NOTES ON THE GROWTH OF MOLLUSCAN PEARLS AND SHELL AND ON *PHOLADIDEA PARVA* CAUSING BLISTERS IN *HALIOTIS*.

By T. H. Haynes.

(A Lecture delivered 14th March, 1924.)

PLATES I TO V.

Pearl Structure.

In some notes which I presented to the Society in 1921 [1] I dealt in a very imperfect manner with the vexed question of the origin of pearls. This evening I propose to exhibit a number of interesting sections, including a selection from a large number of microscopic slides which were exhibited in 1888 by the late Dr. G. Harley to the Royal Society. For precise scientific purposes the preparation of pearl sections is far more difficult than that of rock sections. It is absolutely necessary that pearl sections should be central, and the identity of the specimens clearly established.

I now reproduce (Pl. I, Fig. 1) the section shown previously to you [2] of an Australian pearl × 5 diam., which originally displayed within the translucent centre of the black nucleus a figure resembling a perfect worm. It will be recollected that this frail object broke up during the process of photomicrography, but the following slides show: (1) the full nucleus × 30; (2) the central portion of same × 64; (3) a still smaller portion × 122 (Pl. I, Fig. 2).

In this last figure appear clusters not unlike bunches of eggs, and as the focus is altered the prominent batch becomes dim, and other batches become prominent. I know of no other section of a nucleus of undoubted animal origin in any way approaching this section in interest.[3]

The next slide exhibited a section of a large Australian pearl, fully $\frac{1}{4}$ in. in diameter × 5, taken from a pearl of fine quality, shaped like a cottage loaf. This pearl was converted into two fine "boutons", and this central slice was preserved and given to Dr. W. T. Gordon, who reduced it to a section thin enough for translucence and for microscopic purposes. Whether that pearl originally had two nuclei or not is unknown. The nearest specimen I have is one of Dr. Harley's "Alasmodon" pearls,[4] cut downwards instead of crossways, and affording indication of two nuclei.

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[1] *Proc. Malac. Soc.*, vol. xiv, pp. 221–6.

[2] *Proc. Malac. Soc.*, xiv, pl. viii, fig. 8.

[3] Further examination of this nucleus has recently been made by Mr. J. G. Bradbury, the secretary of the Photomicrographic Society. He was unable to photograph the objects displayed as they are so delicate and colourless that the image is lost in development; but the segments have all the appearance to him of a section of a worm. Recourse will therefore be made to an artist for hand-drawings.

[4] The British freshwater pearl mussel, *Margaritifera margaritifera* (Linn.), was formerly referred by Fleming, Gray and others to Say's genus *Alasmodonta*, corrupted to *Alasmodon*, for which various spellings crept into use.

The late Dr. H. Lyster Jameson, in his paper before the Zoological Society of London in 1902, gave microphotographs of sections of *Mytilus* pearls, which he described one by one as of Vermian origin. They all had black nuclei of large dimensions, but the centres did not admit the passage of light and nothing was recognizable. In that paper Jameson claimed that the grain of sand theory was entirely exploded, and that he had identified the Trematode in seven or eight other molluscs, including *Pinctada maxima*. In the following year Sir William Herdman announced his discovery that Cestodes were the originating causes of the formation of pearls in Ceylon.

In 1912 in another paper before the Zoological Society, Jameson produced a figure (p. 277) of a decalcified *Mytilus* pearl section × 20, the nucleus of which shows no translucence; and another of the nucleus itself × 70. This was a hand-drawing only, and it depicted various distinct divisions, which he identified one by one with certain organs of the Trematode. Such a precise drawing of anatomical detail ought most certainly to have been supported by a photograph. In the same paper Jameson gave drawings of the contents of numerous pearls he had examined:—

(1) (On pl. xlii, fig. 40) Nucleus × 250, containing "calcospherites" (Pl. III, Fig. 6).

(2) (On pl. xlvi, fig. 56) A pearl with grain of sand within × 27. One of eleven out of a batch of twenty-one Ceylon pearls which contained grains of sand (Pl. III, Fig. 5).

(3) (On pl. xliii, fig. 45) A fragment of a radiolarian shell × 600 taken from another nucleus (Pl. III, Fig. 7).

(4) (On pl. xliii, fig. 44) Numerous minute objects × 500 from nuclei including diatoms and sponge spicules.

Jameson's rejection in 1902 of the grain of sand theory fell to the ground; and in a footnote he added that further study and research forced him to admit that he had been mistaken in his identifications of Trematodes in pearls of other molluscs.

I do not doubt that many pearls are of Vermian origin, whether they be Trematodes in Europe or Cestodes in Ceylon; and I believe that every pearl so formed has a comparatively large black centre surrounding the intruder before the first layer of white nacre is laid and conceals it from view; and in the dead centre, if the section is ground thin enough, there is vacancy sufficient to admit light. On the other hand, where the nucleus is of inorganic character from which no noxious emanations occur, there is no dark capsule or anything in the nature of a scab or agglutinized covering.

