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MORPHOLOGY AND ANATOMY OF INDIAN PEARL OYSTER

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INTRODUCTION

In India, great strides had been made in the technology of culture pearl production from the Indian pearl oyster *Pinctada fucata* (Gould). For achieving satisfactory results in the production of culture pearl, it is absolutely essential to have a precise knowledge of the morphology and anatomy of the animal in view of the fact that the mantle and the gonad play a pivotal role in the production of good quality pearls. Herdman (1904) has given an excellent and detailed account of the anatomy of the Indian pearl oyster. Hynd (1955) and Kuwatani (1965 a, b) have also contributed to our understanding of the morphology of the pearl oysters from Australian and Japanese waters, in addition to throwing light on the functional role of the digestive and reproductive organs. Based on a number of dissections made on the oysters of the Tuticorin region, the present account on the anatomy of the most important systems of the pearl oyster is presented in the paper.

PTERIDAE AND ASSOCIATED FAMILIES

The Indian pearl oyster *Pinctada fucata* belongs to the family Pteridae. It differs from other bivalves in possessing a lorg and straight hinge. The long axis of the shell is not at right angle to hinge. The left valve is usually deeper than the right. There is a byssal notch on each valve at the base of the anterior lobe. The colouration of the periostracum varies; often brownish with radial markings (Rao and Rao, 1974).

In the genus *Pteria*, a member of the family Pteridae, the shell is much longer than high, the outer surface smooth and conspicuously scaly and the hind angle is always definitely prolonged, often greatly so. This prolongation usually appears as a definite wing-like expansion marked off from the rest of the shell by an oblique elevated area extending from the umbo to the hind lower margin.

The species belonging to the family Ostreidae are generally characterised by very much reduced foot. Byssus gland is absent. Gills are fused to the mantle and the shells are fixed to the substratum by the left valve which is larger than the right one.

In Pinnidae, the *Pinna* shells are broadly triangular in shape. The posterior margin is truncate or convex-rounded. The valves are very high and thick or rather thin or fragile. Valves are translucent and of light horn-brown to dark purplish brown colour. 8 to 17 radial ribs, which are sometimes scarcely visible, are present.

In Mytilidae the shell is inequilateral with umbo situated either terminally at the anterior end or subterminally, very close to it. The anterior adductor muscle is always much less strongly developed than the posterior (anisomyarian condition). *Modiolus* spp. (weaving mussels) usually 11 to 70 mm in length, attach themselves to substratum by means of byssus threads. The shell is thin, transparent, semitransparent or opaque; margins elevated, arched or straight and colouration with hairy periostracum.

SPECIES OF PEARL OYSTERS

Pinctada chemnitzii (Philippi)

The anterior and posterior ears are well developed and the convexity of the valve is much less. The valves are yellowish-brown with about a few or more

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whitish cream yellowish markings from the umbo to the margin of the shell and the growth processes are rather broad. The non-nacreous border is brownish without any conspicuous blotches.

P. sugillata (Reeve)

The hinge is very much shorter than the widest anterio-posterior axis of the shell. The convexity of the right shell valve is moderate. The colouration of the shell is dark grey with a tinge of brown. Posteriorly the nacreous border as it meets the hinge line, presents a wavy course.

P. margaritifera (Linnaeus)

Teeth are entirely absent from the hinge margin. Anterior border of the body of shell extends far in advance of the anterior ear lobe. Shell valves are moderately convex. The concentric laminae on the external surface of the shells are conspicuous in young animals. The nacreous layer is iridescent, silvery and distally sooty black in colour. Because of the dark marginal colouration this species is called 'black-lip' pearl oyster.

P. anomioides (Reeve)

The posterior ear and posterior sinus are absent. The right valve is nearly flat but the left is moderately convex. Externally the valves are translucent. Faint radial markings are present. The nacreous region is well developed and its posterior border meets the hinge at right angles.

P. atropurpurea (Dunker)

This species is distinguished from the previous species by its copper red colouration, thinner and more translucent valves and the posterior nacreous border meeting the hinge at an acute angle.

P. maxima (Jameson)

This species does not possess denticles on the hinge. The valves are more flat and less hollowed out than in *P. margaritifera*. The hinge is larger than in *P. margaritifera*. However, in the adult, the posterior portion of the hinge is not prominent as in *P. chemnitzii*. The valve is less rounded than in *P. margaritifera*. The cardinal portion may be coloured in a dense manner, dark brown, or purple, sometimes with spots of the same colours, but mostly deeper shades.

P. fucata (Gould)

The left valve is deeper and more concave than the right. The valves are more or less rounded in outline with flattened dorsal edge ending in projecting wings or auricles in front and behind.

