recognition both of his carrying out of the present exploration, by which our knowledge of the Mammals of the Far East is being steadily revolutionized, and of the fact that his own personal acquaintance with the *Cervidæ* and his wonderful collection of living Deer at Woburn have been the basis of much of the considerable ncrease in our knowledge of the group which has taken place of recent years.

"A common deer about the edges of the forest at Chao-Cheng-Shan. They were to be seen at all times of the day in groups of two to five. Rarely were they solitary. During one long tramp I saw fourteen in the day."—*M. P. A.*

2. On a Case of Imperfect Development in *Echinus esculentus*. By James Ritchie, M.A., B.Sc., The Royal Scottish Museum, and D. C. McIntosh, M.A., B.Sc., F.R.S.E.*

[Received May 7, 1908.]

(Plate XXXIII.† and Text-figures 138–142.)

The description of abnormalities is of special value when these are of unusual character and occur in a species little liable to deviation from the type. Moreover, there has not hitherto been recorded any case of the special degree of abnormality illustrated by our specimen. Therefore it is that we venture to set down these observations, in spite of the fact that it seems impossible to account with certainty for the origin, or even to determine precisely the status, of the abnormality (whether it should be regarded as an example of congenital variation, or simply as a case of arrested development due to functional disturbance of the organism by some external factor).

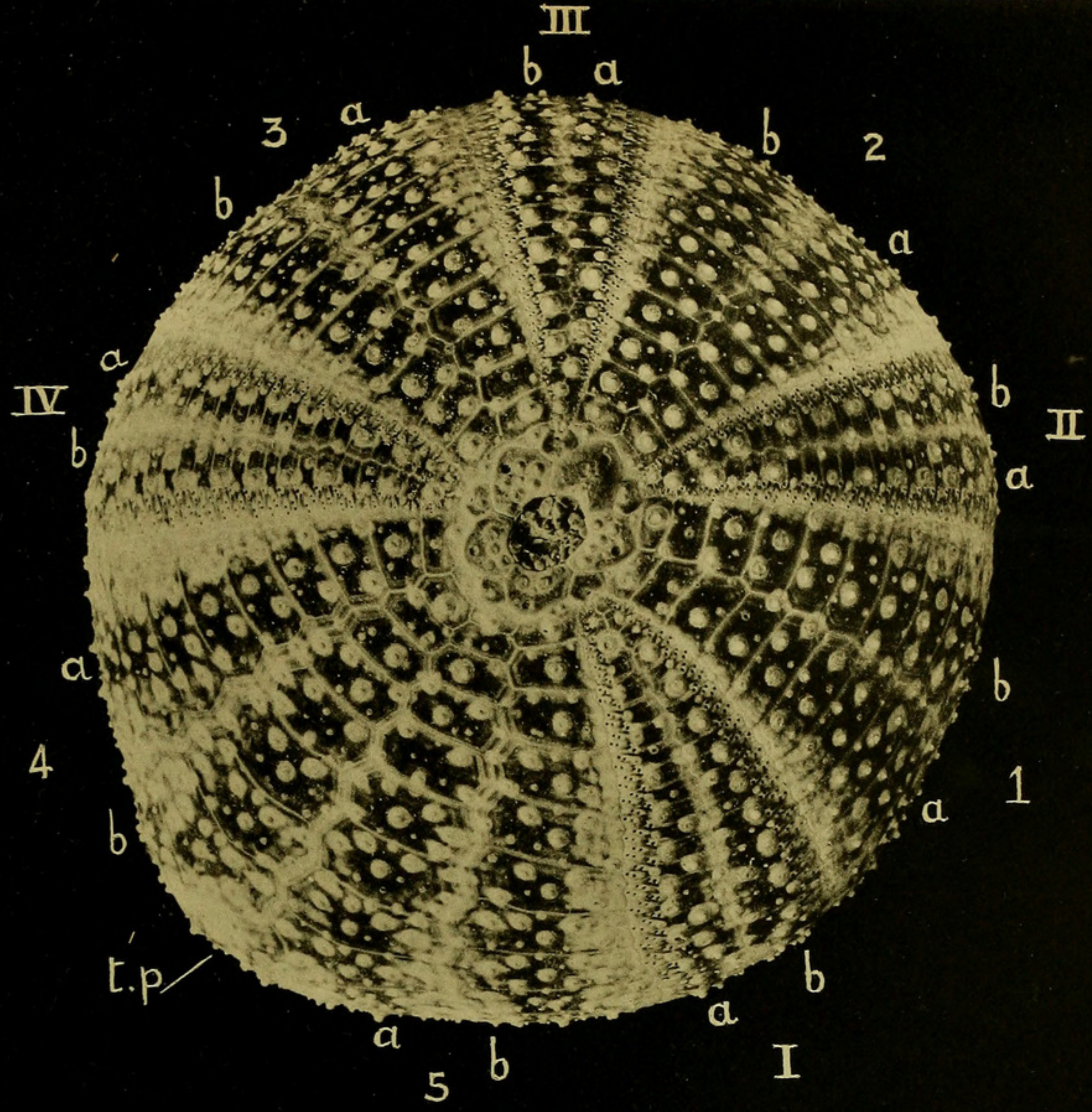
The specimen, an example of the most common British Sea-Urchin (*Echinus esculentus* Linn.), for which we are indebted to Dr. A. Bowman, of the scientific staff of the Scottish North Sea Fishery Investigations, was obtained by him, in July 1907, in Basta Voe, Shetland, where it was trawled from a depth of twenty-four metres. In a note regarding it Dr. Bowman says:— "The malformed Urchin occurred amongst a number of typical ones. Unfortunately I took no notice at the time of any peculiarity in the living animal. . . . The sport was not noticed until the spines etc. were nearly all cleared off. I thought at first it was an unusually flat variety."

