WELCOME

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Third Year B. Sc. Zoology
(Implemented from academic year 2015-2016)

Pattern of examination: Semester

Theory courses: (Sem. III: ZY-331 to ZY-336) : Semester-I

(Sem IV: ZY- 341 to ZY-346) : Semester-II

Practical Course: Annual

ZY-347

ZY-348

ZY-349

Work Load, Mark Distribution and Passing Criteria For Semester - I

Paper/Course No.	Title	Total Number of lectures Per Semester	Internal marks out of **10** (Theory)	External marks out of **40** (Theory)	Total passing marks out of **50** (Theory)
ZY-331	Animal Systematics and Diversity V	48	4	16	20*
ZY-332	Mammalian Histology	48	4	16	20*
ZY-333	Biological Chemistry	48	4	16	20*
ZY-334	Environmental Biology and Toxicology	48	4	16	20*
ZY-335	Parasitology	48	4	16	20*
ZY-336	General Pathology or Cell Biology	48	4	16	20*

Work Load, Mark Distribution and Passing Criteria For Semester - II

Paper/Course No.	Title	Total Number of lectures Per Semester	Internal marks out of **10**	External marks out of **40**	Total passing marks out of **50**
ZY-341	Biological Techniques	48	4	16	20*
ZY-342	Mammalian Physiology and Endocrinology	48	4	16	20*
ZY-343	Genetics and Molecular Biology	48	4	16	20*
ZY-344	Organic Evolution	48	4	16	20*
ZY-345	General Embryology	48	4	16	20*
ZY-346	Medical Entomology	48	4	16	20*

Practical Annual Pattern

Course Code and Title			Internal Mark Out of 20	External Mark Out of 80	Total Out of 100
ZY- 347 (Semester III & IV)	Practical Paper I	Practicals related to ZY-331, ZY-332, ZY-341, ZY-342. 12 Practicals of 4 lectures in each Semester (24 Practicals / year)	8	32	40**
ZY- 348 (Semester III & IV)	Practical Paper I	Practicals related to ZY-333, ZY-334, ZY-343, ZY-344. 12 Practicals of 4 lectures in each Semester (24 Practicals / year)	8	32	40**
ZY- 349 (Semester III & IV)	Practical Paper I	Practicals related to ZY-335, ZY-336, ZY-345, ZY-346. 12 Practicals of 4 lectures in each Semester (24 Practicals / year)	8	32	40**

Theory examination will be of two hours duration for each theory course. There shall be 4 questions each carrying 10 marks. The pattern of question papers shall be:

Question 1	10 sub-questions, each of 1 marks based on entire syllabus	10 marks
Question 2 & 3	2 out of 3 sub-questions, each of 5 marks; short answer type questions; answerable in 10 – 15 lines	20 marks
Question 4	1 out of 2 sub-questions, each of 10 marks; long answer type questions (20 – 25 lines)	10 marks each

Pila globosa (Snail apple)

SYSTEMATIC POSITION

Phylum	-	Mollusca
Class	-	Gastropoda
Order	-	Prosobranchiata
Suborder	-	Pectinibranchiata
Family	-	Pilidae
Genus	-	*Pila*
Species	-	*globosa*

Habit and Habitat of Pila Globosa:

Pila globosa or the apple snail is one of the largest freshwater molluscs. It is commonly found in freshwater ponds, pools, tanks, lakes, marshes, rice fields and sometimes even in streams and rivers. They occur in those areas where there is a large amount of aquatic vegetation like Vallisneria, Pistia, for food. They are amphibious being adapted for life in water and on land.

The animal creeps very slowly by its ventral muscular foot, covering about five cm per minute.

The movement of the animal is like the gliding movement of planarian. During the rainy seasons Pila comes out of the ponds and makes long terrestrial tours, thus, respiring air directly. It can overcome long periods of drought in a dormant condition and buried in the mud; this period of inactivity is called aestivation or summer sleep.

Mollusca Characteristics

The organisms belonging to phylum Mollusca exhibit the following characteristics:

1. They are mostly found in marine and fresh water. Very few are terrestrial found in damp soil.
2. The body is divided into segments. They exhibit organ system level of organization.
3. Their body has a cavity. The head comprises of tentacles and compound eyes.
4. The body is divided into head, dorsal visceral mass, and ventral muscular foot and mantle.
5. The body is covered by a shell made up of calcium carbonate.
6. The ventral muscular foot helps in locomotion.
7. They have a well-developed digestive system and the structure is chitinous.
8. They respire through the general body surface, pulmonary sac, or gills.
9. The blood circulates through the open circulatory system.
10. They have a pair of metanephridia that helps in excretion.
11. The nervous system consists of paired ganglia, connectives, and nerves.
12. The tentacles, eyes, osphradium, and statocysts act as the sensory organs.
13. The sexes are separate and the fertilization is external or internal.
14. Development may be direct or indirect.

External Features of Pila Globosa:

Shell of Pila:

The shell of Pila globosa, as in other Gastropoda, is univalve but coiled around a central axis in a right-handed spiral. The top of the shell is the apex which is formed first and growth of shell takes place from it, the apex contains the smallest and the oldest whorl. Below the apex is a spire consisting of several successively larger whorls or coils followed by penultimate whorl and the largest whorl or body whorl which encloses most of the body.

The lines between the whorls are called sutures. Internally all the whorls of the shell are freely communicated with one another; such a shell is called unilocular. The body whorl has a large mouth or opening, the margin of the mouth is called a peristome from which the head and the foot of the living animal can protrude.

When viewed from the ventral side with the peristome facing the observer, the mouth lies to the right of the columella and the shell is spiralled clockwise, then it is spoken of as being right-handed or dextral. The outer margin of the mouth is called an outer lip, and the inner margin as inner or columellar lip.

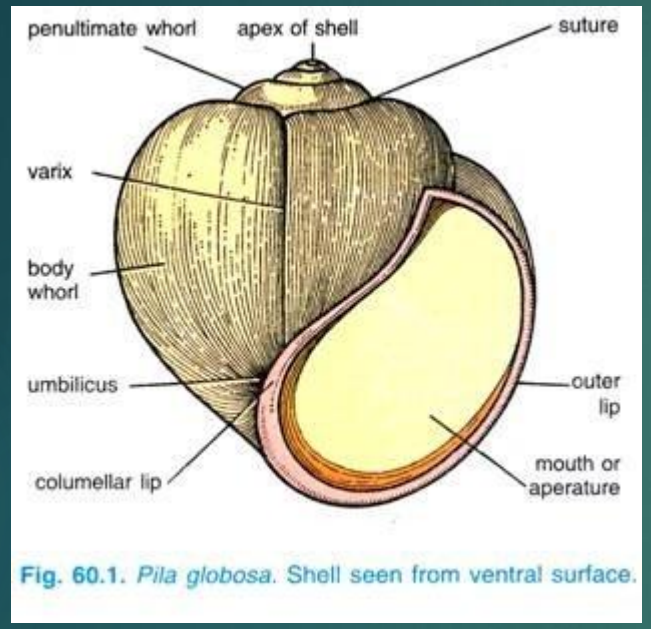


Fig. 60.1. *Pila globosa*. Shell seen from ventral surface.

In the centre of the shell runs a vertical axis or columella around which the whorls of the shell are coiled; the columella is hollow and its opening to the exterior is known as an umbilicus. Shells with an umbilicus are umbilicate or perforate. The lines of growth of shell are visible, some of them appear as ridges known as varices. The shell of Pila globosa varies in colour from yellowish to brown or even blackish

Operculum of Pila Globosa:

Fitting into the mouth of the shell is a calcareous operculum, its outer surface shows a number of rings of growth around a nucleus; the inner surface has an elliptical boss for attachment of muscles, the boss is cream- coloured and is surrounded by a groove. The operculum is, in fact, secreted by the glandular cells of the foot.

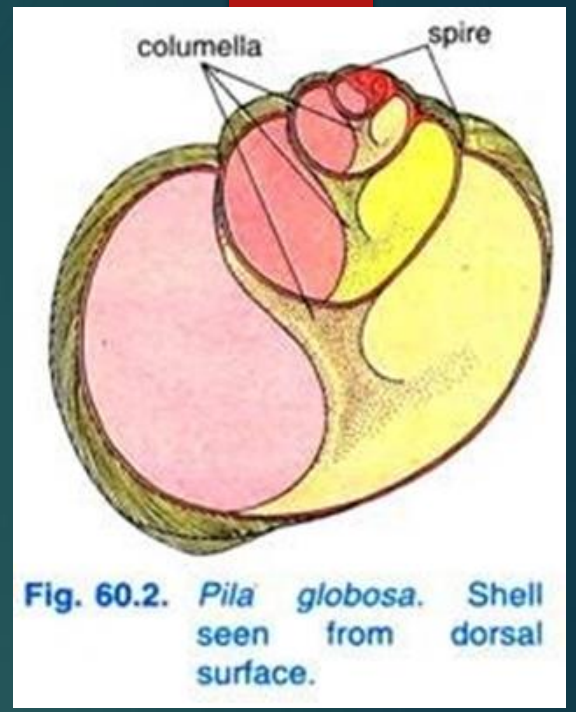


Fig. 60.2. *Pila globosa*. Shell seen from dorsal surface.

Microscopic Structure of Shell :

It consists of three layers-

1) Periostracum
2) Ostracum or Prismatic layer
3) Hypostracum or Nacre or Mother of Pearl

The shell of Pila globosa consists of an outermost pigmented layer called periostracum made of a horny organic conchiolin, below this is a prismatic layer made of crystalline calcareous plates running vertically, the innermost nacreous layer is made of calcareous plates running longitudinally.

Shells of Gastropoda display an infinite variety of shapes, sculpturing, patterns, and colours. Inside the shell is the mantle which secretes the shell.

When the foot is withdrawn the operculum closes the mouth of the shell. In the foot is a pedal mucous gland which forms a slime trail during locomotion. Waves of contraction which sweep from the anterior to the posterior end of the foot provide the main power for locomotion.

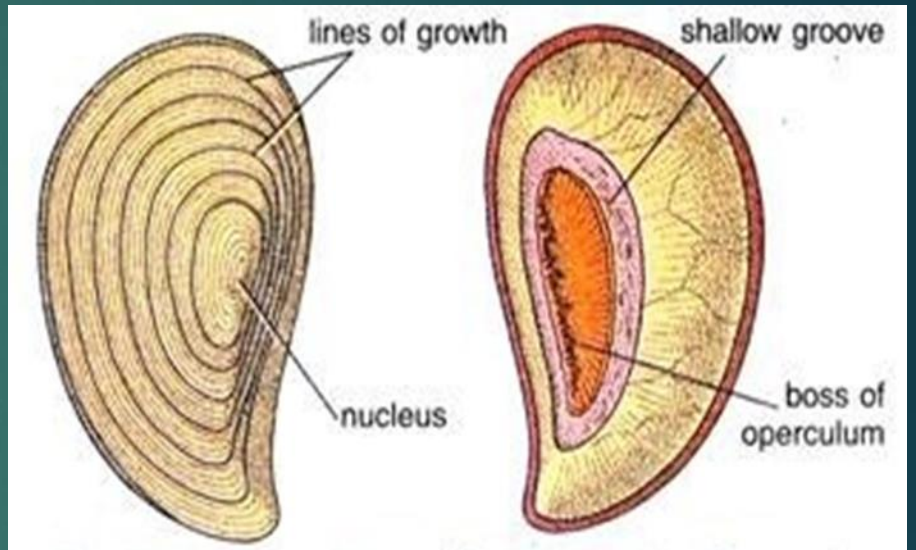


Fig. 60.3. *Pila globosa*. Operculum. A—Outer view; B—Inner view.

