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Aurelia : A Jelly-Fish

Jelly-fishes are animals which belong to the class Scyphozoa of phylum Coelenterata. In this class, medusa is the dominant and conspicuous zooid in life cycle while polypoid form is restricted to a short larval stage. The most common scyphozoan jelly-fish is *Aurelia aurita*, whose biology has been treated in detail in the following text.

Aurelia aurita

A jelly-fish is not a true fish which is a vertebrate animal with a backbone. Whereas the name jelly-fish is given to this invertebrate coelenterate animal because it is made of a jelly-like substance.

SYSTEMATIC POSITION

Phylum	Coelenterata
Class	Scyphozoa
Order	Semaeostomae
Family	Ulmaridae
Genus	*Aurelia*
Species	*aurita*

HABITS AND HABITAT

A. aurita is also popularly known as 'moon-jelly'. It is a cosmopolitan jelly-fish, occurring in warm and temperate seas all over the world. It lives in coastal waters singly or in large shoals. It is found either floating with water currents and waves or swimming feebly by the contraction movements of its bell. It is carnivorous, feeding on small animals with the aid of its long oral arms. It responds to various stimuli and is most active in diffuse light.

EXTERNAL MORPHOLOGY

1. Shape and size. In general structure, *Aurelia* is like a large version of the medusa of *Obelia*. It is easily recognized by its soft bell or umbrella-shaped body with four red or purple horseshoe-shaped gonads on its upper surface and four long and narrow oral lobes hanging downwards from lower surface. Its circular body measures about 90 mm in diameter and presents a convex aboral or **exumbrellar surface** and a concave oral or **subumbrellar surface**.

2. Colouration. Body is perfectly transparent and bluish-white in colour. The reddish or pinkish gonads are clearly visible from the body surface.

3. Manubrium, mouth and oral arms. From the centre of subumbrellar surface hangs down a very short and inconspicuous **manubrium**. At its free distal end is a square **mouth**, from each corner of which hangs down a long, tapering much-frilled and delicate process, the **oral arm**. Each of the four oral arms has a ventral ciliated groove leading into mouth and its edges are armed with nematocysts. The radii, along which angles of mouth and oral arms lie, are referred to as **perradii**. Midway between two adjacent perradii is an **interradius**, and between each perradius and its adjacent interradius, on either side, is an **adradius**.

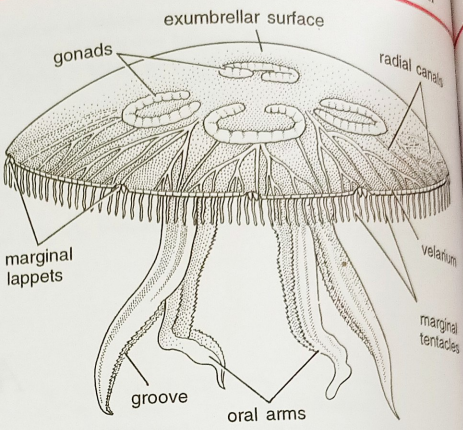

Fig. 1. *Aurelia aurita*. External morphology in dorso-lateral view.

4. Subgenital pits. On each interradius, a little distance from mouth, the sub-umbrellar surface bears a circular aperture. It leads into a small shallow cavity, the **subgenital pit**, lying immediately beneath a gonad and of uncertain function.

5. Gonads. Just above each subgenital pit, within umbrella, is a horseshoe-shaped and frilled **gonad**, red or purple in colour. Free arms of all the four gonads are directed towards the centre of umbrella. There is no connection between gonads and subgenital pits.

6. Lappets and tentaculocysts. The circular margin of umbrella or bell is broken into 8 lobes by 8 indentations or notches, 4 of which are perradial and the other 4 interradial. In each notch, there are two delicate leaf-like processes, called the **marginal lappets**. Between lappets lies a small sensory organ, the **tentaculocyst** or **rhopalium**.

