above. It has been definitely established that the species dies down about October, at about which time very fine specimens upwards to a foot long can be obtained. This fact has, however, been known at this laboratory for several years. By the end of October it is difficult to find Ciona of even medium size, but very small specimens are not uncommon. Breeding commences again after the winter season about April, and from April to October specimens may attain to a length of 15 cms., while those which have wintered and are practically a year old at this time have been found to attain a length of 30 cms. It is thus evident that Ciona is an annual, but passes through at least two generations in a year, and in favourable seasons may yield three, rushing through two generations in the autumn, as in the case of the Sycons. Thus these observations support the statement made by Anton Dohrn that Ciona at Naples passes through three generations in a year. (See footnote, p. 326.) The life-history of *C. lepadiformis* has been found to be very similar to that of *C. intestinalis*. It appears in this district about the end of April—apparently growing from dormant stolons—and grows to huge colonies during the summer, and at the same time passes through at least two generations. At about October these colonies die down and nothing is to be seen of them during the winter until about the following April.

A. aspersa has a somewhat similar life-history, but does not die down as completely in the autumn as Ciona. Between April and September this species has been found to grow to a length of 9 cms., very nearly the maximum size. *M. ampulloides?* has also a very similar life-history to that of Ascidiella, and gives quite good fertilizations at an age of 3 months, and this sub-spherical Ascidian may attain at this age a diameter of 2·5 cms., a size not far from the maximum for this species.*

RATE OF GROWTH IN SOME OTHER TUNICATES.

Botryllus violaceus gives off larvæ at an age not greater than 3 months and grows to large colonies during the summer. Thus in the case of all these Ascidians there are at least two crops of larvæ produced in a year, and in some of them, as in Leptoclinum, Clavellina, and Botryllus, there may be three or more crops in favourable seasons.

* Development in this species is remarkably rapid; the fertilized egg developing into a metamorphosing larva in less than 24 hours.

It is interesting that the maximum rate of growth in this group occurs at about the same time of the year as that found in the Sycons, some Polyzoa, some Molluscs, and some Hydroids. This period of maximum rate of growth occurs about August and September, and it is hoped that when the whole of the material collected has been worked out that it will be possible to estimate more accurately the rate of growth for different times of the year in all the groups.

RATE OF GROWTH IN *SACCORHIZA BULBOSA*.

A few marine algæ have been collected in the course of the experiments, and so far the most interesting growth obtained is that of *Saccorhiza* (*Laminaria*) *bulbosa*, which between April and October, a period of 7 months, was found to grow a lamina 3 to 5 feet long and a subspherical base about 5 inches in diameter.

SUMMARY.

From the foregoing preliminary account it will have been seen that the rate of growth and the period of the life-cycle in marine invertebrates are in many cases much more rapid than has hitherto been suspected. Many forms which have been generally considered annuals with one breeding period, such as the Sycons and other Porifera, some Polyzoa, some Ascidians, some Molluscs and some Annelids, have been shown to pass through two generations, and in many cases there are strong probabilities that they may pass through more than two generations in a year. Even among the Hydroids the rate of growth is probably greater than has generally been suspected.

The results obtained will be discussed in relation to those obtained elsewhere, when the whole of the scattered literature on this subject has been gathered together. So far, however, very few reliable observations have been found on the rate of growth in marine invertebrates, as indeed Weismann* has already noticed, and I should be very glad to receive any references to work of this kind that readers may have come across.

* A. Weismann, *Essays upon Heredity*, Vol. 1, p. 57. Edited by E. B. Poulton, S. Schönland, and A. E. Shipley. Oxford, 1891