Description of Specimen.

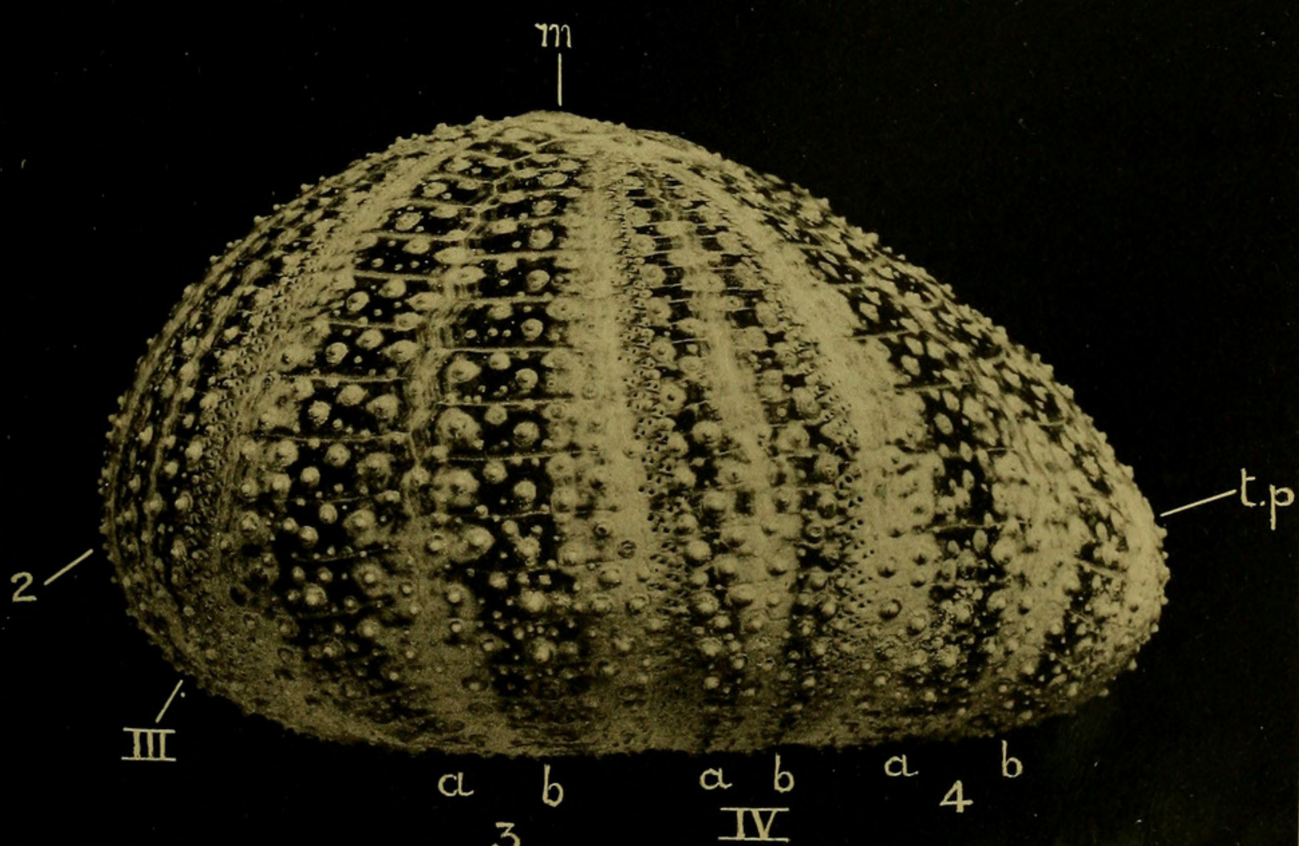
(a) *General Description—Shape, Symmetry, &c.*

At first sight the specimen appears to be, as Dr. Bowman had noted, merely a rather flat variety, with a large oral surface and

* Communicated by F. A. Bather, D.Sc., F.Z.S.
† For explanation of the Plate, see p. 661.


III
b a
3 a
b 2
b
a
IV a
b
b II
a
a
4
b
b
1
a
t.p
b
a
a
b
I
5

1


m
2
t.p
III
a b
a b
a b
3
IV
4

2

a depressed apical region. Closer investigation, however, shows that the general shape has departed considerably from the normal. Viewing the test in plan, one sees marked divergence from the apparent radial symmetry characteristic of regular Sea-Urchins. This is due to a distinct bulging on the side remote from the madreporite, which has caused the ambitus to assume a bilaterally symmetrical, almost oval shape (Pl. XXXIII. fig. 1). The same portion, moreover, viewed in elevation, is seen to be considerably depressed as compared with the globular form which characterises the other regions (Pl. XXXIII. fig. 2). Further, it is to be noted that the apical disc has departed from its normal horizontal position, the madreporite standing at a distinctly higher level than the plates on the opposite side of the periproct, for these appear to have been dragged downwards towards the bulging portion of the test. On the oral surface the peristomal opening is excentric, it too apparently having been dragged towards the bulging portion, for in that region the margin of the opening is only 29 mm. distant from the ambitus, whereas on the opposite side the distance is 34 mm.