7. Marginal tentacles. Between notches or rhopalia, the free edge of umbrella is beset closely with a row of numerous small, delicate and hollow threads or **marginal tentacles**. The tentacles bear batteries of stinging cells or nematocysts.

8. Velarium. Margin of subumbrellar surface, bearing lappets and tentacles, forms a thin and flexible flap, called **velarium** or **pseudovelum**. It

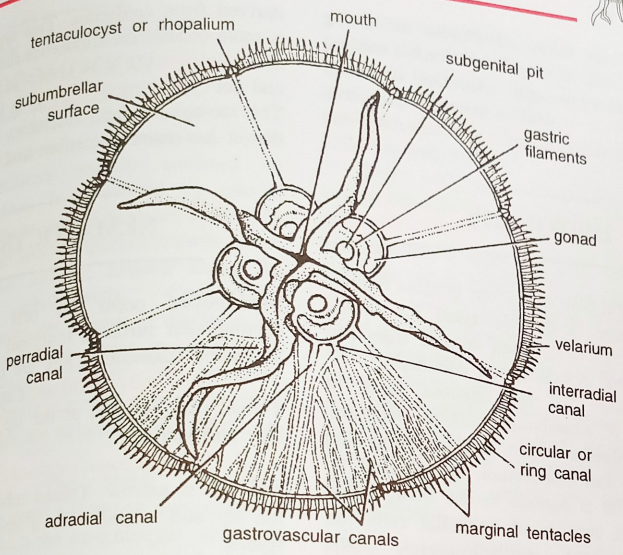

Fig. 2. *Aurelia aurita.* Ventral view.

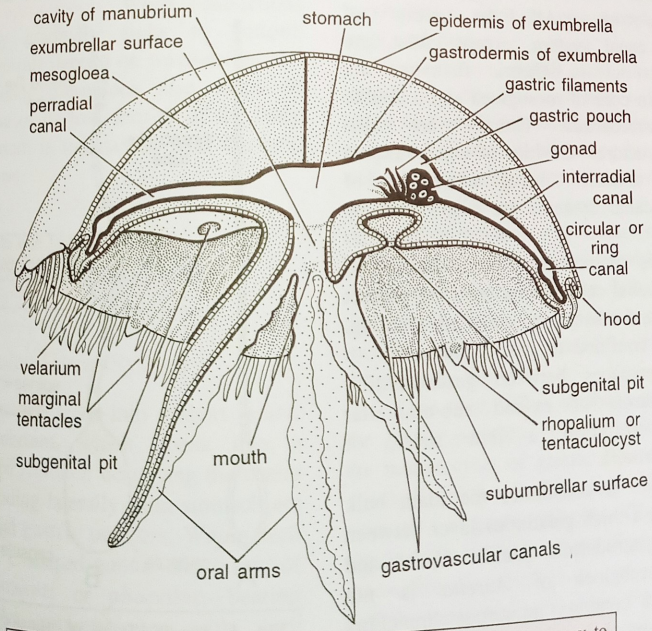

Fig. 3. *Aurelia aurita.* Lateral view with one-third of umbrella cut away to show internal structures and relations of parts.

differs from true velum of *Obelia* in having gastrodermal canals running into it. Such a medusa with a pseudovelum (*e.g.*, *Aurelia*) is called **acraspedote medusa**, while a medusa with a true velum (*e.g.*, *Obelia*) is called **craspedote medusa**.

HISTOLOGY

Basic histological plan of *Aurelia* medusa is more or less the same as that described for *Obelia* medusa. It is **diploblastic** and derived from two embryonic layers, ectoderm and endoderm.

1. Epidermis. All the exposed parts of umbrella, that is, exumbrellar surface, velarium, tentacles, subumbrellar surface including subgenital pits, oral arms and manubrium, are covered by **epidermis**. Gullet is formed by the invagination of epidermis. It consists of epithelial cells (on exumbrellar surface), epithelio-muscle cells (confined to subumbrellar surface) besides sensory cells, nerve cells, gland cells and cnidoblasts. Sensory cells form a sensory epithelium between epithelial cells.