Description of the Shell of *P. fucata*

The shell is thin, about 1.5 mm thick over the greater part of its extent, and lired by an exceedingly brilliant layer of nacre or mother-of-pearl. The outer side of the shell is usually marked by 6-8 radial bands of reddish brown colour on a pale yellow background. The growth processes or projecting imbricating lamellae, which arise from the external surfaces of the shells are laid down by the animal at successive intervals at the distal border. The anterior ear is larger than in the other species. The non-nacreous border on the inner surface of the valves possesses brownish or reddish patches coinciding with the external rays. The nacreous areas of the ears relative to the rest of the shell decreases with age slightly.

Immediately below the hinge line, the posterior border is frequently indented by a sinus markirg of the area of the shell known as the posterior ear, where the sinus is deep ; the posterior ear is relatively large. The byssal groove is short, forwardly curved depression on the external surface of the right valve running from the umbo to the byssal notch.

The large adductor impression is placed subcentrally occupying $\frac{1}{4}$ to $\frac{1}{3}$ the diameter of the shell. The pallial line and scars caused by the insertion of the pallial muscles are fan-shaped bundles formed of fibres radiating outwards. Usually there are 12-15 insertion scars between the umbonal region. Besides these distinct scars, is a narrow continuous insertion band confluent with the posterior and ventral edges of the adductor scars. Its scar merges with that of the adductor scar. The hinge line is a narrow edge and runs along the greater part of the straight dorsal edge ; elongated narrow ridge-like lateral teeth are present as paired elevation of the nacre of the hinge line, posterior to the ligament.

The shell is composed of three layers, the outer, middle and inner. The very thin outer layer is uncalcified cuticular 'periostracum', an extremely delicate horny layer which allows the colour of the layer below to show through and becomes worn off in old shells. At free margin of the shell the periostracum is very thin, transparent and extends beyond the calcareous matter and reflected to join the surface of the ectoderm cells of the mantle edge in the longitudinal groove where it is secreted.

The middle or prismatic layer of the shell shows a cellular structure being formed of calcareous prisms or columns running transversely to the surface and appearing polygonal in section. The prismatic layer is deposited by the mantle epithelium near the free edge just behind the margin which forms the periostracum and many such layers of fusion may be formed successively, each new one inside the last, as the shell grows. The inner layer is the nacre formed of numerous delicate lamellae of the organic matrix conchiolin and calcareous matter. It is transparent under microscope having fine granular appearance in surface view.

General Organisation of the Animal

Mantle

The mantle secretes all parts of the shell. The free edge of the mantle lobes is thickened, pigmented and fringed with branched tentacles. The pallial edge of the mantle is attached to the shell, a little away from the margin. Each pallial lobe may be divided into three parts : the central, distal or muscular and marginal mantle. The central pallial area extends from the middorsal line to the pallial line, where the shell is marked with muscle scars. At the points of attachment of the adductor, the retractors, the levators and pallial muscles the tissue of this part of the mantle is soft, mucoid and opalascent white in colour. The distal or muscular area is translucent and capable of considerable contraction by its muscles and extension by the influx of blood into the large sinus it contains. It is formed of a thick layer of loose connective tissue traversed by nerves and blood space and by the radiating fan-like bundles of pallial muscles (Fig. 1, 8). This region is sensitive to foreign particles.

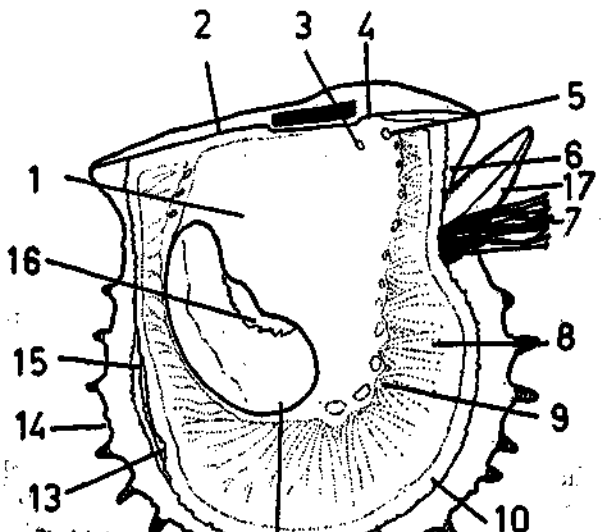

Fig. 1. *Pinctada fucata* with right shell remoed.