All those deviations from radial symmetry are due to, or at least are connected with, the fact that a portion of one of the ambulacra is absent. Orienting the specimen in the recognised manner, by placing the aboral surface upwards, with the madreporite in the right anterior position, and adopting Lovén's notation, we find that the incomplete area is number V, the left posterior ambulacrum, the tube-foot area of the left division of the bivium. On the aboral surface this radial area is absent, but commencing a little above the ambitus, at the bulging portion of the test, it runs thence to the peristome, being fully represented on the oral surface.

The most noticeable result of this partial cutting out of the ambulacrum, apart from the general distortion of the whole skeleton already described, is that the two sets of interambulacral plates (areas 4 and 5) come together, four rows of interambulacral plates thus occurring in close proximity. The two sets are separated by a zigzag suture, whereas the edges of interambulacral plates abutting against an ambulacral area (that is, the edges corresponding to those bounding the above zigzag suture) are normally straight. Less noticeable are such minor distortions as the divergence of the line of bilateral symmetry, which passes through the middle of areas III and 5, from its normal straightness, owing to a bending of the interambulacral suture in the latter area towards the locality of disturbance. Quite distinct as this deviation is on the aboral surface, on the oral surface it does not exist, the line through areas III and 5 being there perfectly straight. Again, abnormal distortion occurs in the interambulacral sutures of areas 4 and 5, and in the junction between areas 5 and I., all of these lines bending with gentle curves inwards towards the point where the ambulacrum has disappeared. These curvatures are obviously due to an increase in the size of the plates in the direction of their long axes, but, marked as the curves are, the increase in the size of the plates is measurably of small moment. The following comparative table indicates the differences in length (*i. e.*, in the direction of the long axis) and in depth (*i. e.*, at right angles to the long axis) of certain interambulacral plates forming a band, interrupted by the ambulacra, round the skeleton. The

TABLE I.

Area…	1		2		3		4		5	
Series.	*a*	*b*	*a*	*b*	*a*	*b*	*a*	*b*	*a*	*b*
Plate. 14……	18·5×6	19·5×6	19×5	20·5×4·8	19×5·2	19×5	21×6·8	18×8	18×7·8	18×6
13……	20×6	20×6	20×5	20·5×4·8	20×5	20×5	22×6·5	20·8×8·5	20×7	20×6
12……	20×6	20×5	19·2×4·5	19·2×4·5	21×5	20×5	20×5·3	17×7	18×6	20·8×6

TABLE showing size-relation between normal interambulacral plates and those most affected by the cutting out of the ambulacral area. The heavy line indicates the relative position of the area of disturbance. The measurements are in millimetres.

missing ambulacrum is truncated opposite the thirteenth inter-ambulacral plate, the plates being numbered from the peristome. The thirteenth plate of each interambulacral area has, on this account, been measured and along with it, for the sake of comparison, the plate which bounds it on the proximal and on the distal side;

so that in the short series of three there are included the plate formed immediately prior to the truncation (12), that formed concurrently with the truncation (13), and that immediately succeeding the truncation (14). The letters *a* and *b* refer to the plate-rows in an area taken in counter-clockwise rotation.

The above measurements indicate that, in those areas (4 and 5) which bound the centre of disturbance, the plates formed concurrently with the disturbance are on the whole slightly longer than the corresponding plates in the other areas, while the plates immediately preceding and immediately succeeding the disturbance are on the whole shorter. But the depth of the plates in the affected areas is in every case greater than the average depth of the corresponding plates in the normal areas. The details here recorded are of value as showing to what measurable extent definite portions of the test have been affected in the effort of the organism to adapt itself to highly abnormal conditions. This phase of regulation will be referred to later.

The following measurements give some idea of the proportions of the test in various directions :—Height = 55 mm. ; long axis = 95 mm. ; short axis = 89 mm. ; circumference at ambitus = 293 mm.

(b) *Detailed Description—Abnormalities in Plates.*

Examination of the elements which make up the test reveals additional features of interest. The numbers of the plates in the various interambulacral series are :—

Table II.

Area	1		2		3		4		5	
Series	*a*	*b*	*a*	*b*	*a*	*b*	*a*	*b*	*a*	*b*
No of plates..	23	24	25	26	24	24	22	22	22	22

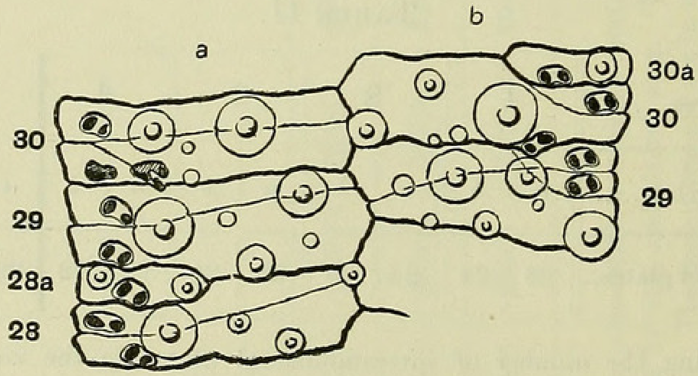
Table showing the number of interambulacral plates in the respective series. The heavy line indicates the relative position of the area of disturbance.