2. Gastrodermis. All the parts of gastrovascular canal system, except gullet, are lined by **gastrodermis**. Gastric filaments are formed by a thin core of mesogloea and a double layer of gastrodermis. Gonads are also gastrodermal structures. Cavities of tentaculocysts and marginal tentacles, being extensions of gastrovascular canal system, are also lined by gastrodermis.

Gastrodermis mainly consists of flagellated columnar endothelial cells. Gland cells are present but nerve cells and muscle processes are wanting. Cnidoblasts are confined to gastric filaments.

In the interspaces between gastrovascular canals, gastrodermis of ex-and sub-umbrellar surfaces fuse to form a thin sheet, of **gastrodermal lamella**.

3. Mesogloea. It constitutes the main bulk of body, forming a thick gelatinous layer between epidermis and gastrodermis. Unlike *Hydra* and *Obelia,* the mesogloea of *Aurelia* is not structureless, but contains numerous branching **elastic fibres** and wandering **amoeboid cells** derived from epidermis. This type of mesogloea is more or less like connective tissue and is known as **collenchyma**. It is **ectomesodermal** in origin and not **endo-mesodermal** as in higher metazoans. The mesogloeal fluid resembles sea water except that it has more potassium and less sulphate.

NEMATOCYSTS

Nematocysts occur on oral arms, ex- and subumbrellar surfaces, marginal tentacles, as well as gastric filaments. They are of three types.

1. Atrichous isorhizas. Capsule is elongated. Thread tube is open at the tip and is without a butt and spines.

2. Holotrichous isorhizas. Capsule is oval and butt is narrow. Thread tube is long, open at the tip and armed with a spiral row of small spines.

3. Heterotrichous microbasic euryteles. Capsule is small. Thread tube is open at the tip and covered by minute spines. Butt is short and its distal dilated portion bears unequal spines.

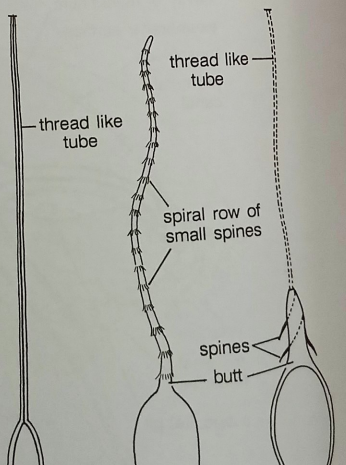

Fig. 4. *Aurelia.* Types of nematocysts. **A.** Atrichous isorhiza. **B.** Holotrichous isorhiza. **C.** Microbasic eurytele.

MUSCULAT
LOCOM

1. **Musculature.** *Aure*
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known as **coronal m**
periphery of sub
longitudinal muscles
manubrium and oral
coronal muscle extend
main radii of umbrell
muscles of tentacles
unstriated.

2. **Locomotion.**
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MUSCULATURE AND LOCOMOTION

1. Musculature. *Aurelia* possesses a well-developed musculature mainly confined to subumbrellar surface. It is formed by muscle processes of epithelio-muscle cells of epidermis. A broad, circular and peripheral muscle band, known as **coronal muscle**, extends along the periphery of sub-umbrella. Conspicuous **longitudinal muscles** are present in the tentacles, manubrium and oral arms. From manubrium to coronal muscle extend **radial muscles** along the main radii of umbrella. Coronal and longitudinal muscles of tentacles are striated, while others are unstriated.

2. Locomotion. The highly developed musculature brings about swimming movements of *Aurelia,* during which the ex-umbrellar surface is kept upwards. Rhythmic contractions of circular muscle force water out from the sub-umbrellar cavity, like a jet. As a result, body is propelled forward or upward. This type of jet-propulsion is known as **hydropropulsion**. When contractions stop, the body gradually sinks to bottom. Horizontal movements depend on wave-action and currents. Gelatinous mesogloea also helps in buoyance because of its low density. If the body is tilted, equilibrium is maintained with the help of 8 tentaculocysts.