Jameson emphatically declared that all pearls are formed in an epithelial sac; and Professor Herdman went very far in the same direction; whereas Southwell, who has probably done more laboratory work on this subject than anyone else, declares that most pearls arise from depositions from the blood, *i.e.* they are analogous to calculi in mammals, and Southwell's estimate of the ratio of such pearls compared with those of sac formation was 13 to 1.

A series of sections illustrating structural arrangement now follow :

(1) Mr. J. G. Bradbury's "Alasmodon" pearl × 12 and × 46. (*See* text figure, *Proc. Malac. Soc.*, xiv, p. 223.)

(2) A very similar one (Dr. Harley's collection) ; a ground section decalcified × 14 and × 46 (Pl. II, Figs. 1 and 2).

(3) Sections of three pearls decalcified whole. Australian : Japanese culture, and Japanese natural.

This illustrates the superiority of ground sections over whole pearls for decalcification, the escape of bubbles of carbon-dioxide being easy in the former, whereas they distort and rupture the animal framework in the latter.

(4) "Oriental" pearl × 24. (Harley.)

(5) Australian baroque pearl × 8. (T. H. Haynes.)

(6) Pink Honduras pearl × 12. (Harley.)

(7) Five sections of "Alasmodon" pearls (Harley), two being of undoubted animal origin.

(8) Four sections (two very small × 550 and 350. Jameson), the second showing changes in structure up to true nacre and then reversion to "hypostracum".

(9) Alexander's pearl, taken from *Pinctada maxima.* Colour of a nightingale's egg ; large size, flattened sphere, nearly ½ in. in diameter. The darker triangle of basaltic-like character is probably the true centre face and the remainder is thickened by a film which would have been ground off, but the section cracked, and it was too risky to proceed further. Three figs. × 5 and × 42.

(10) "Horse mussel" (*Volsella modiolus*) pearl (Jameson), kindly given me by the Trustees of the British Museum. × 9 (Pl. V, Fig. 1) and × 42.

(11) Pearl from small variety of *Tridacna* × 22—one of a series of twenty given to the Museum by the writer forty years ago (Pl. V, Fig. 2).

(12) *Nautilus* pearl given to the writer by the Sultan of Sulu. × 5 and three enlargements × 32 (Pl. V, Fig. 3).

A *Pinna* pearl kindly supplied by the Museum authorities still awaits sectioning.

It is doubtful whether much can be gained by further sectioning as a means for disclosing the mechanical structure of pearls unless research by students of colloidal chemistry brings new light to bear on crystallization in the animal kingdom, and on its periodicity. The marked variations in the viscosity of oyster slime which may safely be taken to represent the "gel" and the changes which occur, from clearness to white cloudiness in that slime, are factors to be considered. The main supply of calcium in sea-water is in the form of sulphate ; and in its conversion to carbonate both in shell and pearl formation, the carbon-dioxide stored by the mollusc and apparently under control probably plays an important part.

There is one radical distinction in the structure of pearls. They all

display a series of circumferential lines of animal matter at regular or irregular distances from one another; but they do not all exhibit lines radiating from the centre outwards, and the presence of such lines seems to be associated with inferiority of sheen beauty and accordingly of value. Pearls showing these radiating lines are often spoken of as "prismatic", but in no section has the space between two such lines given any indication of the corresponding face of a prism to interfere with the passage of light. I regard these radiating lines not as sections, or side views, of a prism face, but as rods corresponding with the ribs which support an open umbrella. The circumferential lines may represent a continuous layer of opaque material through which no light will pass, as in Alexander's brown *Pinctada* specimen and in Jameson's brown specimen figured in his paper of 1912 (pl. xlvi, fig. 57) and his *Volsella* specimen from the Natural History Museum. They may, however, not consist of continuous straight lines, but a side view of a tracery of network of prismatic pattern such as depicted on page 79 of M. Louis Boutan's "Étude sur les Perles Fines", 1921. The drawing is entitled "Impression de l'épithélium du sac perlier", and it displays an interesting similarity to the well-known aspect of the horizontal section of a *Pinna* shell; and it is suggested that the radiating rods run to each angle of the face pattern.

Pearl Sac Formation.

In a recent letter to the *Times* dealing with the objects to which the Cancer Research Fund is to be applied, Dr. J. H. Orton com mented upon the importance of including animal pathology with the other branches of scientific research mentioned in the programme of the promoters; and he remarked that even from the lowly mollusc or the despised sea-worm lessons may be gained of the utmost value to science.

In my former notes I drew attention to certain experiments carried out at the Marine Biological Institute at Plymouth by the late Mr. G. H. Drew on the artificial production of cysts in Pecten. Mr. Drew was an Otto Beit Research Scholar, and almost a fully qualified medical man. Drew's microscope slides have been preserved, and Dr. Orton states that he was a most careful investigator and that his observations may be relied upon.

Drew performed 950 experiments on these unfortunate scallops. His method was to introduce by means of a suitable needle a fragment of ripe living ovarian tissue from one scallop into the adductor muscle of another scallop. The victim was treated antiseptically, and the almost invariable result was the formation of a cyst, with a ciliated epithelial wall-covering, as shown × 400 on Pl. IV, Fig. 8. Many counter experiments were made with ovarian tissue subjected to extreme heat and cold and to chemical treatment, and other materials were tried, such as cork, elder pith, etc., besides tissue

from a different variety. In no such case was an epithelial cyst produced, and in some cases death supervened in a few days from acute inflammation, or occasionally a fibrous cyst-wall was formed.