In fact, the head and the foot together constitute the head-foot complex which is connected to the visceral mass by an inconspicuous neck.

Body of Pila:

The body consists of a head, a foot and a visceral surface, mass. In an expanded animal the head and foot come out of the shell-mouth but the visceral mass lies inside the shell whorls. A collumellar muscle arises from the foot and is inserted in the columella, it attaches the body to the shell and it withdraws the animal inside and closes the operculum.

(i) Head:

There is a distinct head produced into a snout, the head bears two pairs of tentacles. The first pair of tentacles or labial palps are small and lie in front, behind them there is a second pair of tentacles which are long. The tentacles are hollow and capable of much extension and contraction. Behind the tentacles the head has a pair of eyes borne on stalks or ommatophores.

(ii) Foot:

Below the head is a large muscular foot, its lower surface is gray and flattened sole. It is triangular with the apex pointing backwards, it is used for creeping; its upper surface is spotted and the dorsal posterior surface bears the operculum.

(iii) Visceral Mass:

Above the head-foot complex is a visceral mass containing the main organs, it fills all the whorls of the shell and it is spirally-coiled like the shell. The visceral mass exhibits the phenomenon of torsion which is distinct from coiling. It is soft and grey to dark brown in colour.

Mantle or Pallial:

The mantle, also referred to as pallium, covers the visceral mass and it forms a hood over the animal when it is withdrawn. The edge of the mantle is thick and contains shell glands which secrete the shell, above the thickened edge there is a supra-marginal groove.

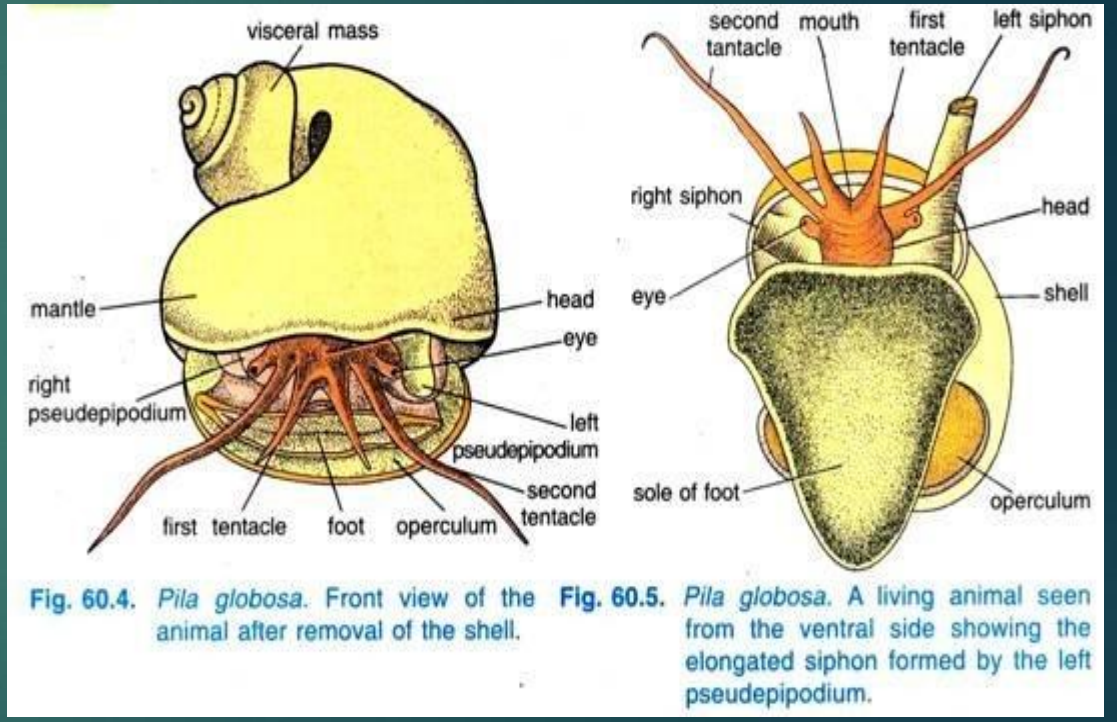


Fig. 60.4. *Pila globosa*. Front view of the animal after removal of the shell.

Fig. 60.5. *Pila globosa*. A living animal seen from the ventral side showing the elongated siphon formed by the left pseudepipodium.

The mantle also has two fleshy lobes called nuchal lobes or pseudepipodia which are joined on either side of the head. The left pseudepipodium forms a long tubular respiratory siphon for aerial respiration and a respiratory current enters, through it, the right pseudepipodium is less developed and not a regular tube, respiratory current passes out through it.

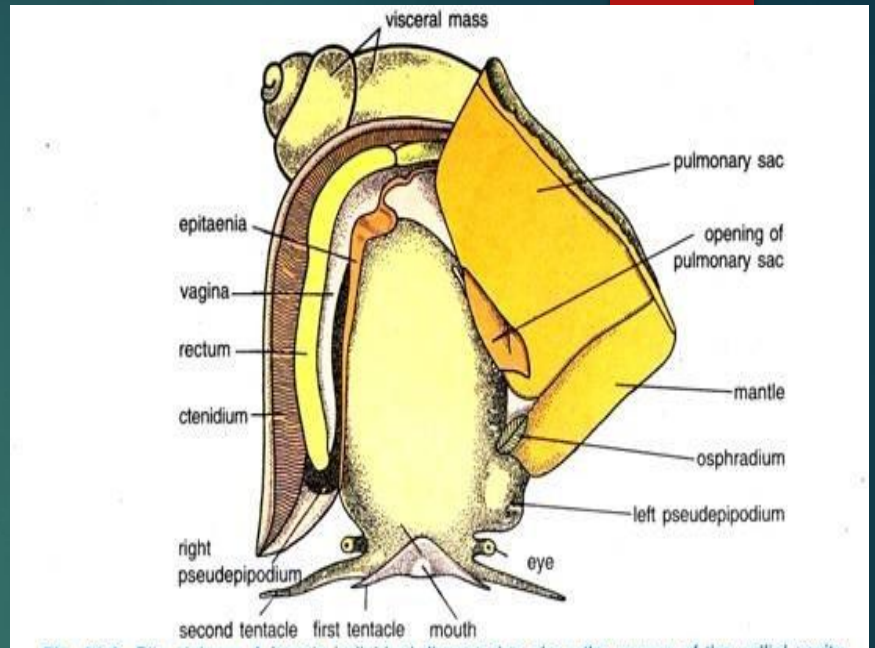


Fig. 60.6. *Pila globosa*. A female individual dissected to show the organs of the pallial cavity.

Mantle Cavity and Pallial Complex:

In the anterior part there is a large space between the mantle and the body, this is a mantle or pallial cavity which has been shifted to the front by a process of torsion. It encloses a number of organs and the head can be withdrawn into it. The mantle or pallial cavity encloses within it a number of important organs which are collectively known as pallial complex.

Near the right pseudepipodium is a prominent ridge or epitaenia which runs backwards up to the end of the mantle cavity, it divides the mantle cavity into a right branchial cavity and a left pulmonary sac.

In the branchial cavity or chamber lie a single gill or ctenidium, rectum and anus, the genital aperture and the anterior chamber of the kidney as a reddish mass near the posterior end of the epitaenia. Near the left pseudepipodium is a fleshy osphradium a typical molluscan sense organ.

Coelom of Pila Globosa:

The coelom is reduced to unpaired cavities of pericardium, kidney and gonad. The renal and pericardial cavities communicate, but the cavity of gonad is unconnected. The visceral organs are surrounded by means of sinuses or spaces containing blood. These blood-filled spaces constitute the haemocoel.

THANKS

STAY AT HOME & STAY SAFE

Digestive System of Pila Globosa:

The digestive system of Pila Globosa comprises:

1. A tubular alimentary canal
2. A pair of salivary glands
3. A large digestive gland

The alimentary canal is distinguished into three regions, viz:

1. The foregut or stomodaeum including the buccal mass and oesophagus,
2. The midgut or mesenteron consisting of stomach and intestine, and
3. The hindgut or proctodaeum comprising the rectum. The midgut alone is lined by endoderm, while the other two are lined by ectoderm.

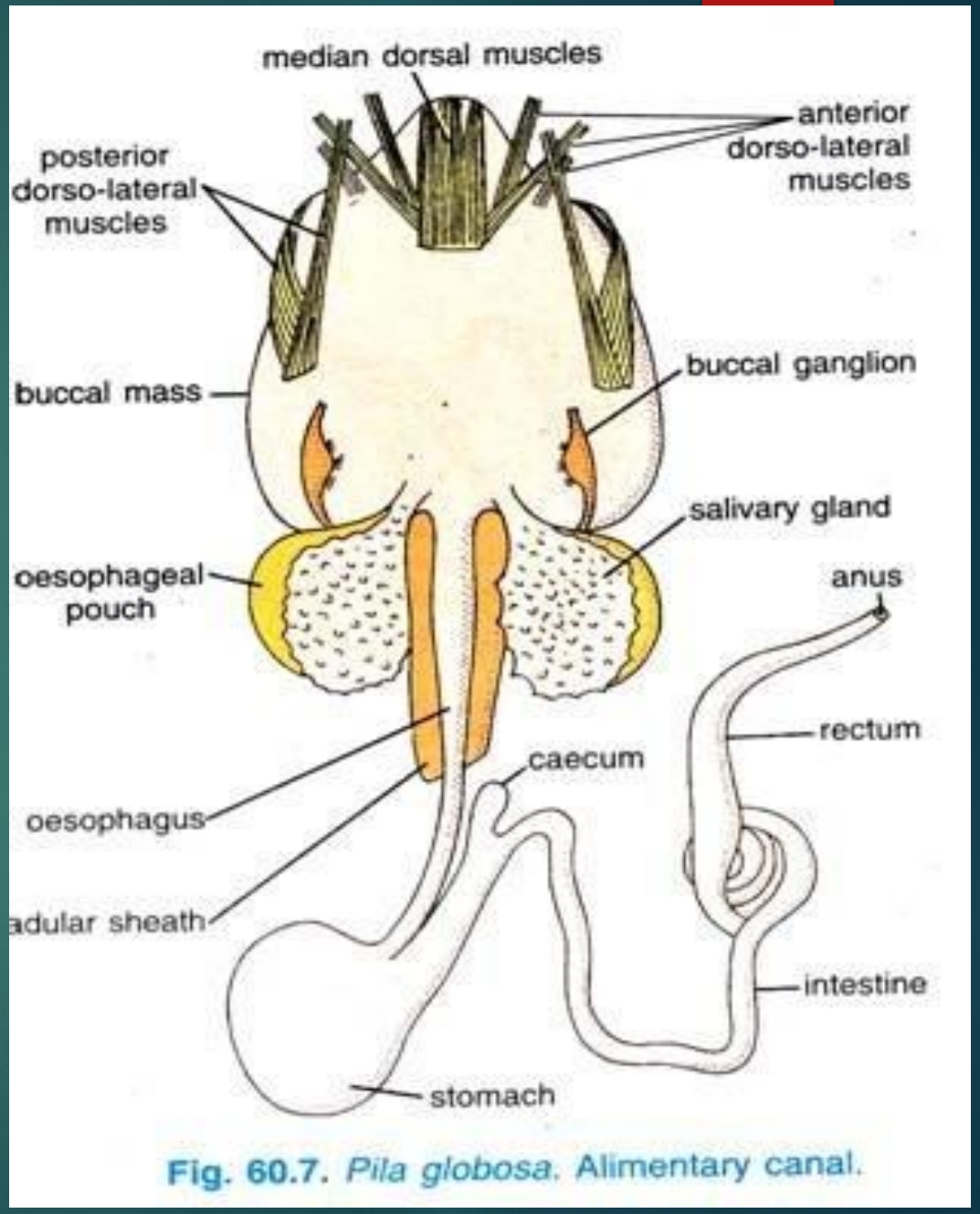


Fig. 60.7. *Pila globosa*. Alimentary canal.