In those areas which bound the incompletely developed ambulacrum, all the series have suffered reduction of plates. Roughly, they contain two plates short of the number normal for the remainder of the test. Amongst the interambulacral plates there is little abnormality other than the increase in length and breadth in areas 4 and 5 already recorded, except in the two plates which between them include the termination of the truncated ambulacral area. These, instead of being rudely rectangular, are pentagonal, the extra face abutting against the terminal plate of the ambulacrum ; and not only is the aboral half of each longer than the adoral, but the portion facing the ambulacrum is considerably deeper than that remote from it (text-fig. 142).

In the plates of the ambulacral areas there are more frequent departures from the usual form. Fully-developed ambulacral plates are formed by the union of small pore-plates, each bearing a single pore-pair. In *Echinus esculentus* three of these primitive plates formed near the apical area, under the shelter of the oculars, are compressed, by the formation of new plates, to form a compound triad, the ordinary plate of the ambulacral area. Even in the fused plate the original pore-plates can be distinguished by shallow boundary grooves; and we are following the usual terminology in designating the two outer plates, which are bounded on one side by the interambulacral area and on the other by the zigzag intra-ambulacral suture, the adoral and aboral primaries; while the median plate touching the interambulacral area but failing to reach the zigzag suture in its own area, is known as a demi-plate. The three pore-pairs in a compound plate are arranged, not in a single vertical series, but lie in three distinct longitudes. These details of plate structure have been recounted in order to facilitate reference to the abnormalities which occur, and which consist, for the greater part, of an imperfect complement, or an incomplete fusion of the primitive plates which ordinarily go to the formation of a compound ambulacral plate.

In the posterior series, *a*, of the right posterior ambulacral area I (text-fig. 138) the twenty-eighth plate, numbered from the

Text-fig. 138.



I.

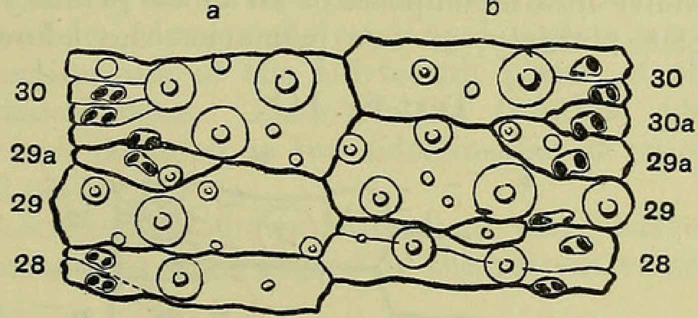
Abnormalities in Ambulacral Areas of *Echinus esculentus*.

Roman numerals beneath the figures indicate the ambulacral area in which the abnormalities occur. Arabic numerals alongside the figures indicate the numbers of the plates, reckoned from the peristome. *a* and *b*, series in ambulacral areas. In text-fig. 142 two interambulacral plates are included, and are numbered according to their area, series, and position in series.

peristome, consists of only two complete primaries, a demi-plate being lacking. It is succeeded by a solitary demi-plate, perhaps the remains of the aboral of twenty-eight, the place of which may have been taken by a fully developed median. Twenty-nine is also formed of two primaries; while thirty, complete as regards the number of plates and pore-pairs, possesses an arrangement altogether unusual. The apparent adoral plate is an included plate, for it touches the zigzag suture, but fails to reach the straight suture between ambulacrum and interambulacrum; the demi-plate is present, but instead of being median, it is external, touching plate twenty-nine and lying in the same latitude as the adoral plate; the aboral primary is normal. The pore-pairs of the adoral and demi-plates are surrounded by a deep hollow instead of by the usual faintly-marked peripodal groove. In series *b* of area I the adoral plate of twenty-nine has no pore-pair, but the median and aboral are normal. Plate thirty contains only two single plates, a very deep adoral and an aboral demi-plate. It is succeeded by a solitary demi-plate, the position of the pore-pair of which would indicate that it represents the missing aboral of the preceding plate.

In area II (text-fig. 139), series *a*, the twenty-eighth plate is formed of two simple individuals, probably an adoral demi-plate and an aboral primary, but the obscurity of the sutures renders certainty impossible. Plate twenty-nine is a single primary possessing no pore-pair. It is succeeded by a solitary demi-plate, this again being followed by a compound plate containing four elements, the aboral of which lacks a pore-pair. In series *b*, twenty consists of

Text-fig. 139.



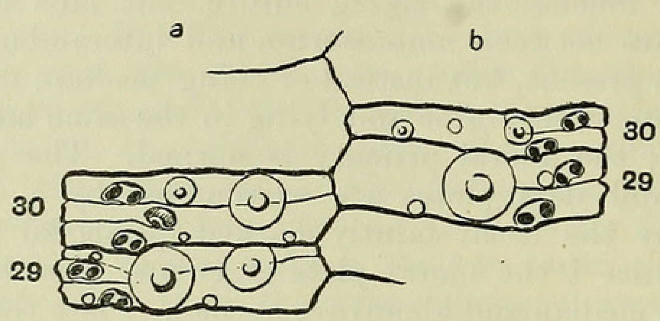
II.

ABNORMALITIES IN AMBULACRAL AREAS OF *Echinus esculentus*.
(For explanation of the lettering see text-fig. 138.)

a union of six primitive plates, no suture separating a first normal triad from a second, twenty-eight consists of two primaries, twenty-nine of only one, while between twenty-eight and twenty-nine is wedged in a small insulated poreless individual. Succeeding twenty-nine come two separate and distinct demi-plates, the distal about half the size of the proximal; and these are followed by thirty, possessing only an adoral primary and an aboral demi-plate.