Drew's work failed to meet with the approval of pathologists in high quarters, and it only found publication in the *Journal of Experimental Zoology* in the United States. This *Journal* is seldom met with in this country, but, through the courtesy of the Librarian of the Zoological Society of London, I have been enabled to study the paper. I am no pathologist in any sense, but I know that in quarters of high repute and of more recent date it is considered Drew did not receive fair treatment.

The study of the growth of a cyst or tumour in the human body is practically an impossibility, but by subjecting a number of scallops to treatment such as that adopted by Drew, all on the same day, and selecting one at a time at various intervals of days for dissection and microscopic examination, Drew was able to trace the growth of the cyst wall and describe the changes which took place, stage by stage, which led up to the final columnar ciliated epithelium forming the inner lining of the cyst wall. Furthermore, he described the stages in the division of a normal fibroblast as shown (Pl. IV, Fig. 1), × 1,000. The second figure (Fig. 2) depicts a portion of the cyst wall after five days, showing fibroblasts in the process of division × 800. The third figure (Fig. 3) shows the cyst wall after twenty days, when the ovarian tissue has completely degenerated and the inner layer of fibroblasts which had developed nuclei had become connected by a continuous layer of cytoplasm. The next (Fig. 4) shows the cyst wall after twenty-three days; and another stage (Fig. 5) after twenty-six days; and a third (Fig. 6) after thirty-six days, showing development of irregular cilia; and the last section (Fig. 7) is after ninety-eight days, when the formation of ciliated epithelium is complete and dividing walls have appeared between the cells—the nuclei are now smaller and the cilia are shorter and more regular.

Thus Drew traced the transformation of fibroblasts which are mesoblast into epithelium, which is epiblast. This was a direct violation of the most rigid axiom of biological science, and Drew's work was therefore banned as heretical by the older school of pathologists. No criticism, however, can alter the fact that Drew produced these cysts over and over again, and he had some of the Pecten so treated under observation for as long as 120 days.

These experiments had no direct bearing on the formation of pearl cysts, but a very interesting comparison can be made between Drew's sections and a section by Jameson × 800 (Pl. IV, Fig. 9) purporting to show a portion of a " fibrous " cyst that surrounded a parasite. This form of cyst is very common in Ceylon pearl oysters, and it corresponds in character with Drew's cysts in their earliest stage and also with the outer fibrous lining in the later stages. A simple

fibrous sac is not pearl-productive, the true pearl-producing sac being one of columnar epithelium similar to that covering the outer surface of the mantle which secretes the nacreous layers of the shell.

The converse of Drew's conversion of fibroblasts into epithelial cells was Leo Loeb's statement in 1899 that he had observed epithelial cells migrate into underlying tissues and take on the appearance of fibroblasts; but Loeb's statement did not find credence in high quarters.

Drew's indispensable factor was that the ovarian tissue used for injection should not only be living but also ripe; that is to say, it must be taken from a scallop in a state of full sexual activity. It is quite likely that the recipient was more or less in the same condition, but it is impossible to avoid the thought that artificial stimulation was conveyed by the injected fragment to the general system of the recipient and played upon the fibroblasts, which were not only transformed into cellular epithelium, but produced ciliation long after the ciliated injected fragment had completely degenerated. In fact, Drew found that the larger the fragment employed the earlier the cilia would be produced.

Reverting to cyst-pearls, attention was drawn to some drawings by Jameson in his paper in the Proc. Zool. Soc., 1912, from "preparations" lent to him by Sir William Herdman.

(1) Epithelial cyst with section of pearl within (on pl. xli, f. 33), showing various types of structure before true nacre appeared. × 80.

(2) A similar instance (on pl. xxxv, f. 9) showing defective epithelium non-pearl productive at one point. × 70.

(3) (*a*) A similar defective cyst (on pl. xxxv, f. 8) × 100. (Pl. II, Fig. 3.)

(*b*) An incomplete cyst (on pl. xxxv, f. 8) × 100.

(4) Pearl without any cyst (on pl. xxxvi, f. 11) × 400.

To conclude the series of sections illustrating structural formation, four more specimens were shown—

Human calculus × 30.
Horse calculus × 10.
Coco-nut pearl × 5 and × 30.
Fossil pearl × 16.

These came from Dr. Harley's collection, but the coco-nut pearl, strange to say, is the identical specimen I sent home forty years ago, given to me by a native in Singapore. Dr. Harley expressed his strong doubt of its having come from a coco-nut because he found it was composed of carbonate of lime, which is not found in the milk or flesh of the coco-nut—a point discussed in 1860, when Dr. John Bacon at the Boston Natural History Society read a paper on this special subject. Some doubt may exist whether this section is truly central, but the central portion presents a formation very different to any other yet seen.