1. Foregut: The foregut includes the mouth, buccal mass and oesophagus.

(i) Mouth:

The mouth is a narrow vertical slit situated at the end of snout. There are no true lips but the plicate edges alone serve as secondary lips.

(ii) Buccal Mass:

The mouth leads into a large cavity of buccal mass or pharynx having thick walls with several sets of muscles. The anterior part of the cavity of buccal mass is vestibule. Behind the vestibule are two jaws hanging from the roof of the buccal mass. The jaws bear muscles and their anterior edges have teeth-like projections for cutting up vegetable food.

Buccal Cavity:

Behind the jaws is a large buccal cavity. On the floor of the buccal cavity is a large elevation called odontophore. The front part of odontophore has a furrowed subradular organ which helps in cutting food. The odontophore has protractor and retractor muscles and two pairs of cartilages, a pair of triangular superior cartilages which project into the buccal cavity, and a pair of large S-shaped lateral cartilages.

Odontophore: On the floor of the buccal cavity is a large, laterally compressed elevation called odontophore or tongue mass. It consists of muscles and cartilages for support. It is covered by firm elastic membrane called subradular membrane and it forms anteriorly round process called the subradular organ. It helps in cutting the food material into smaller pieces. The odontophore has protractor and retractor muscles.

Radula:

The radular sac contains a narrow, cuticular ribbon known as radula or lingual ribbon. It is covered with numerous, minute, curved horny teeth arranged in transverse rows as in a file. Each row has seven teeth, two marginal and one lateral tooth on each side and a central or rachidian tooth in the middle, thus, giving a formula 2, 1, 1, 1, 2. The radula moves forward and backward on the odontophore for rasping food particles; these movements of radula are called chain saw movements.

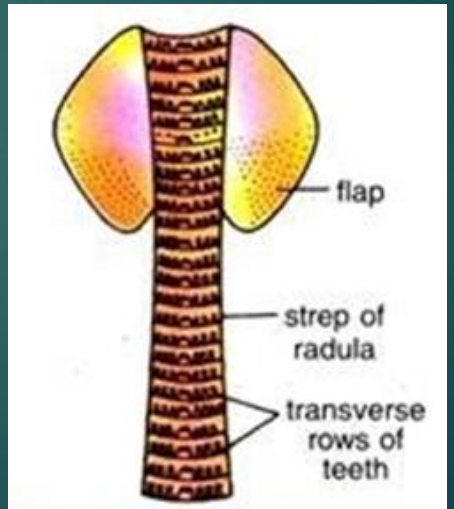


Fig. 60.10. *Pila globosa.* The radula.

The teeth are made of chitin which is reinforced by hardened protein, they have sharp cutting projections which act like a file and rasp vegetable food. The teeth of the radula are worn off in front and new teeth are formed all the time by odontoblasts. On the roof of buccal cavity, above the radula, is a pair of grooved buccal glands which are digestive.

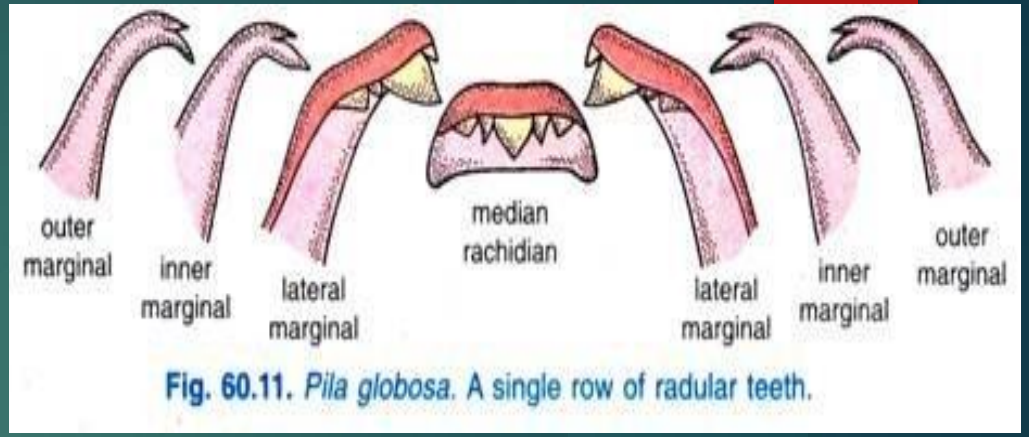


Fig. 60.11. *Pila globosa*. A single row of radular teeth.

Oesophagus:

The buccal mass leads into a long narrow oesophagus. From near the origin of the oesophagus arise a pair of round, whitish oesophageal pouches. They arise by short ducts and lie below the salivary glands. They are prolongations of the oesophagus, they probably secrete digestive enzymes.

Oesophageal pouches serve for a temporary storage of food and digestion begins in them. Some extracellular digestion is brought about in the stomach by the enzymes produced by the salivary glands and oesophageal pouches.

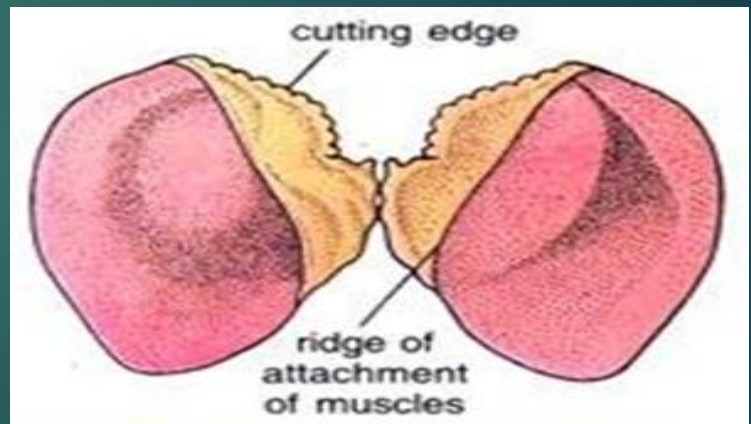


Fig. 60.12. *Pila globosa*. Jaws.

Midgut: The midgut includes the stomach and intestine.

(i) Stomach:

The stomach begins on the left side just below the pericardium and runs backwards as a blind pouch on the postero-lateral sides of the main whorl of the visceral mass. It is a rectangular sac of dark red colour having a broad U-shaped internal cavity of rose-red colour. The stomach is differentiated into two chambers—cardiac chamber and pyloric chamber.

The cardiac chamber is rounded in appearance and possesses longitudinal folds on its inner surface. The oesophagus opens into it. The pyloric chamber is tubular and has transverse folds on its inner surface. From the pyloric chamber arises a short bag-like caecum but it has no crystalline style as found in many gastropods. The duct of digestive gland opens into the stomach at the junction of its two chambers.

(ii) Intestine:

From the pyloric chamber arises an intestine which runs along its anterior edge and further along the digestive gland beneath the posterior renal chamber. It then turns upwards and backwards in the visceral mass where it forms 2½ or 3 coils between the gonad in front and the digestive gland behind, before joining the rectum.

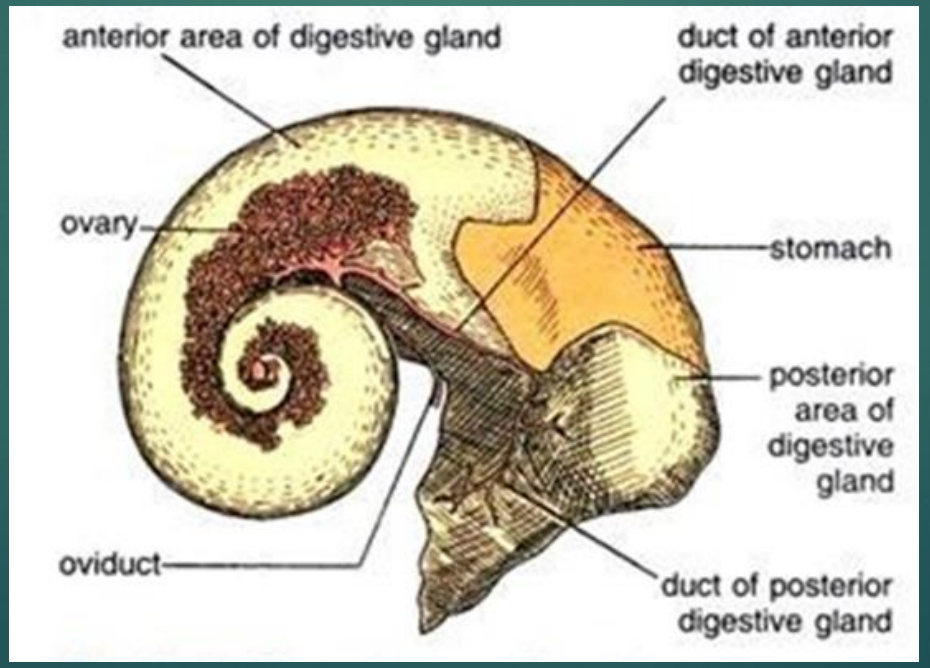
3. Hindgut:

The rectum or terminal part of the alimentary canal is a thick-walled tube. It enters the mantle cavity and passes downwards to open by an anus on the right of the head.

Salivary Glands:

The two salivary glands lying one on each side of the posterior limit of the buccal mass and partially cover the oesophagus. The surface and margins of each gland are greatly cut up, giving it the appearance of a somewhat branched type of gland.

The duct of each gland begins near its internal anterior corner and immediately enters the muscles of the buccal mass and opens into the buccal cavity. The secretion of salivary glands contains mucus and an enzyme which digests starch. The mucus lubricates the radula and helps in the transport of food.



Digestive Glands:

- The digestive gland, often referred to as liver or hepatopancreas of Pila is a somewhat triangular plate or cone with a very convex outer and more or less flattened inner surface. The cone is spirally coiled from the tip inwards and downwards following the whorls of the shell.
- The gland is of a brownish to dirty green colour and is quite soft when fresh. Two main ducts arise from the two main lobes of the digestive gland; these ducts unite just before reaching stomach to open into it by a common aperture.
- The digestive gland is made up of a number of fine tubules bound together by connective tissue. These tubules unite with one another to form larger tubules which terminate in two main ducts corresponding to two main lobes of the gland. The terminal part of each tubule is glandular, called the alveolus and the rest of the tubule is ciliated.
- The alveoli have three kinds of cells, they are secretory, resorptive and calcareous cells or lime cells. The secretory cells produce a brown liquid containing an enzyme which dissolves cellulose of plants in the stomach converting in into pulp. The resorptive cells produce a proteolytic enzyme. This enzyme brings about intracellular digestion of cellulose pulp. The calcareous cells store phosphate of lime.

Food and Feeding:

- The food consists of aquatic plants of succulent nature like Vallisneria and Plstia which are cut by jaws and the odontophore, then the radula moves forwards and backwards filing the food into small particles exactly like the chain-saw mechanism.
- Thus, the food is cut up and masticated inside the buccal cavity.

(iii) Digestion:

- The salivary glands pour their secretion by means of their ducts into the buccal cavity where it mixes with the food.
- It helps in digesting the starch by converting it into sugar.
- In the stomach the food is digested by the secretion of digestive gland.
- Secretion of digestive gland digests various kinds of food but cellulose is digested inside the resorptive cells only.
- Thus, both extracellular and intercellular digestion occur.
- The stomach is the site of extracellular digestion and the digestive gland is the site of intracellular digestion and absorption, this is characteristic of Mollusca.
- Absorption of digested food takes place mainly in the digestive gland and some in the intestine.