1. Mantle lobe, 2. Mid-dorsal line, 3. Right levator of foot, 4. Left anterior levator of foot, 5. Right anterior levator of foot, 6. Oral aperture, 7. Byssus, 8. Pallial muscles, 9. Converged end of pallial muscles, 10. Outer end of pallial margin, 11. Papillae of middle lamellae of pallial margin, 12. Adductor muscle, 13. Pallial fold, 14. Exhalent orifice, 15. Left mantle lobe, 16. Right retractor of foot, and 17. Foot.

The marginal region or mantle edge is chiefly a thickening which ends in two thin membranous folds with pigmented papillate edges (Fig. 1, 11). The outer fold bearing digitate papillae is in the same place as the inner surface of the shell and forms the true pallial edge. The inner fold which bears the flattened palmate papillae, which may be called the pallial veil or velum projects inwards at right angles from the mantle edge, so that the veil of one pallial lobe stretches towards that of the other. The inhalent aperture is somewhere about the middle of the ventral surface, while the exhalent aperture is at the posterior end opposite the opening of the anal funnel and suprabranchial chamber. The exhalent aperture is broadly ovoid or almost circular. Along the posterior margin of the body, from the pallial fold (Fig. 1, 14) upwards to the posterior end of the hinge, the papillae of the veil become greatly reduced in size and simpler in form and in the region of the posterior auricle of the shell, they approach in character those of the pallial margins (Fig. 1, 10). The free pallial margin together with the velum, is in most cases deeply pigmented, dark grey and the degree of pigmentation varies in yellows and browns.

The ciliated pallial path

The inner surface of the pallial lobe is ciliated, but at the ventral truncate edge of the labial palps, a specially marked ciliated path begins which passes to the base of the velum, parallel with which it runs until it reaches the anterior wall of the pallial fold where it passes over the velar edge by means of a slight folding of the latter. The cilia of this pathway are in continuous motion, by which means the unsuitable particles collected by gills are sent forwards but rejected by the palps and conveyed away and passed out from the pallial fold.

The inner surface of the outer mantle fold

The free surface of the columnar epithelial cells of the outer mantle fold is provided with numerous microvilli.

The outer surface of the middle fold

Large numbers of ciliary epithelial cells with microvilli are arranged zonally or in a cluster along the longitudinal line over the middle region of the mantle fold.

Foot

The foot (Fig. 2, 1) is a highly mobile, tongue-shaped organ capable of great elongation and contraction. It arises from the anterior region of the visceral mass nearly midway between the mouth and the intestinal lobe and the anterior branchiae flanking it on either side. The major part of its bulk is composed of network of

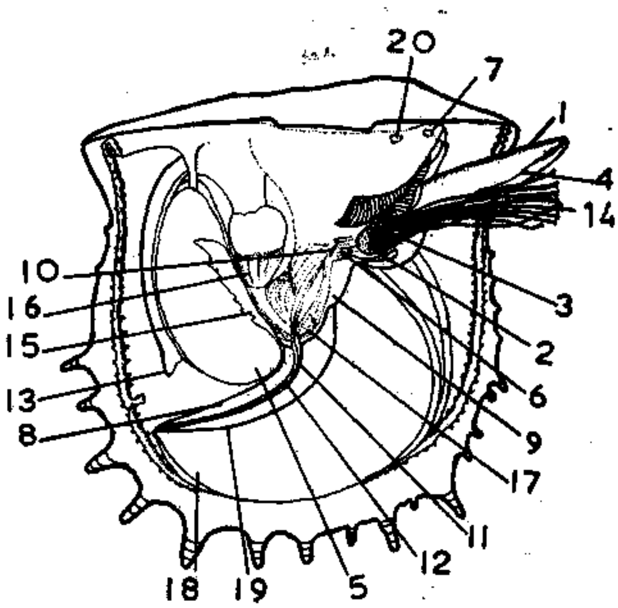

FIG. 2. Respiratory excretory and rerpoductive systems of *Pinctada fucata*.

1. Foot, 2. Byssus gland, 3. Root, 4. Pedal groove, 5. Adductor muscle, 6. Retractor, 7. Left anterior levator, 8. Muscular ctenidial axis, 9. Gonad, 10. Reno-genital aperture, 11. Efferent branchial vein, 12. Afferent branchlia vein, 13. Anal process, 14. Byssus, 15. Retractor, 16. Pericardial gland, 17. Nephridium, 18. Gill, 19. Ctenidial axis and 20. Right posterior levator.

fibres running in various directions thus ensuring a wide range of movement and it is so extensively penetrated by blood spaces that the organ is highly controllable.