Three illustrations of pearls of peculiar interest, which must present puzzles to those supporting cyst-formation as indispensable, then followed :—

(1) The Southern Cross from N.W. Australia (Pl. III, Fig. 4).

(2) Pearl from Papua, as if turned in a lathe (Pl. III, Fig. 1).

(3) Large parti-coloured pearl, 336 grains, and two others, taken from Saville Kent's Report of 1889 to the Queensland Government (Pl. III, Figs. 2 and 3).

Three unique blisters from Papua were also shown, all not only on but largely monopolizing the site of the adductor muscle, a large portion of which must have been rendered quite useless.

(1) Group of pearl nodules, 2 inches in length, on the lower valve exhibiting but little trace of the usual dull wrinkled appearance of pearls or small blisters found in that position.

(2) An extraordinary hollow-chambered mass of fine lustre inside and out (Pl. I, Fig. 3). This was on the upper valve, 3 inches in length.

(3) A parti-coloured blister, 1¼ inches in length, also on the lower valve, with a surface of fine nacre.

These novelties are attractive, but the chief point of interest lies in the presence of the black patches on two of the pearls and the last blister. There is every appearance, and it may be reasonably accepted, that these dark patches are composed of the same material as the hinge which in turn is of the same nature as the byssal fibres.

Sir William Herdman has described how he watched a pearl oyster forming its byssus by the protrusion of the foot through the byssal cleft and its withdrawal after a short period, leaving a newly made fibre attached to the bottom—as many as fourteen strands being formed in one night. In an emergency I have known a young pearl oyster make two strands in five minutes.

Hinge Formation.

The *modus operandi* of the secretion of the hinge substance is unknown; so, also, is that of the absorption of a porcellanous mechanical hinge and its recreation on a larger scale as the mollusc grows in size. The proposition is a simple one. The capacity of a bivalve shell *diminishes* by internal thickening growth. The body of the mollusc *increases* in bulk with growth. Relief can only be obtained by expansion of the shell cavity; and this cannot be attained without severance of the hinge-joint. I am convinced that periodically the mollusc separates its two shells so as to lift the upper valve by the pressure of the growing adductor muscle in order to deposit additional material between the two divided hinge-bases and separate the two valves more and more to accommodate the growing dimensions of the animal within. In a well-preserved specimen, say, of a 10 lb. *Pinctada maxima*, the outline and scaly covering of the young shell

from which it developed may clearly be seen in the corner of the hinge-base, one valve on each side. Obviously these two young valves which were originally close together and are now $1\frac{1}{2}$ inches apart must have often been separated and joined again further apart.

It is very rarely noticed by a shell-opener that the two valves are not firmly bound together, but on more than one occasion I remember the knife passing easily between the two valves after the adductor muscle had been completely severed and the two valves falling apart. In most bivalves the upper and lower valves remain throughout life relatively in the same position, the hinge-base of the upper valve remaining immediately above that of the lower valve. There are, however, other examples, such as *Spondylus*, in which the upper valve moves forward and the hinge-joint is moved correspondingly with it, the hinge-base of the lower valve being thickened horizontally as well as vertically. The hinge-base in the upper valve is not thickened perceptibly.

During the period of division the adductor muscle alone would hold the two valves together, and as a rule in true position, but not invariably. One day I was opening shells on deck with a sick diver (French Louis, a Mauritius man) standing by watching me. Every now and then as I took a fresh shell he would say "That shell has something in it", and sure enough he was generally right—a blister or a pearl turning up within. At length I asked him his reason for his selections, and after some hesitation he enlightened me. Every shell he so selected had its valves slightly askew at the straight hinge-line. Obviously at some period of temporary separation the adductor muscle had failed to retain the two valves in the true position, and they had been rejoined on the skew.

The degree of absorption or dissolution at the division line of the working joint may be but slight, but it must take place along the whole length of the hinge at once, and the quantity of black material liquified at one time may be not inconsiderable. It is not necessarily converted into a thin colourless solution, but means of expelling it are probably extant. Black markings never occur on the shell surface, and it is very rare to find them on a pearl (Pl. III; Figs. 2 and 3), and still rarer on a blister, although some specimens show that it does occur; and the conclusion is fairly strong that in these cases the liquified hinge material escaped into the shell and came into contact with, and adhered to these two pearls and this blister now shown, while the mantle went on with the deposition of nacre and maintained the brightness of the surface.

The blister was within easy reach of contamination, but the pearls *must* have been loose, *outside* the tissues of the animal and free of any sac, to have received contact with the floating black liquid.

The few cases of such pearls that I have found have always been pearls of a more or less spherical shape which roll about in the shell

with the movements of the animal and prove very difficult to fasten to the shell. For this reason the most likely place to find a blistered spherical pearl is in the angle of the hinge where it would lodge securely. Two specimens (exhibited), from which fine round pearls were extracted, illustrate this, and a third specimen of a portion of a shell showing a deep hole from which a spherical pearl was taken. This last specimen gives clear indication of the oyster's difficulty in fixing this pearl; in fact, it looks as if it had frequently broken from a recent attachment and wobbled about until finally fixed. A pearl rolling about in a shell would continually receive fresh deposition of nacre over its whole surface, and thus maintain its sheen.