Respiratory Organs of Pila:

The respiratory organs consist of ----

1. a single ctenidium or gill,
2. a pulmonary sac or lung and
3. a pair of nuchal lobes.

1. Ctenidium or Gill:

- The ctenidium or gill is the organ of aquatic respiration. The ctenidium is situated on the dorsolateral wall of the branchial chamber of the mantle cavity.
- It is composed of a long series of thin triangular leaflets or lamellae, lying parallel to each other, which are attached to the mantle wall by their broad bases but have their apices hanging free in the branchial chamber.
- The line of attachment of the lamellae to the wall of the mantle forms the ctenidial axis.
- The ctenidial axis is provided with an afferent blood vessel (carrying deoxygenated blood) and an efferent blood vessel (carrying oxygenated blood) from gills to heart.
- All the gill lamellae are not of the same size; these are largest in the middle and gradually smaller towards the two ends. Such a gill is known as monopectinate gill.
- Each lamella bears transverse ridges or pleats on both its anterior and posterior surfaces.
- These pleats are low ridges gradually decreasing in size from the base of the lamella to its apex. Each ridge contains branches of blood vessels.
- Each lamella has a smaller right side, which receives blood from the afferent vessel, is called the afferent side and a longer left side, from which blood goes into the efferent vessel, is called the efferent side.

- The ctenidium of Pila, though situated on the right side of the animal, is morphologically the gill of the left side, which has shifted to the right on account of the development of an extensive pulmonary sac on the left side.
- This is shown by the blood supply and the innervation of the ctenidium and is further confirmed by the situation of the osphradium which still retains its original position on the left side of the animal.
- Histologically, each lamella appears to be a hollow cavity lined on either side by the epithelium containing non-ciliated columnar cells, ciliated columnar cells and a few glandular cells.
- The epithelial layer is followed by a thin basement membrane below which are found connective tissue cells having scattered nuclei and oblique muscle fibres.

Pulmonary Sac or Lung:

- The pulmonary sac or lung is a closed cavity like a bag which hangs from the dorsal wall of the mantle in the pulmonary chamber.
- The dorsal wall of the pulmonary sac is densely pigmented, while the ventral wall is creamy white.
- The walls of the sac are highly vascular, i.e., richly supplied with blood vessels. The pulmonary sac communicates with the pulmonary chamber of the branchial cavity by an aperture known as the pneumostome.

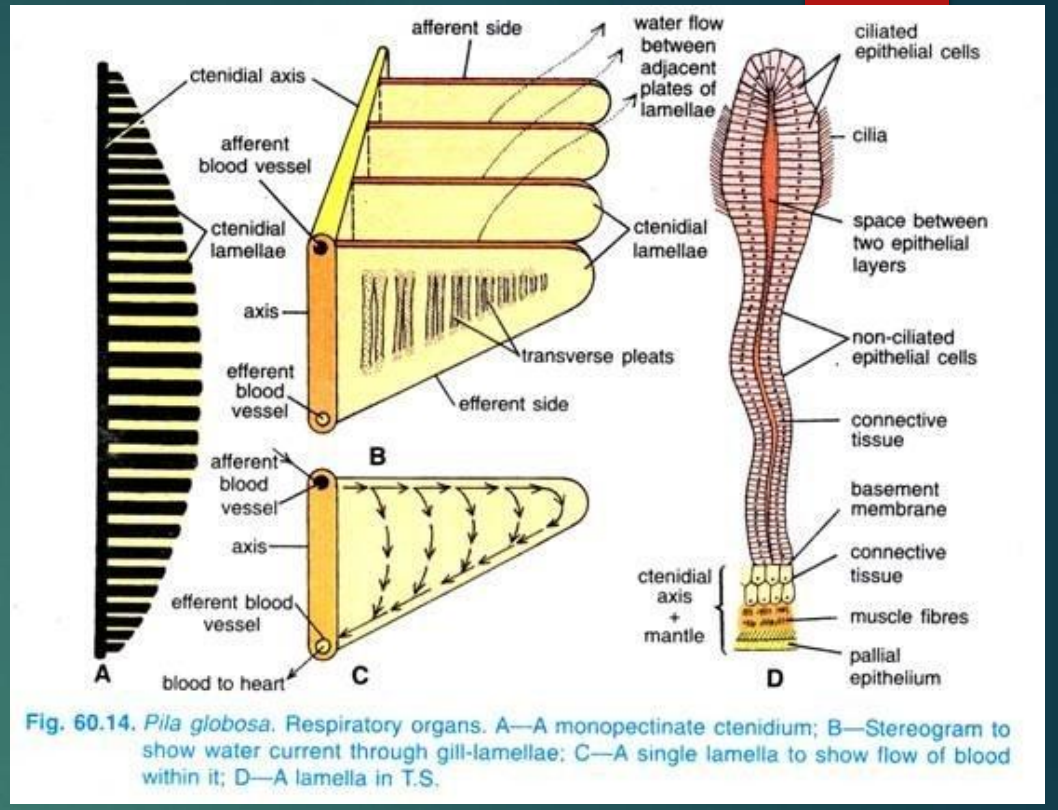


Fig. 60.14. *Pila globosa*. Respiratory organs. A—A monopectinate ctenidium; B—Stereogram to show water current through gill-lamellae; C—A single lamella to show flow of blood within it; D—A lamella in T.S.

Nuchal Lobes:

The right and left pseudepipodia or nuchal lobes are fleshy and highly contractile processes of the mantle on either side of the head. They form elongated funnels or siphons during respiration for the entry and exit of water.

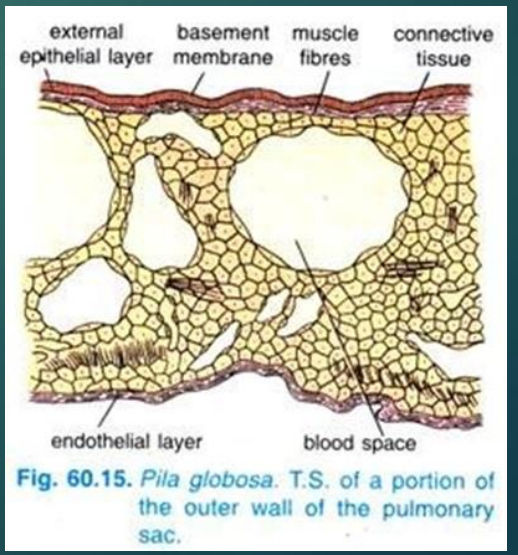


Fig. 60.15. *Pila globosa*. T.S. of a portion of the outer wall of the pulmonary sac.

Mechanism of Respiration:

There are two types of respiration in Pila which are as follows:

(i) Aquatic Respiration:

True aquatic respiration takes place when the snail lies at the bottom of a pond or aquarium, when it is floating or lying suspended in mid-water and when it is attached to plants or Weeds in water. At this time the head and foot is fully extended and the two nuchal lobes further increase in size and the left lobe takes the form of a distinct gutter in which a current of water flows.

In aquatic respiration a current of water enters the left nuchal lobe and first comes in contact with the osphradium which tests the nature of the water.

It enters the mantle cavity and passes over the epitaenia into the branchial chamber to bathe endothelial layer blood space the ctenidium, then the current passes out through the right nuchal lobe (Fig. 60.16 A). The ctenidium takes in oxygen from the current of water and gives out carbon dioxide which diffuses into water.

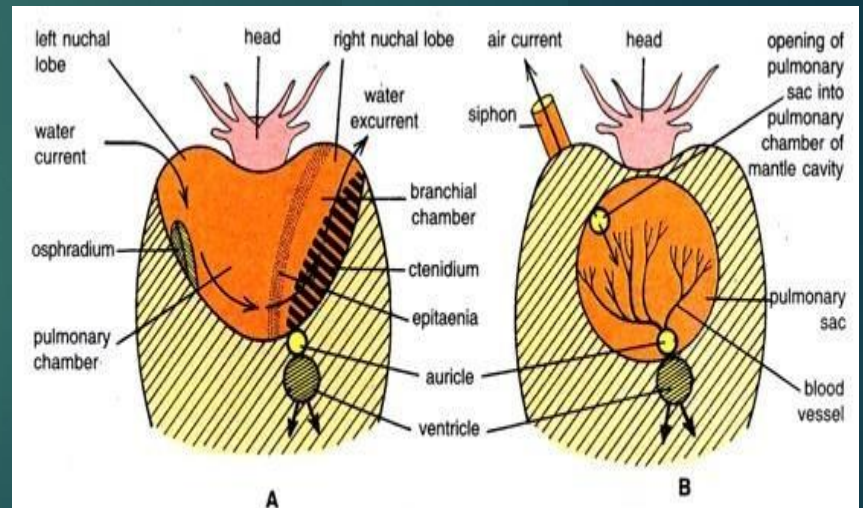
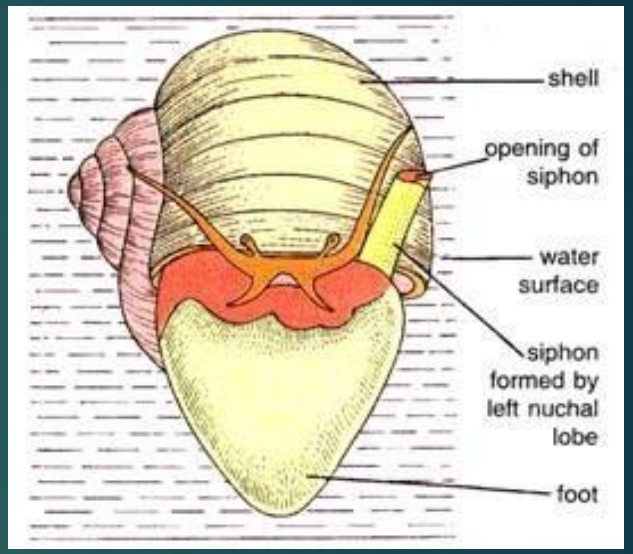


Fig. 60.16. *Pila globosa. Diagrams showing mechanism of respiration. A—During aquatic respiration; B—During aerial respiration.*

Aerial Respiration:

- The pulmonary sac or lung is used in aerial respiration in two ways. When the snail comes to the surface of water its left nuchal lobe projects as a tube above the water and air is drawn into it, the air goes to the pulmonary chamber and then into the lung; the branchial chamber being shut off by the epitaenia pressing against the mantle.
- When the snail comes on land it takes in air directly into its lung through the mantle cavity and no siphon is formed by the left nuchal lobe.
- In both types of aerial respiration alternate contractions and relaxations of the muscles of the lung walls take place, when the muscles contract the floor of the lung gets arched increasing its cavity and air is drawn into the lung, when the muscles relax the cavity of the lung decreases and air is expelled, inward and outward movements of the head and foot also help in the process of taking in air.
- The blood vessels in the lung take in oxygen from the air and give out carbon dioxide (Fig. 60.16 B). Pila globosa also respires by its pulmonary sac during aestivation period by means of the air already imprisoned in the pulmonary sac.



Blood Vascular System of Pila Globosa:

Due to double mode of respiration the blood vascular system of Pila globosa has become very much complicated. It is of open type.

It consists of:

(i) Pericardium
(ii) Heart
(iii) Arteries
(iv) Sinuses
(v) Veins, through which the blood flows.