Byssus gland

The byssus gland organ (Fig. 2, 2) is lodged at the proximal end of the foot upon the ventral aspect. The byssal gland lodges the common root (Fig. 2, 3) of a bundle of stout laterally compressed bronze green fibres, the byssal threads. Each fibre of the byssus anchors the pearl oyster to rocks and other objects by means of a discoid attachment at the distal extremity. The anterior edge of the mouth of byssal gland passes into the pedal groove (Fig. 2, 4) extending medially along the whole of the remaining length of the ventral surface of the foot.

MUSCULAR SYSTEM

The pearl oyster is monomyarian, possessing only the posterior adductor (Fig. 2, 5) the largest and the most important muscle in the body.

Adductor muscle

The adductor muscle stretches transversely across the body from valve to valve. It is a massive wedge-shaped bundle. The narrow end points upwards and lies immediately behind the ventricle of the heart. The terminal part of the rectum runs in the middle line along the posterior surface. Two distinct regions of the muscles are obvious ; one, a narrow tendonous strip made up of white glistening fibres forming the posterior border and the other, broad and massive semitranslucent fibres occupying the remainder of the mass .The power exerted by the adductor in bringing the valves together by its contraction is very considerable with rapid action resembling ratchet mechanism.

The retractor

The retractors of the foot are a pair of symmetrically disposed muscles lying in the horizontal plane of the body (Fig. 2, 6). The V-shaped muscles originate from the byssal gland. The ends are attached to the right and left valves without making a separate scar on the nacre.

Levators

The levators of the foot are four, two anterior and two posterior (Fig. 2, 7). Each of the anterior pair has its insertion at the apex of the umbonal recess of its respective valve passing vertically downwards on either side of the mouth spreading laterally, fan-like as they go. The left anterior levator is stronger and by contraction of the strong cord of fibres, the food is drawn over the left side of the valve which is convex and more spacious. The posterior levators are two short insignificant bundles (Fig. 2, 20) which originate high upon the anterior levator, exactly on level with the mouth passing through the visceral mass to be attached to the valves behind the anterior levator scar. The contraction of the anterior levator (Fig. 2, 7) causes the foot to be retracted and dorsally raised. The intrinsic muscles of the foot are diffused forming a muscular enveloping sheath in the foot, with ill-defined muscle bundles passing from side to side, providing a framework wherein ramify the tubules of the digestive glands. The branchial muscles cause the shortening of the gills and withdrawl of their posterior extremities. They run within each ctenidial axis (Fig. 2, 8) from end to end, close to the dorsal edge. There are also muscle bundles running longitudinally down each side of the principal filaments.

Pallial muscles

The pallial muscles (Fig. 1, 8) are all retractors, and together constitute the orbicular muscle of the mantle. They are a series of fan-shaped muscles radiating towards the mantle edge from a number of insertion centres (15-18) of various sizes arranged semi-circularly. Together these form the well marked pallial line of scars on the shell. With the exception of heart and the somewhat indistinct appearance of striation on the larger portion of the adductor, the muscle fibres throughout the body are non-striped.

DIGESTIVE SYSTEM

The oesophagus (Fig. 3, 2), stomach (Fig. 3, 3) and the greater portion of the intestine lie within the viscero pedal mass. Two horizontal lips conceal the aperture of the mouth. The labial palps (Fig. 3, 4) are smooth on the surface, turned away from the mouth and grooved on the opposed faces enclosing the mouth aperture. The mouth (Fig. 3, 1) is a large, slit like depression placed transversely between the anterior

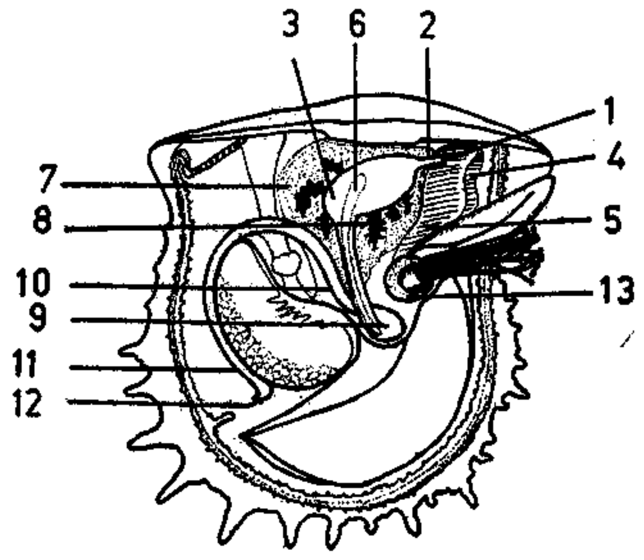

FIG. 3. Digestive system of *Pinctada fucata*.