In ambulacrum III (text-fig. 140) plate twenty-nine in series *a* contains the normal number of plates, but the aboral is faintly marked and is imperforate. The succeeding plate is also a normal triad, but the peripode of the median element contains only one pore, and must in its present condition have been functionless. It is moreover the nearest to the centre of the plate, whereas the median pore-pair should lie in the outermost row. Series *b* contains two abnormal plates, twenty-nine and

Text-fig. 140.



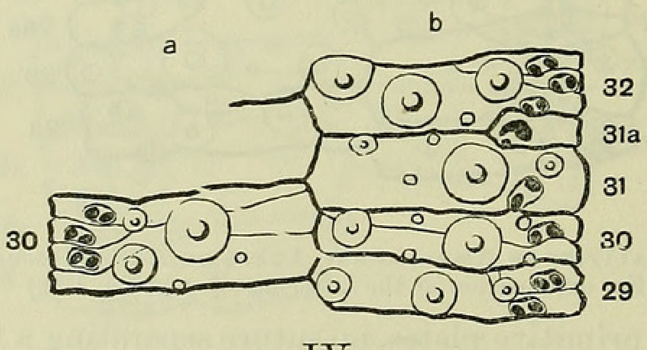
III.

Abnormalities in Ambulacral Areas of *Echinus esculentus*.
(For explanation of the lettering see text-fig. 138.)

thirty, each composed of two pore-plates. The absence of distinct sutures in the first renders identification of plates impossible, but the second is composed of an adoral primary and an aboral demi-plate. Thirty is an intercalated plate having no corresponding individual in the adjoining ambulacral series.

Series *a* of area IV (text-fig. 141) contains but one abnormal plate, thirty, which is composed of four primitive plates, three of which appear to be primaries, only that preceding the aboral being unmistakably a demi-plate. Of the four the adoral is imperforate. In series *b*, twenty-nine is composed of an adoral primary succeeded by a demi-plate; thirty, of two primaries, the adoral without

Text-fig. 141.



IV.

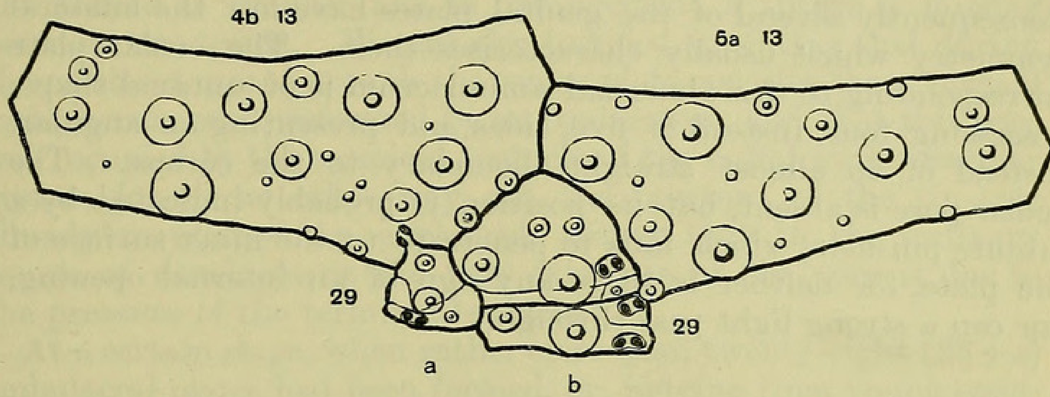
Abnormalities in Ambulacral Areas of *Echinus esculentus*.
(For explanation of the lettering see text-fig. 138.)

pores; thirty-one, of a single huge primary; thirty-one *a*, of a separate demi-plate, perhaps an isolated portion of thirty-one; and thirty-two, of three plates, the adoral a large primary, the other two, small demi-plates crushed into the upper corner of the compound plate. Thirty is an intercalated plate with no corresponding individual in the adjacent row. Thirty-eight is also unusual, being composed of five elements, the adoral and median of which are primaries, while the remainder are demi-plates.

The aboral, however, almost reaches the zigzag intra-ambulacral suture.

Ambulacrum V (text-fig. 142) is the area the development of which is incomplete, and here also abnormal plates occur. In series *a* the twenty-ninth, or last plate of the series, is much deformed, for, while it contains the usual triad, the median demi-plate is poreless; while the adoral and aboral primaries are much misshapen, the latter being roughly square and having its pore-pair lying in

Text-fig. 142.



V.

ABNORMALITIES IN AMBULACRAL AREAS OF *Echinus esculentus.*
(For explanation of the lettering see text-fig. 138.)

a peninsula-like corner almost without the boundary of the plate. In series *b* the penultimate plate, twenty-nine, contains but two elements, an adoral primary and an aboral demi-plate. It is followed by a large rudely-triangular plate whose apex falls at the junction-line of the thirteenth plates of the adjoining interambulacral areas. Each of the terminal plates of this aborted area is bounded on two sides instead of on one by interambulacral plates.

The following table shows at a glance the relative positions of these abnormalities with regard to the respective areas in which they occur:—

TABLE III.