Pericardium:

- The pericardium is a thin-walled ovoid sac lying dorsally on the left side of the body whorl behind the mantle cavity. It extends anteriorly up to the stomach and digestive gland.
- It is a fairly deep cavity which communicates with that of the posterior renal chamber through a reno-pericardial aperture.
- The pericardium corresponds to the coelom of annelids and vertebrates.
- It encloses the two chambers of the heart, the main aortic arches and the aortic ampulla.

Heart:

The heart of Pila has a single auricle and one ventricle found enclosed in the pericardium. Physiologically, the heart is said to be myogenic.

(a) Auricle:

- The auricle lies in the dorsal part of the pericardium, while the ventricle is situated just below it in the same vertical axis.
- The auricle is a thin-walled, highly contractile sac and more or less triangular in shape.
- The efferent ctenidial vein from the ctenidium and the efferent renal vein from the posterior chamber of the renal organ open into the apex of the auricle, while the pulmonary vein from pulmonary sac opens at a slightly lower level at its anterior end.
- The auricle communicates with the ventricle by an aperture auriculo-ventricular opening having two semi-lunar valves, so arranged as to allow the blood from the auricle to flow into the ventricle but not in the reverse direction.

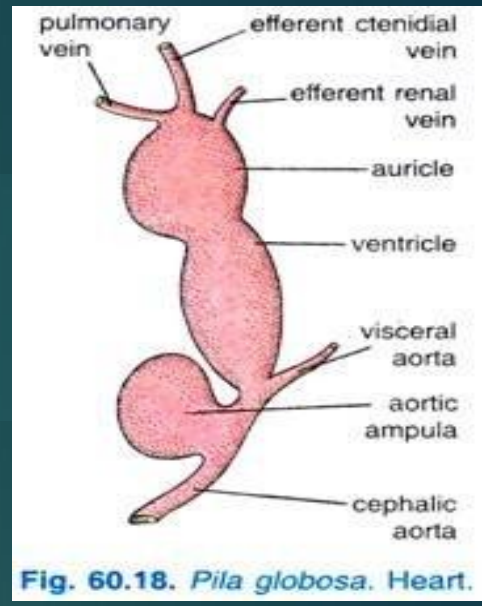


Fig. 60.18. *Pila globosa*. Heart.

(b) Ventricle:

- The ventricle is ovoidal in shape and has thick spongy wall formed of a large number of muscular strands forming a meshwork which greatly reduces the cavity of the ventricle.
- The aortic trunk arises from the lower end of the ventricle and divides immediately into two branches, the cephalic aorta and visceral aorta.
- The opening between ventricle and aortic trunk is guarded by two semi-lunar valves which prevent the flow of blood from back into the ventricle.

(c) Arteries:

- From the ventricle arises an aorta or aortic-trunk which divides into two branches, a cephalic aorta and a visceral aorta.
- The cephalic aorta has a bulbous outgrowth called aortic ampulla, a characteristic of the members of the family Pilidae, which aids in circulation of blood and controls blood pressure.
- The opening of aortic ampulla into cephalic aorta is devoid of valves.
- The cephalic aorta sends arteries to the head and buccal mass, the visceral aorta forms arteries going to the visceral mass.

(d) Cephalic Aorta:

- The cephalic aorta, immediately beyond aortic ampulla, gives out three arteries; first supplying to the skin, the cutaneous artery, second supplying to the oesophagus, the oesophageal artery and third being stout and thick supplies to the left side of the mantle (organs like left nuchal lobe and osphradium), the left pallial artery.
- The cephalic aorta on its inner side gives out an artery supplying to the pericardium, renal chambers and to a portion of the genital organs, the pericardial artery.

The main trunk of cephalic aorta then runs ahead and crosses over the oesophagus so as to reach to its right side.
It now gives off numerous small branches to the oesophageal area and a large branch to the right side which finally gives out a right pallial artery, supplying to the right part of mantle, a right siphonal artery, supplying to the right nuchal lobe and a penial artery, supplying to the copulatory organ.
The main trunk of cephalic aorta, however, also branches to give a radular sac artery supplying to radular sac, an optic artery supplying to the eyestalks and eyes, a tentacular artery supplying to the tentacles and pedal arteries supplying to the foot.

Visceral Aorta:
The visceral aorta runs into the visceral mass and supplies to its different organs by giving off many branches.
These branches are:
A pericardial artery to the pericardium, skin and digestive glands, a gastric artery to the stomach, many small intestinal arteries to the intestine, many renal arteries to the roof of the posterior renal chamber, a hepatic artery to the digestive gland and gonad, several small arteries to the tip of the genital duct and then finally the visceral aorta terminates in the rectal wall.

Sinuses:
The blood after being distributed to the various parts of the body through the arteries and their branches passes into small lacunae, which in turn unite to form large sinuses.
There are four chief sinuses in the body:
(a) Anterior peri-visceral sinus.
(b) Anterior peri- intestinal sinus.
(c) Branchio-renal sinus and
(d) Pulmonary sinus.
(a) Anterior peri-visceral sinus:
It lies above the foot and beneath the floor of the pallial cavity surrounding the anterior part of the alimentary canal. It collects blood supplied by the cephalic aorta, except pericardial artery, and some branches of visceral aorta.
(b) Anterior peri-intestinal sinus:
It lies on the columellar axis next to the intestine and the terminal part of the genital duct and runs along the coils of the intestine up to the junction of the anterior and posterior renal chambers. It collects blood from viscera mainly distributed by visceral aorta.
(c) Branchio-renal sinus:
It lies along the right side of the anterior renal chamber. It collects blood from renal chambers.
(d) Pulmonary sinus:
It lies in the walls of the pulmonary sac. It collects blood from pulmonary sac.

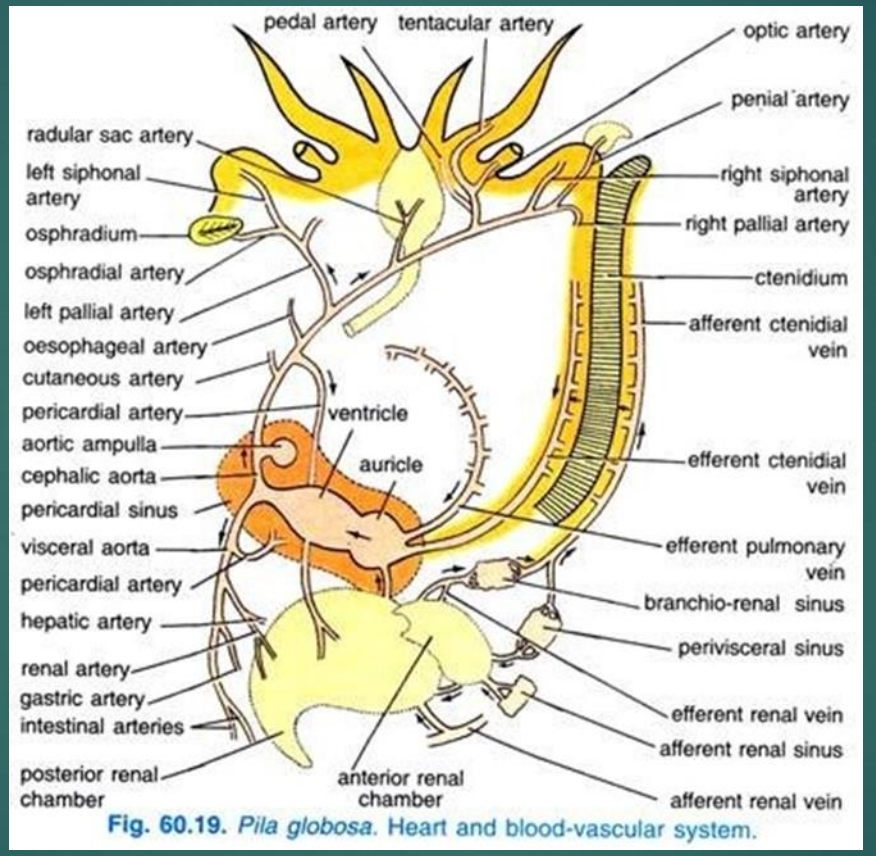


Fig. 60.19. *Pila globosa.* Heart and blood-vascular system.

Veins:
The veins carry venous blood from different parts of the body to the auricle directly or through the gill, mantle and kidney.
The chief veins are as follows:
(a) Afferent ctenidial vein:
It lies above the rectum and receives branches from the rectum, terminal part of the genital duct, peri-visceral sinus and branchio-renal sinus. It sends blood through numerous branches, to the gill-lamellae for purification.
(b) Efferent ctenidial vein:
It lies along the roof of the anterior renal chamber and carries blood from ctenidial leaflets, mantle and conveys to the auricle.
(c) Afferent renal vein:
It is situated on the roof of posterior renal chamber, and originates from the peri-intestinal sinus. It pours its blood into the posterior renal chamber.
(d) Efferent renal vein:
It carries the blood of the posterior renal chamber to the auricle.
(e) Pulmonary vein:
It collects blood from the walls of the pulmonary sac and opens into the auricle.

Blood:

The blood of gastropods contains a respiratory pigment called haemocyanin which is a compound of copper and protein, haemocyanin is dissolved in the plasma and gives a faintly blue colour to the blood.

But in a few gastropods, such as Planorbis, haemoglobin is found in place of haemocyanin. In the blood plasma are stellate amoebocytes which are phagocytic, they remove waste substances and some of them carry on intracellular digestion.

Course of Circulation:

All parts of the body are supplied with blood from the ventricle through the cephalic and visceral aortae. The cephalic aorta carries blood to the head and its associated structures, a part of the mantle, the buccal mass, the oesophagus, the copulatory organ and the columellar muscle.

The visceral aorta supplies the whole of the visceral mass. The blood is collected from the various parts of the body into two main sinuses the peri-visceral and peri-intestinal. From these sinuses, the blood passes either into the ctenidium, pulmonary sac or into the renal organ.

During aquatic respiration the blood from the peri-visceral sinus goes to the ctenidium and is purified; an efferent ctenidial vein then takes this blood into the auricle. During aerial respiration the blood from the peri-visceral sinus goes to the lung and is purified; a pulmonary vein takes this blood into the auricle.

The blood from the peri-intestinal sinus takes two courses, it either goes from this sinus to the anterior renal chamber and from there to the ctenidium and is purified, then through the efferent ctenidial vein it goes to the auricle.

Or the blood from the peri-intestinal sinus goes to the anterior renal chamber, then to the posterior renal chamber (blood from the peri-intestinal sinus can also go direct to the posterior renal chamber without going to the anterior renal chamber); in any case the blood from the posterior renal chamber goes through an efferent renal vein into the auricle.

Thus, the auricle receives pure blood from the ctenidium or the lung and impure blood from the posterior renal chamber, this mixed blood enters the ventricle and is distributed to the arteries. The renal chambers, however, remove waste substances from the blood.

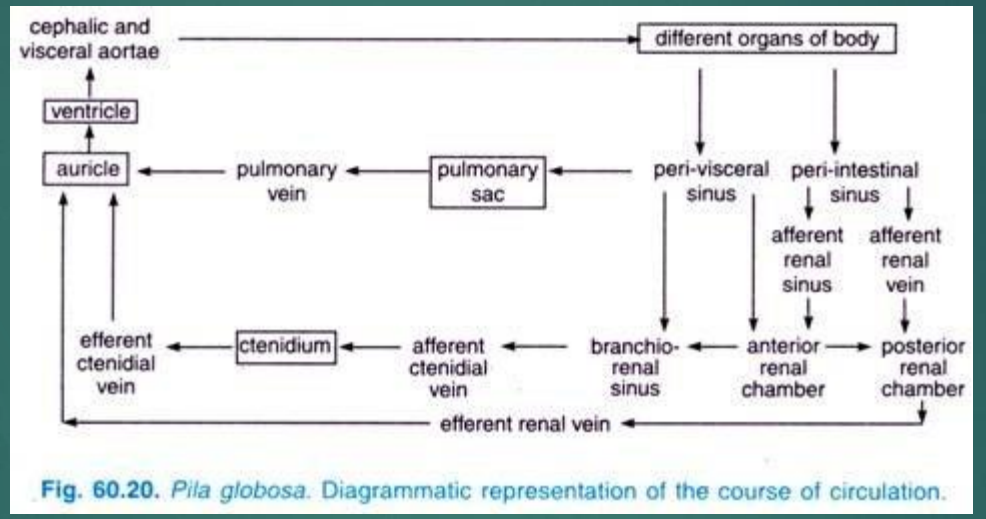


Fig. 60.20. *Pila globosa*. Diagrammatic representation of the course of circulation.