1. Mouth, 2. Oesophagus, 3. Stomach, 4. Left outer labial palp, 5. Left inner labial palp, 6. Crystalline style, 7. Liver, 8. Digestive diverticula, 9. Descending portion of intestine, 10. Ascending portion of intestine, 11. Rectum, 12. Anal process and 13. Byssal gland.

levator muscles of the foot. The cavity contracts inwards to the narrow width of the short conducting tube, the so called oesophagus, which is straight, dorso-ventrally compressed and ciliated. The hinder end opens into the anterior end of the stomach which is an organ of surprising elaboration. Folds and depressions diversify the walls and floor of the stomach and break them into definite areas. In life, it is too delicate and too intricately united with the surrounding tissues to be dissected free. The tissues consist largely of greenish brown masses often termed as liver (Fig. 3, 7) (which have no resemblance to that organ in the vertebrates) or better termed as digestive diverticula (Fig. 3, 8). Dense clusters of secreting alveoli open into ductules and these larger ducts lead into the cavity of stomach. The most conspicuous portion of the stomach is a slightly projecting vertical fold arising from the posterior wall marking out the cardaic stomach into a right and left chamber. This fold disappears towards the roof where it is smooth and unbroken, except for a well marked pit. The wide bipartite opening into the intestine and intestinal caecum marks the hinder end of the pyloric chamber. A peculiar (gelatinous) rod flattened and oblique occupies a sub-central position anterior to where the postero-ventral fold disappears midway along the floor. To the right of this area of the dendritic plate is a ridge with a furrow running up to the antero-lateral bile duct. A deep rugose-sub-oesophageal pit is well marked, anterior to the dendritic plate and high upon the right lateral wall. The posterolateral furrow leads from the posterolateral duct towards the intestinal aperture. On the left side, a short anterolateral fold lies between the preintestinal depression of suboesophageal pit.

There are eleven terminal ducts opening into the intestine—(*a*) anterolateral duct, (*b*) posterolateral duct opening in posterior third stomach, (*c*) the postero-ventral duct, (*d*) three subventral ducts, (*e*) two pre-intestinal ducts opening within preintestinal depression and (*f*) three small suboesophageal ducts below the oesophageal aperture.

The head of crystalline style projects out of the sac where it is formed and across the cavity of the stomach where it bears against an irregular area of cuticle bearing a projecting tooth, known as the gastric shield. This area is not ciliated.

The intestine may be divided into three sections of approximately equal length namely the descending, the ascending portion and the rectum (Fig. 3, 9-11). The first portion passes ventrally through the posterior part of the visceral mass. Then it passes behind the base of the byssal gland and between the two pedal retractor muscles wherefrom it changes its direction curving forwards and downwards to the visceral mass passing on as ascending branch. A longitudinal fold projects inwards from the anterior and one from the posterior wall of the descending intestine. The apices of the two folds are so close together at the lower third so as to form two distinct tubes. The larger cavity is completely filled with a clear gelatinous solid cylinder, the crystalline style (Fig. 3, 6). The narrow tube on right side is the true intestine, the wider left being the sheath of the crystalline style which is imperfectly separated from the anterior portion of intestine with which it communicates by a longitudinal cleft. The upper end of the style certainly projects into the stomach.

The valvular folding of the intestinal ridge gives entrance to the ascending intestine which curves backwards along the base of the visceral mass to the left of the descending intestine (Fig. 3, 9). The ascending portion crosses to the right at the posterior extremity of the ventral surface of the visceral mass where the two intestinal divisions intersect. The intestinal loop thus formed is the visceral loop. From the point of intersection the ascending intestine turns sharply upwards, running parallel with and closely adjacent to the upper part of the descending portion (Fig. 3, 10). The portion of the intestine forming the second limb of the visceral loop is continued into it as a somewhat undulating ridge disappearing midway. At the point where this diversion of the intestine assumes a dual course, an increase takes place in diameter, side by side with the appearance of a long longitudinal fold-typhlosole, projecting from the anterior wall, curving over to the posterior side of the tube, then running vertically upward without further change of course. Longitudinal furrows channel the surface. As it approaches the level of the floor of the stomach, the typhlosole thins down rapidly to a low ridge, and the intestine itself then curves posteriorly in the direction of the heart. This change in direction and thinning of typhlosole marks the beginning of rectum.