Area............	I		II		III		IV		V	
Series	*a*	*b*	*a*	*b*	*a*	*b*	*a*	*b*	*a*	*b*
Total no. of plates.	49	50	54	54	58	58	53	53	29	30
No. of first plate in each abnormal group.	28	29	28	28	29	29	30	29	29	29

Summarising these observations regarding the ambulacral areas, we find that, of the ten rows of ambulacral plates grouped in the five ambulacral areas, not a single row is free from more or less marked abnormality. Further, all the abnormalities, with two exceptions, are grouped in a band, broken by the interambulacra, which passes round the test at a definite distance from the peristome. The exceptions are the twentieth plate in II *b* and the thirty-eighth in IV *b*.

With regard to the apical disc as a whole there is little worthy of note. The plates are normal in number and arrangement, but the whole disc has become slightly elongated as if the part towards the abnormal area had been dragged downwards by it. Consequently several of the genital plates have lost the bilateral symmetry which usually characterises them. The ocular plate corresponding to the abnormal ambulacrum is of unusual shape, possessing four, instead of five, sides and presenting an angular, instead of an almost straight, boundary to the corona. The ocular pore is absent, but its position is probably indicated by a minute pin-hole, which fails to penetrate to the inner surface of the plate, for neither is there any sign of an internal opening, nor can a strong light pass through.

Probable Development of the Specimen.

To bring those observations into relation to one another, the most satisfactory way is to trace the probable development of the shell. It is with the idea of attaining an approximation to chronological sequence that the plates have throughout been reckoned *from the peristome*, and not from the apical termination of the series to which they belong. This mode of reckoning has the disadvantage of increasing the difficulty of numerical determination owing to the excessive compression of plates which takes place as the peristomal region is approached, but it has the advantage of following the natural course of development. For it is evident that, since all the coronal plates are formed around the margin of the apical disc and are pushed thence down the sides of the test, the oldest plates will lie around the peristome. Thus, counting from the oldest plates recognisable towards those more recently formed, we get a measure of the age of the animal computed according to a standard, not of time but of development *. Thus, instead of saying that when a certain plate was formed, the test was three months old, a statement which our ignorance of the growth of the Echinoid imago renders impossible, we can say that at that time the test was, say, ten plates old, the actual age of course being indicated by the formula $10+x$, where x represents the number of the plates which have been pushed over the edge of the peristome in any one series. But since we

* Such a measure, it need scarcely be said, is not absolute but comparative, for the first plates, and we know not how many of their successors, have already been pushed over the edge of the peristome and are no longer reckonable. Assuming, however, that in each series the rate of pushing over is approximately the same, we arrive at a measure sufficiently accurate for all practical purposes.

can assume that x is approximately the same for the various ambulacral plate-rows *of the same specimen* at any latitude, it is virtually a constant for a particular latitude and therefore cannot affect our comparison.

In this Shetland specimen the development, up to a certain stage, appears to have been normal. Thus on the oral surface not only is the arrangement of the various rays regular, but the line of bilateral symmetry is straight; while in the minute structure of the plates no abnormalities occur, save the single insignificant deviation on area II *b*, where, although the plates are normal in number and in arrangement, a suture is missing between two triads. We are also justified in stating that during the earlier stages of growth the ocular plate opposite the abnormal ambulacrum was perforated by an ocular pore, and that this pore was occupied by the terminal tentacle of the radial water-vascular system, for in no other way can the presence of the pin-hole already mentioned be explained, seeing that in the ordinary course of development the very existence of the pore is due to the presence of the terminal tentacle *.

At a certain stage, when rather more than twenty-eight ($28+x$) ambulacral plates had been formed, or, judging from young specimens with a similar number of plates, when the test was between 20 and 25 mm. in diameter, some functional derangement took place. As an immediate consequence ambulacrum V ceased to grow, no more plates being added to that area after the thirtieth. But a more general disturbance also occurred, for in each of the rows of the five ambulacra abnormal plates were formed; and in these groups of aberrations, containing sometimes a sequence of as many as five peculiar plates, the first abnormal plate, as a glance at Table III. will show, is the twenty-eighth or the twenty-ninth or, in a solitary case, the thirtieth. This approximation of numbers indicates, as we have already shown, that the plates were formed approximately at the same stage of development; and the significance of the close numerical correspondence between the commencing points of the abnormal series is not lessened when we consider the difficulty of counting the number of plates at the edge of the peristome, and the uncertainty as to the relative numbers that have been pushed off during development. In themselves, considered separately, the abnormalities described are perhaps of little significance, although we have been unable to find, from examination of other tests, that such abnormalities are of frequent occurrence. But that abnormalities so distinct should manifest themselves at all points of the test at practically the same period is indeed remarkable. There can be but one explanation, namely, that a *general* derangement affecting all

* "[Die Primordialtentakel] werden endlich von den sich bildenden Radial-(Ocellar-)Platten deren Rand sie berühren, umwachsen und sind so zu den Terminal- oder Endfühlern geworden. . . . Sie treten dann durch einen Porus der Platte hindurch." Hamann, Otto, "Die Echinodermen"; Bronn's Klassen und Ordnungen des Thier-Reichs, ii. Bd., 3 Abth, p. 1167.

the ambulacral areas took place about the time that ambulacrum V ceased to grow. The derangement was in most cases, however, only a temporary one, for in all the areas, save No. V, the elasticity of the organism appears to have overcome the functional disorder, and after the formation of a few unusual plates, the normal growth was resumed. Nevertheless, a slight indication of after-effect is afforded by differences in the size of the tubercles, for a cursory glance shows that they are smaller above the affected zone than below it. This variation, however, is somewhat discounted by the fact that even in normal specimens a similar, though less marked, difference in size exists between the tubercles above and below the ambitus *.