Excretory System of Pila Globosa:

There is a single large renal organ or kidney or organ of Bojanus lying behind the pericardium. It is a thick-walled sac which is much folded within.

The renal organ consists of two distinct chambers:

A right anterior renal chamber and a left posterior renal chamber. The renal organ of Pila globosa corresponds to the left kidney of Diotocardia, while the right kidney in this order has been modified to form the genital duct.

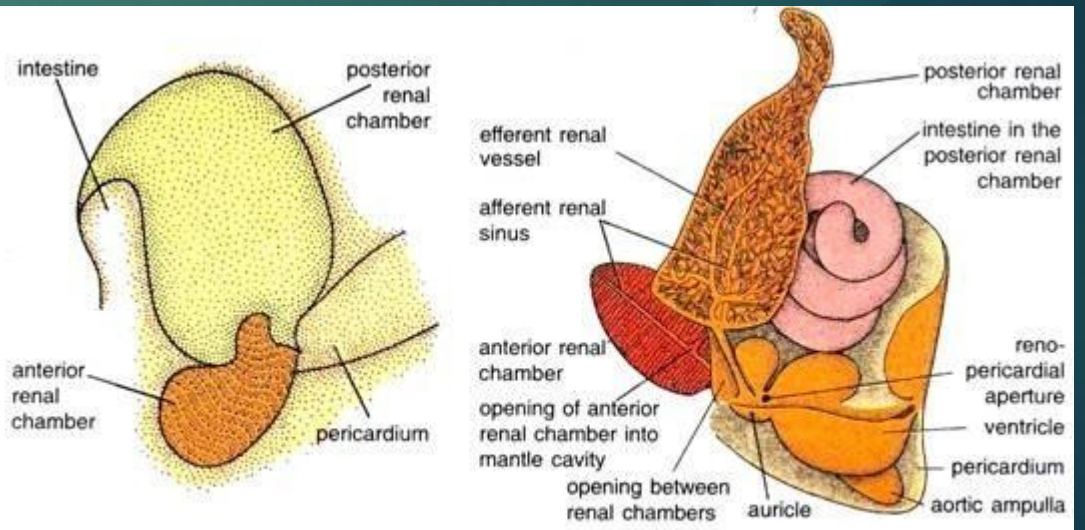


Fig. 60.21. *Pila globosa*. Renal chamber seen from above.

Fig. 60.22. *Pila globosa*. Pericardium and two chambers of renal organ.

Anterior Renal Chamber:

It is a reddish organ somewhat ovoidal in outline, situated in front of pericardium and the posterior renal chamber. It projects into the mantle cavity and opens into it in a deep crypt through an elongated opening lying to the right of the epitaenia. The upper surface of the chamber shows shallow grooves corresponding to the internal lamellae, which hang downwards from the roof into the cavity of the chamber.

The lamellae on the roof are arranged on either side of a median longitudinal axis, the efferent renal sinus. The lamellae on the floor are arranged on either side of a similar median axis, the afferent renal sinus which is the branch of the peri-intestinal sinus. It breaks up into numerous branches to supply the lamellae on both the sides.

Posterior Renal Chamber:

The posterior renal chamber is a broad, somewhat hook-shaped area of a brownish to dusky grey colour, situated behind the anterior renal chamber in between the rectum on the left and pericardium and digestive gland on the right. It contains a large cavity in which a genital duct and a few coils of intestine lie.

The roof of the chamber is richly supplied with blood vessels resulting from a repeated division of the afferent and efferent renal vessels of this chamber.

The posterior renal chamber communicates with the pericardium by a reno-pericardial aperture at one end and with the anterior renal chamber through an aperture at the other end. The floor of the posterior renal chamber consist of a thin lining of tissue which separates its cavity from the organs which project into it.

Physiology of Excretion:

Both the renal chambers in Pila globosa have a true excretory function and excrete nitrogenous waste products. Owing to a single external opening, the excretory products from the posterior chamber are collected and emptied into the anterior chamber, from where they are discharged into the pallial cavity through the external renal opening.

The kidney is a coelomoduct communicating at one end with the coelom (pericardium) and at the other end with the exterior (mantle cavity). The kidney removes nitrogenous waste from the blood, waste is discharged into the mantle cavity. Excretory matter contains mostly ammonia, and some ammonium compounds, urea and uric acid.

In order to conserve water ammonia is converted into the relatively insoluble uric acid.

This adaptation for water conservation is particularly striking in Pila globosa which is seasonally amphibious, during its aquatic phase it excretes ammonium compounds, but during its terrestrial phase it excretes uric acid. In most Gastropoda the digestive gland plays a role in excretion because it contains some excretory cells that take up waste which is eliminated by way of the stomach and intestine.

Nervous System of Pila Globosa:

The nervous system of Pila globosa consists of paired and unpaired ganglia with their commissures and connectives. The commissures are the nerves which establish connections between similar ganglia, while connectives are the nerves which connect two dissimilar or different ganglia. However, the paired ganglia of Pila are cerebral, buccal, pleural, pedal and visceral, while unpaired ganglia are supraintestinal and infraintestinal.

These ganglia with their commissures and connectives are described below:

1. Cerebral Ganglia:

There are two triangular cerebral ganglia, one on each side above the buccal mass, they are connected to each other by a thick cerebral commissure running transversely above the buccal mass, and by a thin labial commissure lying below the buccal mass. Each cerebral ganglion is further connected with the buccal ganglion of its side through a very slender cerebro-buccal connective. Thick band-shaped cerebro-pleural and cerebro-pedal connectives serve to connect each cerebral ganglion with the corresponding pleural and pedal ganglia. Each cerebral ganglion gives off several nerves supplying anteriorly the skin of snout, the tentacle and the buccal mass; and posteriorly the tentacle, the eye and the statocyst.

2. Buccal Ganglia:

At the junction of the buccal mass and oesophagus are two buccal ganglia. They are connected to each other by a transverse buccal commissure. They are also connected to the cerebral ganglia by a cerebro-buccal connective on each side, the connectives lie above the buccal mass. Nerves from each buccal ganglion supply the buccal mass, radular sac, salivary glands, oesophagus and the oesophageal pouches.

3. Pleuro-pedal Ganglionic Mass:

In fact, the pleural and pedal ganglia of each side join together to form a pleuro-pedal ganglionic mass situated below the buccal mass. In a pleuro- pedal ganglionic mass, the pleural ganglion is placed towards the outer side and the pedal ganglion to the inner side. The pleuro-pedal ganglionic mass is connected to the cerebral ganglion of its side by a cerebro-pleural connective and cerebro-pedal connective.

The two pedal ganglia are connected to each other by two pedal commissures lying closely parallel to each other. The right pleuro-pedal mass has an infra-intestinal or a sub-intestinal ganglion also fused with it. A slender, loop-like infra-intestinal nerve behind the pedal commissure, connects the pleural ganglia of both the sides. A statocyst is connected by a band of connective tissue, to each pedal ganglion.

Supra-intestinal Ganglion:

The supra-intestinal ganglion is a slightly swollen, more or less fusiform ganglion lying in a sinus about a quarter of an inch behind the pleuro-pedal mass of the left side.

It is connected with the pleuro-pedal mass by a stout connective, called zygoneury. It gives off on the inner side a thin supra-intestinal nerve which runs anteriorly above the intestine to the right side to join the right pleural ganglion. The supra-intestinal ganglion also sends off posteriorly a branch, the left visceral connective which connects it with the visceral ganglion.

5. Visceral Ganglion:

The visceral ganglion is formed by the fusion of two spindle-shaped ganglionic masses.

It lies near the base of the visceral mass close to the anterior lobe of the digestive gland and to the right of the pericardium. The visceral ganglion is connected with the supra-intestinal ganglion by a stout supra-intestinal or left visceral connective. It is further connected with the fused right pleural and infra-intestinal ganglion through the infra-intestinal or the right visceral connective.

Nerves from the cerebral ganglia go to the head, tentacles and eyes. The buccal ganglia send nerves to the buccal mass. Nerves from the pedal ganglia innervate the foot, and those from the pleural ganglia go to the mantle, ctenidium and siphons. From the visceral ganglion nerves go to the intestine, kidney and gonads. These nerves constitute the peripheral nerves.

Characteristics of Nervous System:

The nervous system of Pila globosa shows two characteristics, firstly most of the ganglia, except the visceral, are concentrated near the buccal mass, secondly the visceral loop is twisted into a figure of 8 due to torsion. The twisted condition of the nervous system is a primitive feature, because in most gastropods there is a secondary bilateral symmetry shown by the ganglia and connectives.

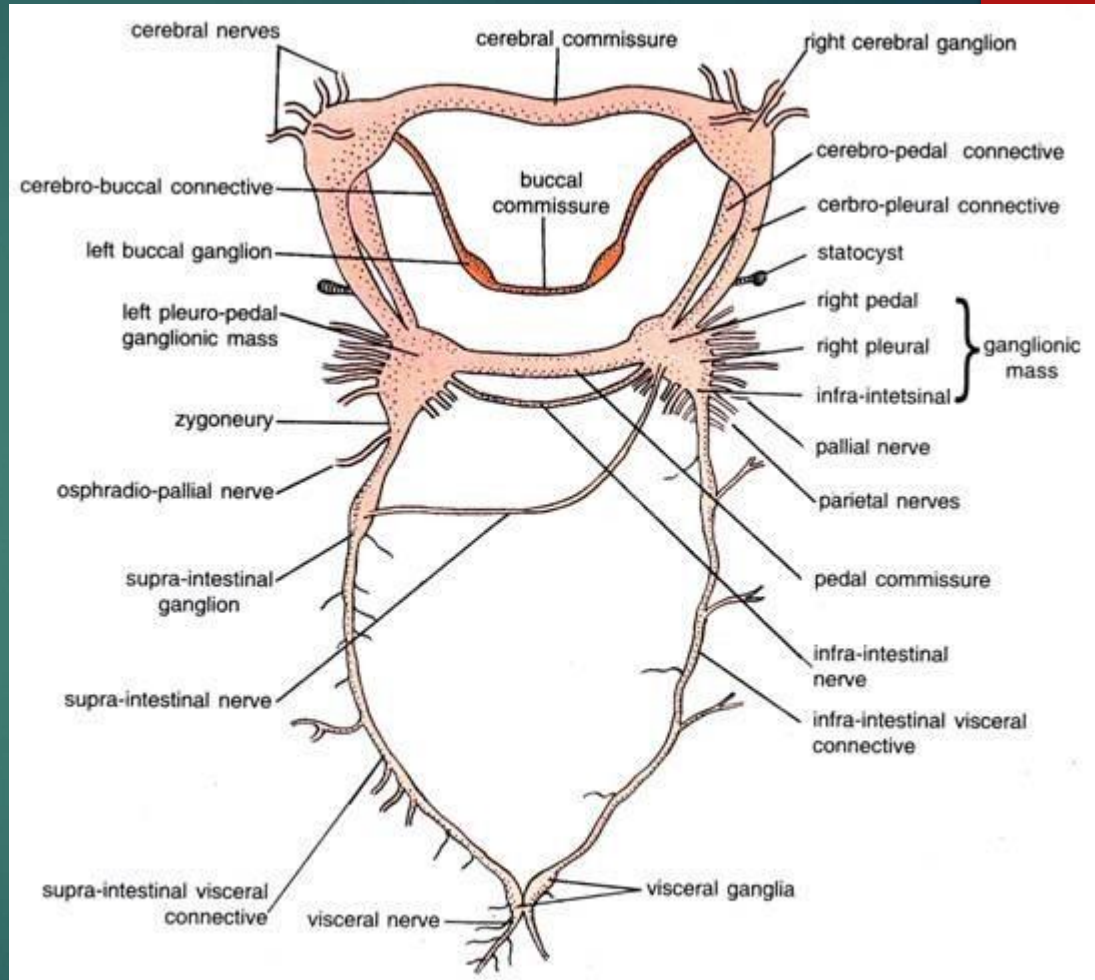


Fig. 60.23. *Pila globosa*. Nervous system.