With regard to shells on the skew as pearl-producers, it is a coincidence to be noted that in the great American river-mussel fisheries "cripples", otherwise mutilated, abnormal shells, are esteemed as the most promising of all for a lucky find.

Blister Formation in *Haliotis*.

In conclusion, a slide was shown exhibiting a specimen supposed to be *Pholadidea parva* taken from the hollow of a blister in *Haliotis* (Pl. V, Fig. 4 *a* and *b*).[1] It is interesting to find the blistering instinct in a univalve as well as in bivalves, but in *Haliotis* the procedure is very different to that with which we are now so familiar in pearl oysters. The latter are nearly always attacked on the *lower* valve; in *Haliotis*, of course, the attack is from *above*. A specimen of this blister, untouched, will show that entry and a horizontal burrow, about $\frac{1}{2}$ in. long and $\frac{1}{16}$ in. in width, occur prior to point where a blister is formed. At this point the borer turns at right angles downwards towards the interior of the shell, the burrow enlarging gradually until it excavates the chamber within the blister, $\frac{1}{2}$ in. in length, and completely fills the same. It was evidently a race between the borer growing and enlarging the cavity and the *Haliotis*' power of shell secretion as a barrier to penetration. The borehole through which the supply of water is maintained is long and of very small dimensions; therefore it is probable that special means are employed, such as the emission of carbon-dioxide or forcible ejection of water, to keep the orifice clear of obstruction, owing to the constant fall of planktonic material which is so profuse in tropical waters.

EXPLANATION OF PLATES.

Plate I.

FIG.
1.—The Australian "Worm Pearl". × 5. (T. H. Haynes.)
2.—Centre of the nucleus of the same. × 122. (T. H. Haynes.)
3.—Blister on upper valves of Mother-of-Pearl Shell. Nat. size. (Spencer.)

[1] Figs. 4*c* and 4*d* relate to another smaller specimen, but unfortunately the photograph 4*d* does not show the light shining through the small entry to the burrow.

FIG.

PLATE II.

1.—"Alasmodon" (i.e. *Margaritifera margaritifera*) Pearl, ground section, decalcified. × 14. (Harley.)
2.—"Alasmodon" (i.e. *Margaritifera margaritifera*) Pearl, ground section, decalcified. × 46. (Harley.)
3.—Decalcified Pearl in Cyst. Defective secretion at one point. × 100. (Jameson.)

PLATE III.

1.—Pearl from *Pinctada maxima*. × 5. (Spencer.)
2.— ,, ,, With black marks. Nat. size. (Saville Kent.)
3.— ,, ,, With caps. Nat. size. (Saville Kent.)
4.—"Southern Cross Pearl" from *Pinctada maxima*. Slightly reduced.
5.—Nucleus containing a grain of sand. × 27. (Jameson.)
6.— ,, ,, calcospherites. × 250. (Jameson.)
7.—Radiolarian Fragment from a nucleus. × 600. (Jameson.)

PLATE IV.

(Growth of Cysts in Pecten. Reduced to half-size.)

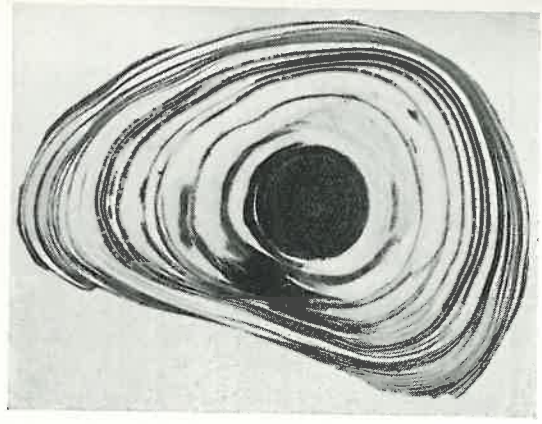
1.—Stages in division of a normal fibroblast. × 1,000. (Drew.)
2.—Cyst wall after 5 days: composed of layers of fibroblasts mostly in an active state of transmutation. × 800. (Drew.)
3.—Cyst wall after 20 days: inner layer of fibroblasts with changed character of nuclei and connected below by a continuous layer of cytoplasm. × 800. (Drew.)
4.—Cyst wall after 23 days: nuclei have developed nucleoli; cytoplasm more definite and the cells suggestive of an embryonic type. × 800. (Drew.)
5.—Cyst wall after 26 days: layer of cells bounding the degenerated injected ovarian tissue nucleus now well defined, with distinct basement membrane; nuclei again altered, and nucleoli disappeared. × 800. (Drew.)
6.—Cyst wall after 36 days: development of long irregular cilia; fibroblasts in outer layer quiescent. × 800. (Drew.)
7.—Cyst wall after 98 days: formation of ciliated epithelium complete with dividing walls between the cells: nuclei smaller and cilia shorter and more regular. × 800. (Drew.)
8.—Complete cyst lined with typical columnar ciliated epithelium. Bands of fibrous tissue on each side formed in the track of the needle. × 400. (Drew.)

msl. fbr. = muscle fibre.
div. fbl. = dividing fibroblasts (i.e. in course of subdivision).
b. sin. = blood sinus.
msl. nuc. = muscle nuclei.
b.c. = blood corpuscle.
mig. fibl. = migrating fibroblast.
fbl. = fibroblast.
fbl. lyr. = layer of fibroblasts.
deg. ov. = degenerating ovarian tissue (injected).
cil. ep. = ciliated epithelium.