The disappearance of the two rows of ambulacral plates from area V rendered necessary considerable modifications in the test, and this regulation was carried out mainly in two ways. The plates of the adjoining interambulacral areas increased a little in length and considerably in depth, and closing in around the truncated area came together in the mid-line, where they were united by a zigzag suture. As a direct result of the increase of the plates, the sutures in the neighbourhood became distorted. The increase in the size of the interambulacral plates, however, was not sufficient to make up for the loss of a double row of ambulacral plates measuring over 15 mm. across, hence another modification became necessary in order that the space between the adjoining areas on each side might be spanned. This was brought about by the plates passing directly across the space instead of building a material-wasting globular dome, the result being evident in the flattened portion of the test which lies between the truncated ambulacrum and the apical disc.

The increase in the depth (that is, direction of short axis) of the plates, and the flattening of the surface of the shell have together had the effect of pushing the incomplete ambulacrum further from the apical area, so that it has come to form the centre of a distinct bulge in the outline of the test, while it has also given rise to an abnormally flattened area on the oral surface.

It was perhaps at this period of disturbance that the terminal tentacle disappeared and that fresh deposits of calcareous matter began to close up the unoccupied ocular pore.

Relation to Previously Described Cases of a Similar Character.

Mr. W. Bateson has brought together the cases of abnormality in the major symmetries of Echinoids recorded prior to 1894 †. The remaining records up to 1902 are mentioned by Hamann ‡.

* F. Jeffrey Bell: 'Catalogue of British Echinoderms in the Brit. Mus. (Nat. Hist.),' p. 152. London, 1892.

† Bateson, W., 'Materials for the Study of Variation,' pp. 441 *et seq.*, London, 1894.

‡ Hamann, Otto, *l. c.* p. 1293.

We can find no later reference to new descriptions of abnormalities of a similar nature in major symmetries, although two early cases are mentioned by Gauthier * which Bateson appears to have omitted. The first, a specimen of *Echinobrissus orbicularis*, is described by Cotteau † as having the anterior ambulacrum completely atrophied; the second, a *Pyrina ovulum*, in which the right posterior ambulacrum was wanting, has also been described by Cotteau ‡.

The majority of the cases cited belong to fossil forms, this being no doubt due to the greater readiness with which an abnormality may be detected in a clean fossil test than in a recent well-preserved specimen, where plate-groupings are obscured by epiderm and spines. The cases to which the present example bears closest resemblance are those grouped by Bateson in his class (2), wherein the specimens are distinguished by the "partial or total disappearance of a definite ambulacrum or interambulacrum." At first glance the parallel between the Shetland specimen and the *Echinus melo* described by Philippi § appears to be almost complete, but in that case, as in the specimens described by Bell ||, Chadwick ¶, and Osborne **, the defaulting member constitutes a complete morphological system, the homologue of an Asteroid ray, whereas in the present specimen only the ambulacral portion of a ray has suffered reduction. There is a much closer resemblance to specimens of *Hemiaster*, described by Gauthier ††, in which only the ambulacral portion of a ray has disappeared. Of those specimens the case of *Hemiaster batnensis*, No. I, appears to show the closest analogy. There the corresponding ambulacrum, the left posterior, has partly ‡‡ disappeared, having at a certain stage received a check in development, the stage being indicated by the dying out of the ambulacral pores and by a slight depression in the test. As a consequence four sets of interambulacral plates follow one another without interruption, and the posterior interambulacral suture

* Gauthier, M. V., "Sur quelques Échinides monstrueux appartenant au genre *Hemiaster*." C. R. Assoc. Franc. pour l'avanc. des Sciences, 13th Sess., 1884 (Paris, 1885), p. 259.

† Cotteau, G., Echinides nouveaux ou peu connus, 1862, p. 66, pl. ix.

‡ Cotteau, G., *l. c.*, 1867, p. 133, pl. xviii.

§ Philippi, F. W., Arch. für Naturg. iii, 1837, p. 241, and plate.

|| Bell, F. Jeffrey, Journ. Linn. Soc. (Zool.), xv. 1881, p. 126, and plate.

¶ Chadwick, H. C., "Note on a Tetramerous specimen of *Echinus esculentus*". Trans. Liverpool Biol. Soc., 1898, p. 288, and plate.

** Osborne, H. L., "A case of variation in the number of ambulacral systems of *Arbacia punctulata*": American Naturalist, vol. xxxii. 1898, p. 259, and figs. (The reference to Lang's 'Comparative Anatomy,' vol. ii, p. 321, is evidently a slip for p. 341.)

†† Gauthier, M. V., 1885, *l. c.*, p. 258, and plate.

‡‡ Bateson seems to err in placing this example among those in which "one ambulacrum is *wholly* wanting in the affected radius" (*l. c.* p. 443); for while the functional part of the ambulacrum is not represented on the test as found, yet in the earlier stages of development the ambulacrum apparently did exist, for beyond the point where the ambulacral groove ought to run "apparaissent quelques paires de pores arrondis, qui continuent l'aire ambulacraire de l'autre côté [that is, the oral side] du fasciole." Gauthier, *l. c.*, p. 259.

has become somewhat distorted. As in our case also, the complement of apical plates is perfect, while the ocular pore (Bateson says merely "ocular") corresponding to the imperfect area is absent. There is therefore a remarkable correspondence between the two examples.