Sense Organs of Pila Globosa:

In Pila Globosa, the special organs of sense are a single osphradium, paired eyes, statocysts, and tentacles.

1. Osphradium:

Osphradium hangs from the mantle near the left pseudepipodium. It is oval with 22 to 28 fleshy leaflets arranged on the sides of a central axis. It is a chemoreceptor and tests the current of water which enters the mantle cavity through the left pseudepipodium, it also exercises selection over the food taken in.

The evolution of gastropod osphradium parallels that of ctenidia, in primitive forms an osphradium is present for each ctenidium, in prosobranchs which have one ctenidium there is only a single osphradium; the osphradium disappears in those gastropods which have lost the ctenidia, or have a reduced mantle cavity, or have become pelgic.

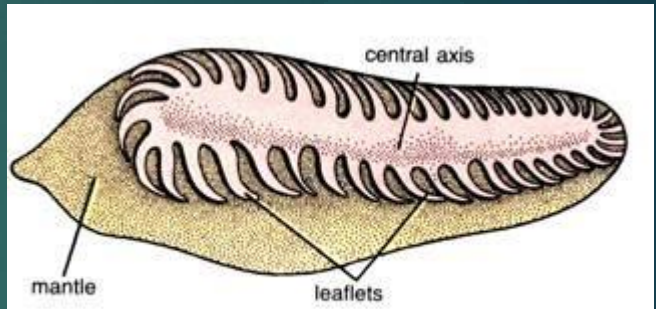


Fig. 60.24. *Pila globosa*. Osphradium.

Statocysts:
Located in the foot near each pedal ganglion lies a statocyst in a depression. It is a round capsule lined with epithelial cells and surrounded by connective tissue. In the cavity of the capsule are small calcareous statoconia. The statocysts receive nerves from pedal and cerebral ganglia, they are organs of equilibrium and regulate the position of the snail.

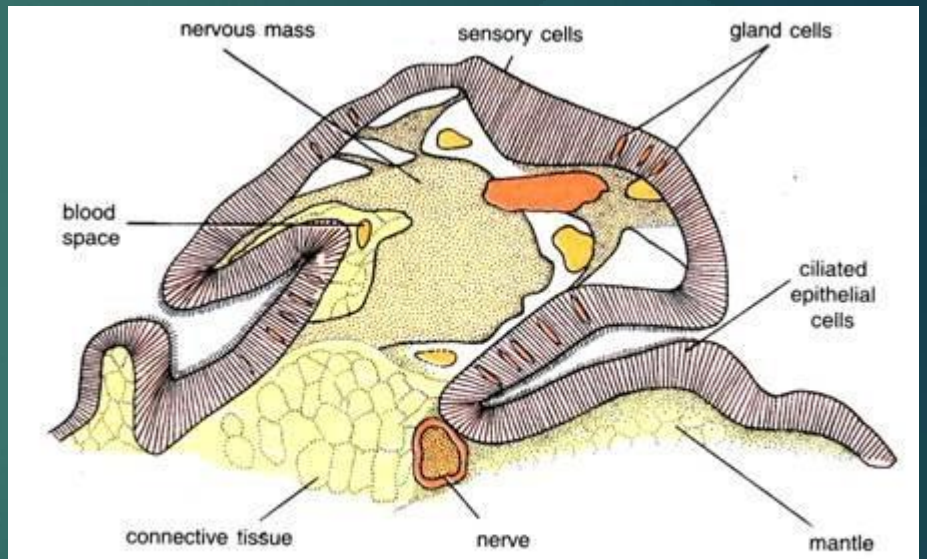


Fig. 60.25. *Pila globosa*. T.S. of osphradium.

Eyes:
There is a pair of eyes, each borne on an ommatophore. An eye is an oval capsule, its wall is the retina made of pigmented sensory cells, it is continued in front as a thin, non- pigmented, transparent cornea. The overlying epidermis is transparent; in the interior of the capsule is a clear ovoidal lens surrounded by a dense vitreous body. An optic nerve innervates the retinal cells. Eyes are sensory to light.

4. Tentacles:
The tentacles and foot are liberally supplied with nerves, they are sensory to contact, tentacles contain both tactile and chemoreceptor cells and probably gustatory also. The first pair of tentacles are olfactory.

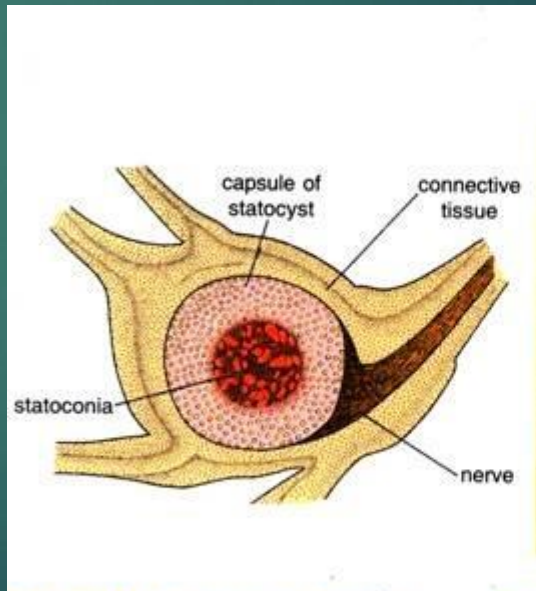


Fig. 60.26. *Pila globosa*. Statocyst.

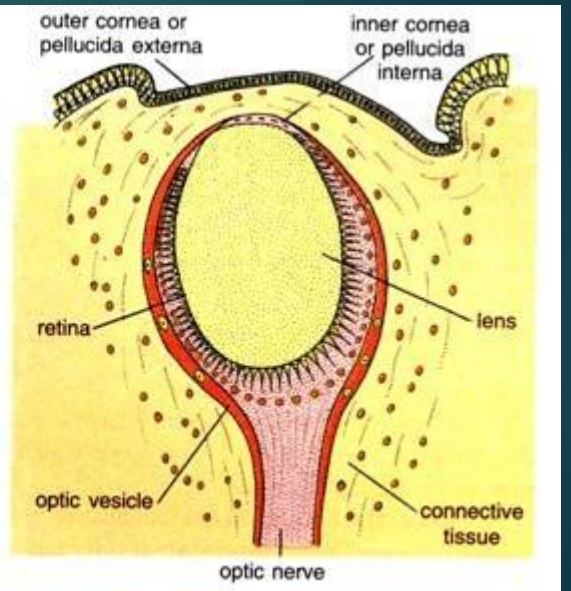


Fig. 60.27. *Pila globosa*. Horizontal longitudinal section of the eye.

Reproductive System of Pila Globosa:

In Pila Globosa, the sexes are separate, i.e., dioecious and there is a definite sexual dimorphism. The shell of the male is usually smaller in size and less swollen than the female. There is a well developed copulatory organ in the male but it is quite rudimentary in the female.

(i) Male Reproductive Organs of Pila Globosa:

The male reproductive organs consist of:

1. Testis with its fine vasa efferentia
2. Vas deferens with the vesicula seminalis and the terminal glandular part of the vas deferens
3. Penis with its sheath
4. Hypobranchial glands.

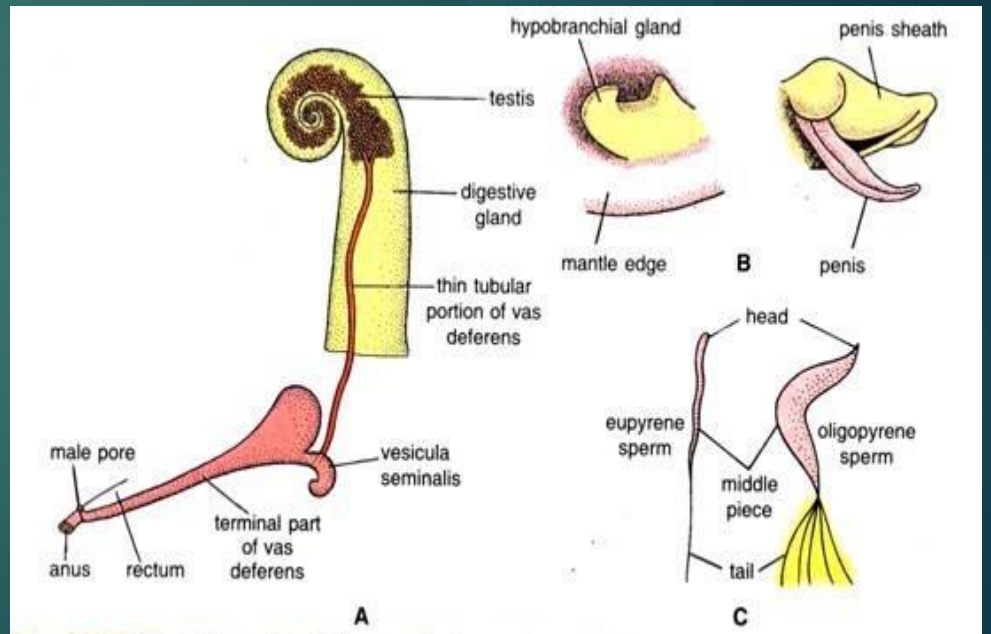


Fig. 60.28. *Pila globosa*. A—Male reproductive organs; B—Male copulatory organs in surface and ventral view; C—Sperms.

Testis:

It is a flat plate-like whitish structure, more or less triangular in outline, situated in the upper part of the first 2½ – 3 whorls of the shell. It lies closely attached to the digestive gland along its upper and inner or columellar edge and is separated from the shell by a thin cutaneous membrane. The cream-coloured testis is easily distinguished from the digestive gland which is brownish or dirty green. Minute ducts the vasa efferentia lead downwards from the different parts of the testis and may unite with one another before opening into the vas deferens.

2. Vas Deferens:

From the posterior end of testis arises a thin vas deferens.

It consists of three distinct parts:

(i) Proximal thin tubular portion leading from the testis,

(ii) Vesicula seminalis and

(iii) Thick glandular portion which opens into the mantle cavity near the anal opening. The vas deferens starts from the posterior end of the testis and runs immediately beneath the skin along the inner or columellar edge up to the postero-renal chamber. It then turns to the left and on reaching the level of the pericardium turns upwards and to the right to open into the vesicula seminalis on its ventral side.

The vesicula seminalis lies to the right of the pericardium immediately below the line of junction of the anterior and posterior renal chambers. It is slightly curved and has a flask-shaped appearance with its posterior blind end broadly rounded.