The rectum (Fig. 3, 11) runs posteriorly through the upper part of the pericardium. Beyond this it curves ventrally and passes round the posterior aspect of adductor muscle in the median line, ending in an erectile ear-like process, the anus, situated opposite the exhalent orifice of the mantle. The anal process (Fig. 3, 12) is comparatively larger and slightly curved. It stands out at right angle to the last section of the rectum, and the tip is directed posteriorly. The anal aperture is situated at the base on the ventral aspect.

Respiratory System

The gills (Fig. 2, 18) consist of four crescent shaped plates, two half gills on each side which hang down from the roof of the mantle cavity like book leaves. They represent a series of ciliated sieves the whole constituting a feeding surface of utmost efficiency. Two rows of long delicate branchial filaments (Fig. 2, 19) are inserted at right angles along the whole length of the axis or vascular base which extends from the ventral border of the palps anteriorly curving round ventrally and posteriorly to a point opposite the anus with its convexity first forwards and then downwards. Where they terminate the mantle lobes of the two sides are briefly united by way of the inner mantle folds thus dividing the mantle cavity into a large inhalent chamber containing the gills and a much smaller exhalent chamber. Water enters by the one and leaves by the other. The outwardly directed parallel filaments of each series are folded upon themselves, so that they are V shaped, the folding being in such a way that that external filaments turn outwards and internal inwards. Consequently each branchial plate furrow of the double filaments, consists of two lamellae, the direct and the reflected, which enclose narrow interlamellar space.

The common base of each ctenidium is a vascular attached ridge reaching from the anterior end of gills. Hollow outgrowths, inter-lamellar junctions, containing branches from the afferent vessels convey blood from the axial trunk to the base of reflected lamellae. The blood enters certain of the individual filaments, flows outwards to the free margin, passing over to the direct filaments returning inwards to the branchial or ctenidial axis (Fig. 2, 19) where it joins the different vessel by openings along each side.

Neighbouring filaments are joined by continuous organic union mainly at the lower and the upper ends of the reflected filaments, where there are longitudinally running blood vessels. Elsewhere the filaments are joined chiefly by the interlocking stiff cilia of the large ciliated discs which occur at intervals, throughout their length. The normal function of the ordinary cilia on the branchiae is to create a current of water which enters the pallial chamber and passes over and through the branchial lamellae so as to purify the blood flowing in the filaments and to convey the food particles to the mouth. Yonge (1960) has elaborately dealt with the mechanism of the food movements to the palps from the water current thus set up.

Circulatory System

This consists of a heart with a series of arteries which lies above the adductor, being contained in a pericardium (Fig. 4, 1) and consisting of a single ventricle (Fig. 4, 2) and a pair of contractile thin walled auricles (Fig. 4, 3), one on each side. They receive blood from the body by way of the gills and the mantle, and pass it to the ventricle. Back flow is prevented by valves. There it is driven by contraction into the anterior and posterior aorta (Fig. 4, 5). The latter is short and serves the adductor, rectum and the anus ; the rest of the body is supplied by the anterior aorta which gives off a series of minor arteries (Fig. 4). These

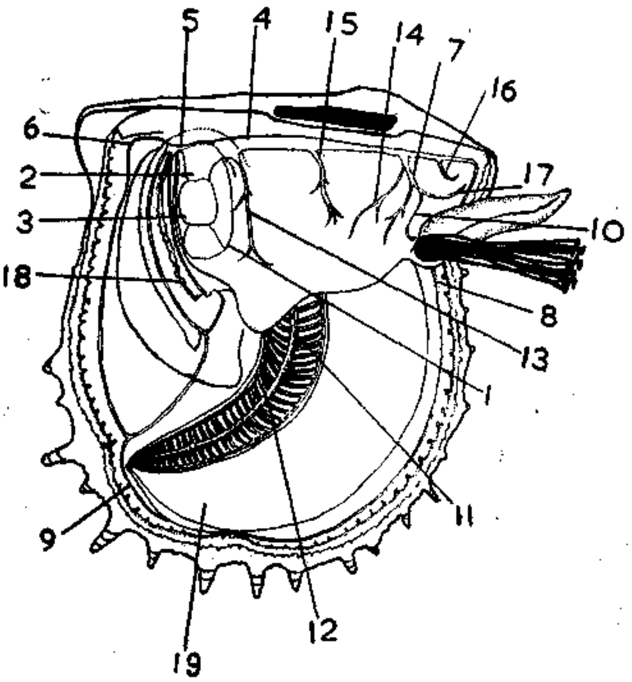

FIG. 4. Circulatory system of *Pinctada fucata.*

1. Pericardium, 2. Ventricle, 3. Auricle, 4. Anterior aorta, 5. Posterior aorta, 6. Posterior pallial artery, 7. Hepato pedal artery, 8 and 9. anterior pallial artery, 10. Pedal artery, 11. Efferent branchial vein, 12. Afferent branchial vein, 13. Visceral artery, 14. Anterior hepatic artery, 15. Posterior hepatic artery, 16. Upper labial artery. 17. Lower labial artery, 18. Right mantle lobe and 19. Gill.