9.—Part of a fibrous cyst, surrounding a small parasite, in Ceylon Pearl Oyster. × 800. (Jameson, Proc. Zool. Soc., 1912, pl. xxxiii, f. 3.)
il. = inner, highly nucleated layer of cyst.

PLATE V.

1.—Section of Pearl from "Horse Mussel" (*Volsella modiolus*). ×9. (Jameson.)
2.— ,, ,, *Tridacna*. × 22. (T. H. Haynes.)
3.— ,, ,, *Nautilus pompilius*. × 5. (T. H. Haynes.)
4*a*.—*Pholadidea parva*.
4*b*.—Blister chamber in *Haliotis* containing the same. Nat. size. (T. H. Haynes.)
4*c*., 4*d*.} Similar views of another example. Nat. size. (T. H. Haynes.)



1

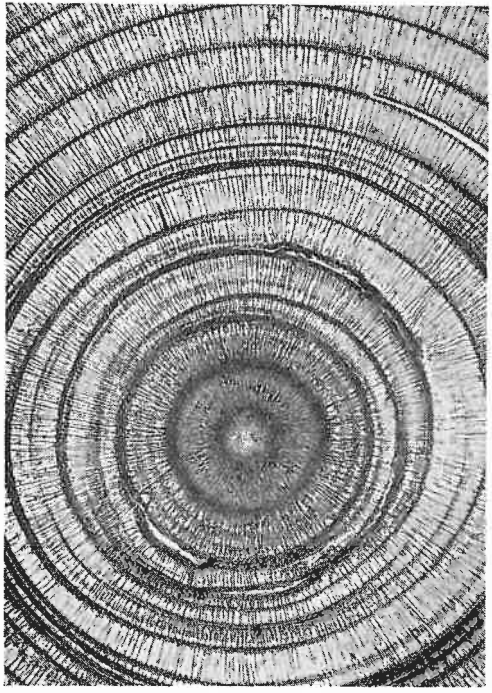
2

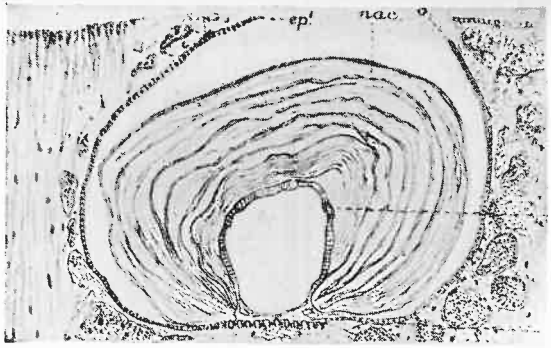
3

SECTIONS OF AUSTRALIAN PEARL AND BLISTER ON MOTHER-OF-PEARL SHELL.

Vol. XVI, Pl. I.

2





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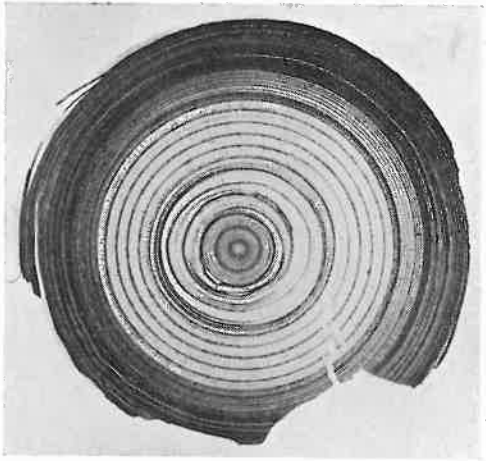


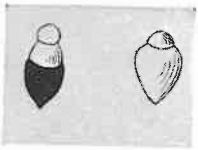
1

SECTIONS OF PEARL OF FRESHWATER MUSSEL AND DECALCIFIED SECTION OF PEARL IN CYST.

Vol. XVI, Pl. II.

1

2



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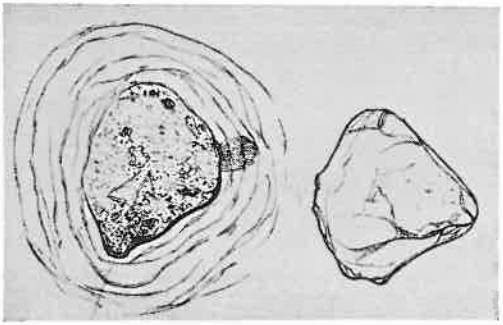