The vesicula seminalis opens on the left side into the terminal glandular part of the vas deferens. In the mantle-cavity, the vas deferens lies closely attached to the left side of the rectum and ends in a prominent claw- shaped structure the genital papilla having the male genital aperture a little behind the anus.

Penis Sheath and Penis:
The edge of the mantle bears on its inner surface a thick glandular flap of a yellowish colour. The flap is attached on its right-side but is free on its left; its edges are slightly rolled in to form a spout-like sheath, penis sheath for the penis. The penis is a long and stout flagellar structure, about half an inch long arising from the attached right side of the flap of the mantle.
It is seen as a slightly curved structure lying within its sheath. It is swollen at its point of attachment but gradually tapers to the free tip, bearing a deep groove all along its length on its inner surface. The penis is capable of extension.

Hypobranchial Gland:
At the base of penis sheath is an oval hypo-branchial gland. It consists of tall cells containing small basal nuclei. The surface of the glandular area is somewhat pleated but there is no duct and the secretions of the gland cells are apparently poured directly on the surface.

Eupyrene sperms and
(ii) Oligopyrene sperms.

The eupyrene sperms are hair-like having an elongated spirally twisted nucleus with a small conical acrosome in front, and a mitochondrial middle piece behind, followed by the end piece in the form of a long vibrating tail.
The anterior and posterior limits of middle piece are marked by the proximal ring-shaped centrosome and distal granular centrosome respectively. The axial filament springs up from the proximal centrosome; in the region of the middle piece the axial filament is enseathed by the mitochondrial material, but in the end piece the filament is naked.

The anterior and posterior limits of middle piece are marked by the proximal ring-shaped centrosome and distal granular centrosome respectively. The axial filament springs up from the proximal centrosome; in the region of the middle piece the axial filament is enseathed by the mitochondrial material, but in the end piece the filament is naked.
These sperms move actively forward in a spiral course, measure about 25 μ in length and 1.2 μ in breadth and they can only fertilise the eggs. The oligopyrene sperms on the other hand, have a very sluggish and serpent-like movement.
The acrosome is poorly developed, the nucleus is elongated, broad and curved but not spirally coiled ; the middle piece is short and the number of axial filaments varies from 4—8. These sperms measure about 32.5 μ in length and 3 μ in width and they cannot fertilise the eggs; these are probably having some secondary function.

Female Reproductive Organs:
The female reproductive organs consist of:

1. Ovary with numerous minute ducts
2. Main oviduct
3. Receptaculum seminis
4. Uterus
5. Vagina
6. Hypobranchial gland.

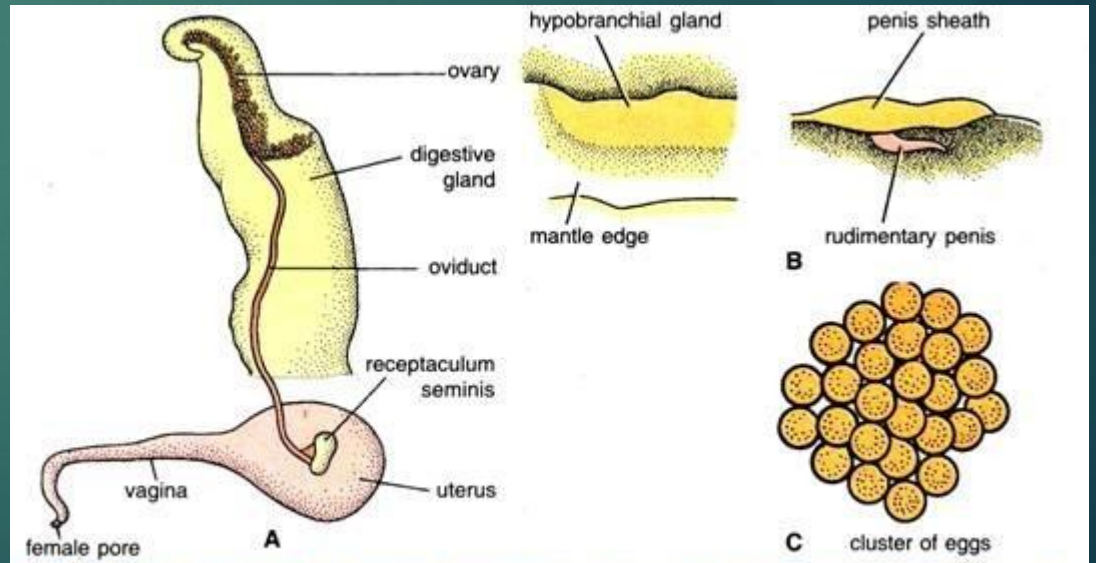


Fig. 60.29. *Pila globosa*. A—Female reproductive organs; B—Female copulatory organs in surface and ventral view; C—Eggs.

Ovary:

The ovary in the female lies in the same position as the testis in the male but it is not so extensive. It occupies the upper and inner surfaces on the first 2 – 2½ whorls and is covered over by a thin but stout skin-coat. Ovary is a much branched structure of a light orange colour which becomes darker in fully mature individuals.

The branches of ovary consist of single-layered acini which are more or less flask-shaped, with their closed rounded ends directed outwards and the elongated necks of the flasks descending to meet those of the adjacent acini to form minute ducts which in their turn open into the main oviduct.

2. Oviduct:

The narrow and transparent oviduct originates from about the middle of the ovary. It runs anteriorly just below the skin along the inner margin of the digestive gland. Near the renal organ it turns downwards and then upwards to enter the receptaculum seminis.

Receptaculum Seminis:
It is a bean-shaped structure, lying in the cavity of the posterior renal chamber closely attached to the uterus. A thin-walled pouch arises directly from the wall of the uterus and is called the pouch of the receptaculum.

4. Uterus:
It is a large pear-shaped structure, deep-yellow in colour. It lies inside the body whorl below the intestine and the right of the renal chambers. The apex of the uterus points forwards and is continued as the vagina, while its basal portion is broad and rounded and is connected on its outer side with the receptaculum seminis.

Vagina:
The vagina is a white or cream coloured, band-like structure lying immediately beneath the skin. It extends from the uterus to the upper end of the columellar muscle. The vagina enters the mantle cavity at its right posterior corner and continues forwards to the female genital aperture situated on a small papilla, a little behind the anus.

6. Hypobranchial Gland:
The hypobranchial gland of female is poorly developed. There is a rudimentary glandular thickening in the area of hypobranchial gland.

Copulatory Apparatus:
The female has a rudimentary penis lying beneath the glandular fold at the edge of the mantle. It is a thin flagellar structure with a rudimentary groove along its inner surface. The flagellum is about a quarter of an inch in length and has nearly the same thickness throughout except the tip where it is slightly pointed. There is no trace of the folding's of the penis sheath.


Egg mass of *Pila*. Veliger larva.

Copulation in Pila Globosa:
Copulation in Pila globosa (Fig. 60.30) occurs either in water or on land, it lasts for 3 hours. Male and female Pila come together facing each other.
The penis of the male is expanded and gets attached to the genital papilla by its base. Then the penis and its sheath are inserted into the mantle cavity of the female. The tip of the penis is put into the female genital aperture and spermatozoa are transferred through the vagina into the receptaculum seminis.

Fertilisation of Pila Globosa:
Eggs are fertilised in the uterus and oviposition starts a day or two later. The fertilised eggs are laid in masses of 200 to 800 in moist earth near ponds and lakes.

Development of Pila Globosa:
In their development Mollusca pass through two larval stages, there is a trochosphere larva which soon grows into a veliger larva.
The development of the trochosphere is the same as in polychaete Annelida. The typical trochosphere develops in Patella. A free- swimming trochosphere is found only in some primitive gastropods, such as Diotocardia, but in all others the trochosphere stage is reduced and passed within the egg.
More characteristic of marine gastropods is a free swimming veliger larva which hatches from the egg.
The veliger is a modified trochosphere but represents a more advanced stage of development, its organs show greater degree of development than those in the trochosphere larva. It has a ciliated apical organ on the head, a curved gut, larval nephridia and a ciliated pre-oral prototroch; but it has organs not found in the trochosphere.

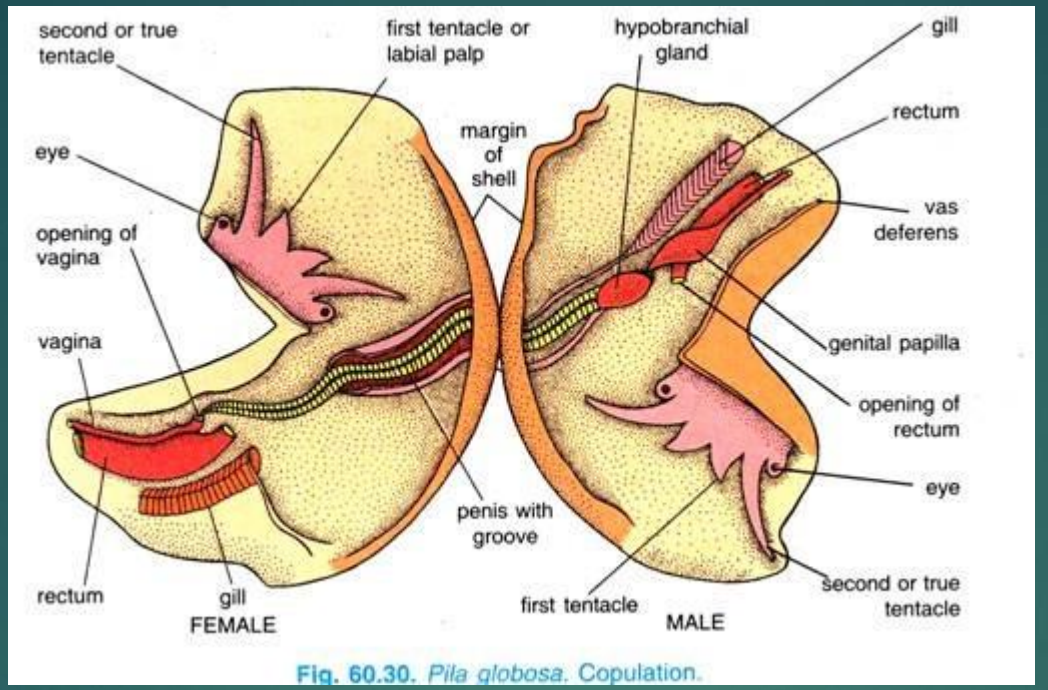


Fig. 60.30. *Pila globosa*. Copulation.

The prototroch develops into a characteristic swimming organ, the velum which is a bilobed circlet with strong cilia, it is formed as an outward extension of the prototroch. The velum causes a current which brings food into the mouth, and it serves as an organ of locomotion for the free-swimming veliger.

On the dorsal side of the veliger is an embryonic shell gland which secretes a shell, the shell soon loses its simple form and assumes a spiral shape due to unequal growth; larval retractor muscles are formed. On the ventral side is a foot lying between the mouth and the anus. On the dorsal side between the velum and the anus the ectoderm forms a mantle.

The mesoderm forms two bands which do not segment but break up into cells, some of which form muscles. Torsion takes place during the veliger stage, the shell and visceral mass are rotated through 180 degrees in relation to the head and the foot, but coiling of the visceral hump usually precedes torsion.

Torsion may be very rapid taking only a few minutes, or it may be a gradual process taking several days.

A stage is reached when the veliger cannot only swim by its velum but it can also creep by its foot. Gradually the velum becomes smaller. In freshwater and terrestrial Mollusca there is no free-swimming larva, both the trochosphere and the veliger stages are passed within the egg shell, and a tiny snail hatches from the egg shell.

Thank You