open into the sinuses or blood spaces in which blood slowly circulates. The aorta finally communicates with a pair of large blood vessels that run around the margin of each mantle lobe. Deoxygenated blood is collected in veins (Fig, 4, 12) which carry it either into the gills or excretory organs. Blood flows round the organs and is purified by removal of waste products of metabolism. From the kidney it is pumped into the marginal vessel of the mantle by a pair of accessory hearts. Finally blood from the mantle together with that from the gills returns to the heart through efferent branchial vein (Fig. 4, 12) by way of auricles. The blood is colourless.

EXCRETORY SYSTEM

The excretory system consists of the paired nephridia and numerous small pericardial glands (Fig. 2, 16) projecting from the walls of the auricles. The nephridia (Fig. 2, 17) consist of two large symmetrical pouch-like sacs occupying either side of the hinder half of the viscero-pedal mass. Each opens into the pericardium by a wide duct and to the exterior by a minute pore. They intercommunicate by a wide channel beneath the auricles. In outlines each is roughly triangular, the apex passing into the channel under the auricle, while the elongated base looks towards and forwards coinciding with the base of the anterior third of the gill of that side, and thus conforming to the inclination of the gill.

The outer wall of the nephridium is thin and membranous ; it is fused with the body wall, as is also the most anterior portion of the inner wall, namely, that strip extending from the base of the gill to the visceropedal mass. From this line it runs back, overlying and in contact with the hinder part of the gonad, gradually narrowing as it approaches the auricle.

The external renal aperture is a minute oval opening with a sphincter muscle. It opens immediately below the genital aperture within an inconspicuous lipped slit placed at the junction of the inner plate of the inner gill with the visceral mass at a point about midway between the ventral border of the latter and the base of the foot.

Each nephridium consists of a glandular and non glandular portion. By separating the right and left ctenidia and reflecting each, the glandular region is seen as narrow, elongated coloured strip, yellow or pale brown or even dark dull red, bordering the anterior part of the inner base of each gill. It consists of spongy tissue, occupying the anterior angle formed by the meeting of the inner and outer walls of the organ, and the secretion passes from the cavernous chambers of the glandular region directing into the spacious cavity of the main or non-glandular portion.

The passage connecting the right and left nephridia lies beneath the auricles. It is a wide tunnel with thin membranous walls, bounded behind by the lower part of the pericardium. While in front its wall lies against the visceral mass below it fuses with the body wall and so forms part of the root of the adductor embayment of the suprabranchial chamber. The renopericardinal tubules are a pair of wide lateral prolongations of the precardiac part of the pericardium, thinwalled and membranous and directed forwards. Each gradually narrows towards the anterior end where it opens into the nonglandular part of nephridium of its own side. The aperture is a curved slit, with the concavity facing towards the ventral aspect. It has but one lip, the tube opening at a very acute angle. It is situated upon the inner wall of the nephridia. A small area around is tinted with brown pigment. The presence of accessory pericardial glands on the walls of auricles is said to have excretory function. These glands are dark brown in colour. The lower or auricular end of the pericardium is also glandular. Its epithelium is thrown into folds formed of granular vacuolated cells of the same character as those of the nephridium.

NERVOUS SYSTEM

The laterally symmetrical nervous system has three pairs of galglia (1) the cerebral ganglia at the sides of the oesophagus, (2) the pedals joined to form a single ganglion at the base of the foot and (3) a pair of large visceral or parieto-splanchnic ganglia lying upon the anterior surface of the adductor.

The stout paired cerebrovisceral connectives (Fig, 5, 1) link the cerebral with the parieto-splanchnic ganglia, while a pair of cerebro-pedal connectives (Fig. 5, 4)