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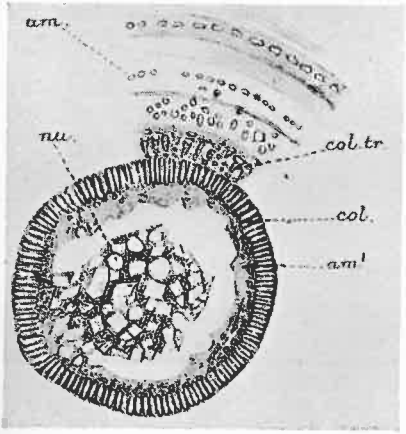
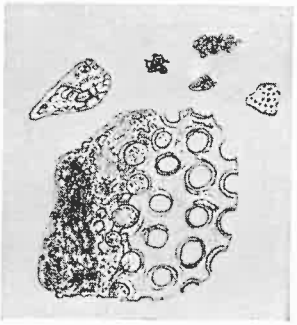
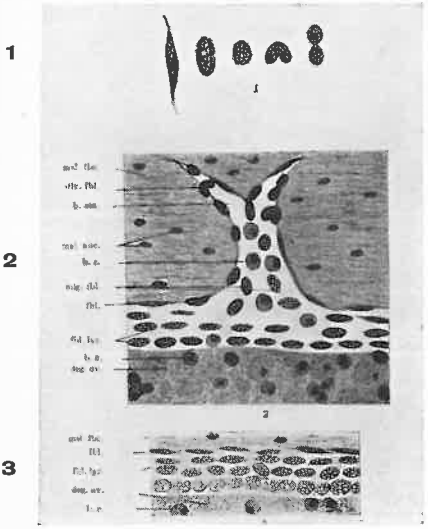


6



7

REMARKABLE PEARLS AND EXAMPLES OF NON-PARASITIC NUCLEI.



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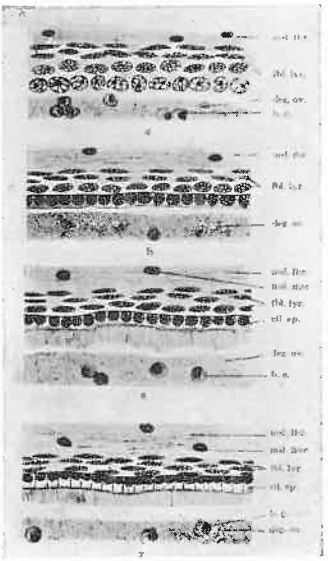

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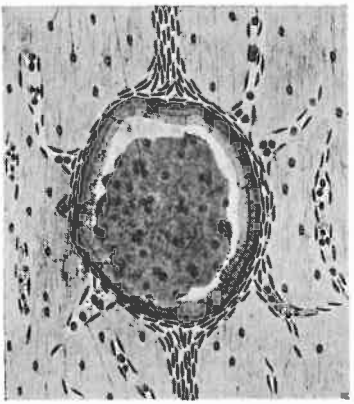

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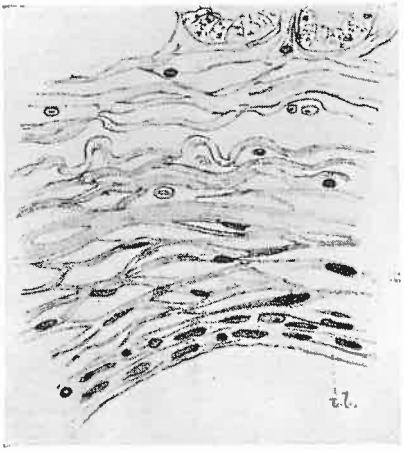
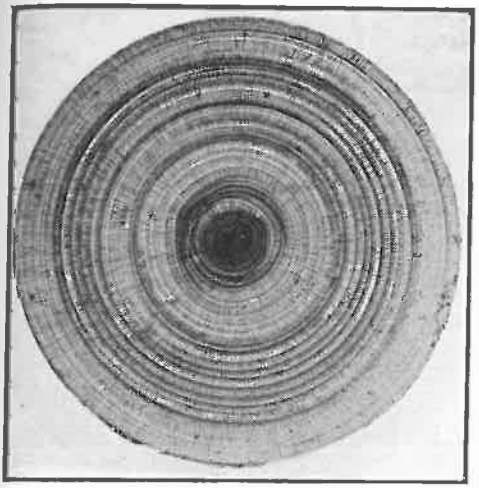


9

CYST FORMATION IN PECTEN AND CEYLON PEARL OYSTER.



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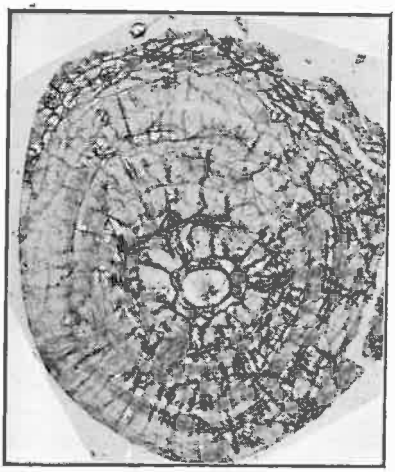