Possible Origins of the Abnormalities.

In the majority of such cases as have been described, authors have made no reference to the probable origin of the abnormality. Gauthier dismisses the case of *Hemiaster batnensis*, above mentioned, with the rather depreciatory remark, "il ne présente qu'une simple atrophie." Bateson in his remarks prefacing the summary of the Echinoderm variations, says that "it cannot be doubted that the variation[s] seen in Echini . . . are truly congenital. Similarly, though in *Asterias*, &c., reduction in the number of arms might otherwise be thought to be due to mutilation, it cannot be so in Echini." * But while the majority of the abnormalities appear to be congenital, so sweeping a statement must be avoided, since it would preclude our even considering the possibility of reaction to immediate external influences. For, although in the meantime we cannot definitely point to any member of a major symmetry which has demonstrably suffered alteration through external factors, the occurrence of such alteration is not at all improbable, considering the extraordinary sensitiveness of Sea-Urchins to unusual conditions of environment †.

Hamann, realising the difficulty of confining attention to only one of several possible causes, says, in his résumé of the form-abnormalities in Echinoids, that, should the aberrancies not be due to discontinuous congenital variation, their origin might be set down to loss and subsequent regeneration or to fusion ‡. Renamed in accordance with this conception of the potential influence of external factors, Class (2) of Bateson becomes, according to Hamann, that of incomplete regeneration ("unvollständige Regeneration"). But even this conception confines the possibilities within far too narrow limits. "Loss" implies the previous existence of some part which disappears, and it

* Bateson, 1894, *l. c.* p. 433.

† Lo Bianco states that on the coast-line, where, previous to the 1906 eruptions of Vesuvius, thousands of Echini had been scattered on the rocks, not a single *live* specimen could be found subsequent to the ash showers. None of the other marine invertebrate groups mentioned by Lo Bianco suffered to the same extent as the Sea Urchins. Lo Bianco also demonstrates that in the case of the artificial introduction of ashy material into a vessel containing Echini, the Echini had already begun to putrefy on the morning of the third day after the experiment began, while two days later the organs were completely macerated and the spines had fallen off. The rapidity with which the Sea Urchins succumbed shows sensitiveness to derangement of function. Lo Bianco, Salvatore, "Azione della pioggia di cenere, caduta durante l'eruzione del Vesuvio dell' Aprile 1906, sugli animali marini": in Mittheil. Zool. Stat. Neapel, Bd. xviii. Heft i. 1906, pp. 91 *et seq.*

‡ "Wenn die Abnormitäten nicht sprungweise congenitale Varietäten sind so käme für ihren Ursprung Verlust und nachträgliche regenerative Processe . . . . oder Verschmeltzung in Betracht." Hamann, O., *l. c.*, p. 1294.

is almost impossible to conceive that, in a Sea-Urchin where the morphological systems are welded together into a united whole, a definite area could be lost in part, in the way that the arm of a Starfish could be lopped off. It is possible to conceive, however, that damage to the growing point of an area might check, temporarily or permanently, the growth of that area. Moreover, it is not necessary to suppose that the damage be followed by regeneration, although test-regulation must be an almost inevitable consequent. We assume that, since the whole question is one of major symmetries, the regeneration referred to by Hamann is regeneration in a major symmetry as a whole (*i. e.*, the equivalent of the regrowth of the arm of a Starfish) and not the insignificant substitution of new plates for broken ones, a form of regeneration the comparative triviality of which is better indicated by the term *replacement* (the *réparation* of Prouho).

On account of these difficulties the phrase " incomplete regeneration " cannot be taken to comprehend the connotation of Bateson's Class (2), for neither loss nor regeneration is an essential agent in producing such results as are included in that class. As a wider designation and one which seems to include most of the possibilities, we suggest *arrested development.*

Congenital variation—facile phrase—might well account for the original abnormalities, and test-adaption for the subsequent and consequent distortions. But as an alternative to congenital variation, reaction to immediate external influences appears to offer an explanation as probable and more simple. Although lack of experimentation renders conjecture somewhat hazardous, it is possible that some voracious enemy * or some wave-borne rock fragment might break not only the newly-formed and extremely delicate plates at the apical end of an ambulacral area, but along with them might damage, either indirectly, by destroying the controlling nerve, or directly, that portion of mesenchyme in which the ambulacral plates are built up. The check to further development received by the ambulacrum would give an opportunity to the interambulacral plates on each side to push outwards and usurp the position hitherto occupied by the ambulacrum; and even if new generative mesenchyme were thereafter to be regenerated in the old ambulacral position, it is conceivable that by an adaptation of function these new plate-forming cells might, instead of forming new and independent plates, reinforce the interambulacral-forming cells, by depositing their calcareous material along the edges of the interambulacral plates. Such reinforcing power would account for the greater depth which characterises the interambulacral plates between the abnormally truncated ambulacrum and the apical disc. That in such a case

* Prouho has observed young Mullets not only snatching off the spines but even raising the epiderm on the surface of *Dorocidaris papillata.* Such a wound is sufficient to cause the underlying plates to be thrown off and replaced. Prouho, H., "Recherches sur le *Dorocidaris papillata* et quelques autres Echinides de la Mediterranée" : in Arch. Zool. Expér. ser. ii, vol. 5, 1887, p. 250.