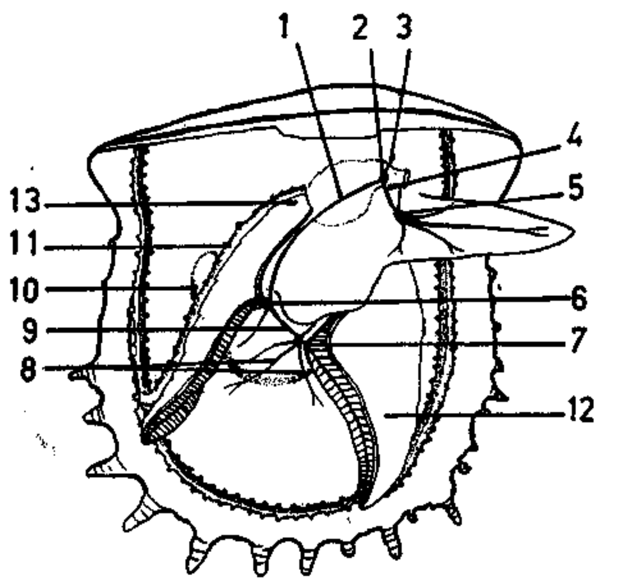

FIG. 5. Nervous system of *Pinctada fucata*.

1. Cerebro-visceral connective, 2. Cerebral ganglion, 3. Cerebral commissure, 4. Cerebropedal connective, 5. Pedal ganglion, 6. Visceral ganglion, 7. Branchial nerve, 8. Posterior pallial nerve, 9. Visceral commissure, 10. Adductor muscle, 11. Right mantle. 12. Left inner gill and 13. Right inner gill.

join the cerebral with the pedal nerve mass. The cerebral ganglia are supra-oesophageal in position, and a nerve cord or commissure passing over the oesophagus connects the two cerebral ganglia (Fig. 5, 2). A single stout transverse visceral commissure forms the two parieto-splanchnic ganglia (visceral ganglia) (Fig. 5, 6).

The cerebro-visceral connectives taking their rise at the posterior end of the cerebral ganglion, each passes backwards and downwards bound within the visceral mass till it merges opposite the upper angle of the base of the foot. Then it passes ventrally over-laid by the renal sinus entering the tissue at the base of the gills. It turns slightly forwards still passing ventrally and ends in its respective parieto-splanchnic ganglion. The cerebral ganglion of each side gives off anteriorly a stout nerve, the anterior common pallial. This passes forwards, bifurcating. The outer branch (external pallial nerve) runs along the pallial edge, uniting and anastomosing with the corresponding external pallial branch of the postetior common pallial trunk. The lateral palps and otocysts are innervated by the cerebral ganglia.

The cerebro-pedal connectives arise from the posterior and outer sides of the cerebral ganglia and run downwards within the visceral mass just behind the levator muscles of the foot to the pedal ganglion. They lie close together in their course. Three principal nerves arise from the pedal ganglion (Fig. 5, 5) which innervate the foot and the byssal gland. Each of the visceral or parieto-splanchnic ganglia receives from above the stout cerebro visceral connective, the two ganglia being themselves united by a single transverse visceral commisure (Fig. 5, 9). Each ganglion also gives off two stout distributory nerves an anterior lateral and a posterior lateral. Each branchial nerves (Fig. 5, 7) leaves the ganglion at the anterior lateral corner, turns down into the base of the gills and then backwards to the posterior tips following the afferent vessels. The posterior pallial nerves (Fig. 5, 8) emerge from the posterior end of the visceral ganglion ; from the base of each, a stout nerve passes straight back till it reaches the pigmented pallial sense organs of its respective side, a little anterior to the anus.

The common pallial trunk passes backwards and outwards bifurcating ; the external branch, the larger, is the external pallial nerve. The inner branch follows a median course but divides. The outer of the resultant nerves becomes the median pallial nerve ; the inner internal pallial nerve. By the ramification of these three nerves in the muscular marginal region of the mantle and by their anastomosing a complex network of nerves termed 'pallial plexus' is formed.

Reproductive System

The sexes are separate except in occasional cases. The gonads are paired but asymmetrial; they form a thick envelop covering the stomach, liver and the first two sections of the intestine, connecting a greater part of the outside of the proximal portion of the viscero-pedal mass (Fig. 3, 9). The gonads do not hide the byssal gland. When the viscero-pedal mass is viewed from the right side of the byssal gland it is seen as a broad band reaching from the base of the foot backwards to the right retractor muscle. This band appears to divide the right gonad into a larger part dorsally and a ventral smaller portion. No portion of the reproductive glands extends into the foot proper or into the mantle.

The male and female gonads are practically indistinguishable. Both are creamy yellow in colour. The male gonad in some cases is rather paler than the female. The gonads, testes or ovaries as the case may be, consist of branched tubuli with myriads of succate caeca, the alveoli. The spermatozoa and ova develop in these. The accumulated ripe gametes fill these alveoli and tubuli and later pass into three trunks which converge into one just within the external genital aperture (Fig, 2, 10). This opens immediately dorsal to the renal aperture of the same side.

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