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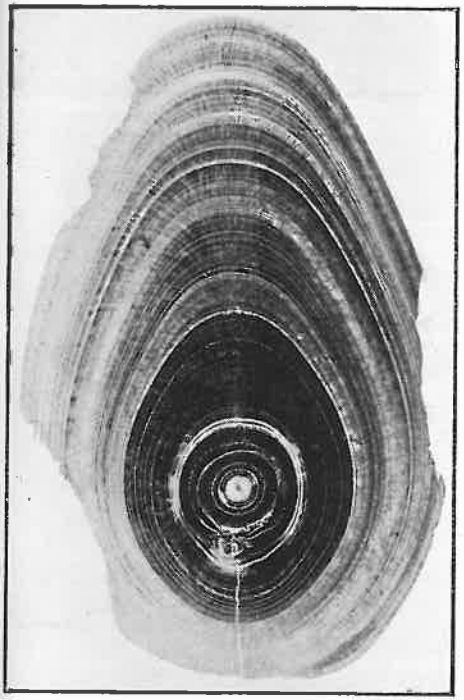

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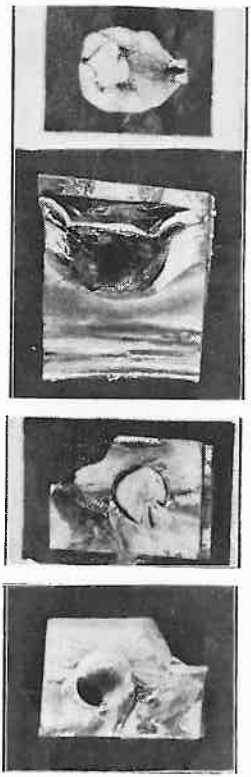

a

b

c

d

4

SECTIONS OF PEARLS AND *HALIOTIS* BLISTER.

FIG.

PLATE II.

1.—"Alasmodon" (i.e. *Margaritifera margaritifera*) Pearl, ground section, decalcified. × 14. (Harley.)

2.—"Alasmodon" (i.e. *Margaritifera margaritifera*) Pearl, ground section, decalcified. × 46. (Harley.)

3.—Decalcified Pearl in Cyst. Defective secretion at one point. × 100. (Jameson.)

PLATE III.

1.—Pearl from *Pinctada maxima*. × 5. (Spencer.)

2.— ,, ,, With black marks. Nat. size. (Saville Kent.)

3.— ,, ,, With caps. Nat. size. (Saville Kent.)

4.—"Southern Cross Pearl" from *Pinctada maxima*. Slightly reduced.

5.—Nucleus containing a grain of sand. × 27. (Jameson.)

6.— ,, ,, calcospherites. × 250. (Jameson.)

7.—Radiolarian Fragment from a nucleus. × 600. (Jameson.)

PLATE IV.

(Growth of Cysts in Pecten. Reduced to half-size.)

1.—Stages in division of a normal fibroblast. × 1,000. (Drew.)

2.—Cyst wall after 5 days: composed of layers of fibroblasts mostly in an active state of transmutation. × 800. (Drew.)

3.—Cyst wall after 20 days: inner layer of fibroblasts with changed character of nuclei and connected below by a continuous layer of cytoplasm. × 800. (Drew.)

4.—Cyst wall after 23 days: nuclei have developed nucleoli; cytoplasm more definite and the cells suggestive of an embryonic type. × 800. (Drew.)

5.—Cyst wall after 26 days: layer of cells bounding the degenerated injected ovarian tissue nucleus now well defined, with distinct basement membrane; nuclei again altered, and nucleoli disappeared. × 800. (Drew.)

6.—Cyst wall after 36 days: development of long irregular cilia; fibroblasts in outer layer quiescent. × 800. (Drew.)

7.—Cyst wall after 98 days: formation of ciliated epithelium complete with dividing walls between the cells: nuclei smaller and cilia shorter and more regular. × 800. (Drew.)

8.—Complete cyst lined with typical columnar ciliated epithelium. Bands of fibrous tissue on each side formed in the track of the needle. × 400. (Drew.)

msl. fbr. = muscle fibre.
div. fbl. = dividing fibroblasts (i.e. in course of subdivision).
b. sin. = blood sinus.
msl. nuc. = muscle nuclei.
b.c. = blood corpuscle.
mig. fibl. = migrating fibroblast.
fbl. = fibroblast.
fbl. lyr. = layer of fibroblasts.
deg. ov. = degenerating ovarian tissue (injected).
cil. ep. = ciliated epithelium.

9.—Part of a fibrous cyst, surrounding a small parasite, in Ceylon Pearl Oyster. × 800. (Jameson, Proc. Zool. Soc., 1912, pl. xxxiii, f. 3.)
il. = inner, highly nucleated layer of cyst.

PLATE V.

1.—Section of Pearl from "Horse Mussel" (*Volsella modiolus*). ×9. (Jameson.)

2.— ,, ,, *Tridacna*. × 22. (T. H. Haynes.)

3.— ,, ,, *Nautilus pompilius*. × 5. (T. H. Haynes.)

4*a*.—*Pholadidea parva*.

4*b*.—Blister chamber in *Haliotis* containing the same. Nat. size. (T. H. Haynes.)

4*c*. } Similar views of another example. Nat. size. (T. H. Haynes.)
4*d*. }