DIGESTIVE SYSTEM

[I] Gastrovascular Canal System

The rectangular **mouth** leads into a short **gullet**, within the manubrium, which opens into a spacious, four-lobed **stomach** occupying the centre of umbrella. Extending laterally from stomach are four wide interradial **gastric pouches**. Within each gastric pouch is a C-shaped **gonad** and a row of small **gastric filaments** or **phacellae**, bearing nematocysts. Gullet communicates with each gastric pouch through a groove-like **gastro-genital canal** that runs between the two free ends of a gonad. Around each gonad runs an **exhalent channel** that also communicates with gullet through **gastro-oral canals**. **Radial canals** branch out from pouches to join the **circular** or **ring canal** in bell margin.

From each gastric pouch lead three radial canals through three small apertures. Middle or **interradial canal** divides at once into three branches out of which the outer two produce sub-branches before meeting the ring canal. Outer two **adradial canals** do not branch but meet the ring canal directly. Thus 8 unbranched adradial canals and 4 branched interradial canals emerge from 4 gastric pouches. Besides, 4 **perradial canals**, each emerging from an aperture between two adjacent gastric pouches, run to meet the ring canal, after showing branching pattern like that of interradial canals. All the canals are lined by ciliated gastrodermis.

[II] Nutrition

1. Food. *Aurelia* is exclusively carnivorous. It is mainly a suspension or ciliary feeder. It feeds upon planktonic organisms and small marine invertebrates, such as crustaceans, worms, their eggs and larvae.

2. Ingestion. Small planktonic organisms are carried directly into stomach with the entering water current. Some small organisms that may get entangled in mucus of sub-umbrellar surface are collected by oral arms. Sometimes, as medusa sinks slowly or swims gently downwards, prey is captured on contact with tentacles and oral arms. Nematocysts of oral arms paralyse and entangle these organisms, which are then swept up along the lateral tracts of oral arms and passed into mouth. Undesirable particles are rejected and dropped on the way.

If the prey, still is in living condition, reaches the gastric pouches, it is paralysed and killed by the nematocysts of gastric filaments.

3. Digestion. Digestion takes place in stomach and gastric pouches. Gland cells of these regions secrete most of the digestive enzymes for **extracellular digestion** of proteins, fats, carbohydrates and even chitin. Partly digested food particles circulate through canal system and are

ingested by gastrodermal cells for **intracellular digestion** in food vacuoles. Undigested food leaves the body with the outgoing current of water.

4. Distribution. Water circulating through canal system transports digested food to the gastrodermis of all parts. Further, wandering amoeboid cells in mesogloea transports food from gastrodermis to epidermis.

5. Reserve food. Reserve food, in the form of glycogen and fat droplets, is stored in the gastrodermal cells of gastric filaments.

CIRCULATION OF WATER

Beating of cilia of gastrodermal cells lining the gastrovascular canals, sets up a current of water. It circulates through the gastrovascular canal system along a fixed route. Inhalent water current enters the mouth and passes through narrow gastrogenital canals into gastric pouches, and finally through unbranched adradial canals enters the circular canal. From circular canal, exhalent water current returns through perradial and interadial canals. Perradial canals convey it directly into stomach from where it passes into gullet and finally exits along the **basal grooves** of oral arms. Interradial canals convey it to the basal grooves of the oral arms via exhalent and gastro-oral canals. This arrangement greatly prevents the mixing of water currents entering and leaving the gastrovascular canal system. Bell contractions during locomotion and movements of oral arms help in circulation. One complete circulation takes about 20 minutes.

Circulation of water helps in nutrition, respiration, excretion and reproduction.

RESPIRATION AND EXCRETION

There are no special organs for respiration and excretion. Oxygen dissolved in water diffuses directly into epidermis as well as gastrodermis, both of which are constantly bathed by water.

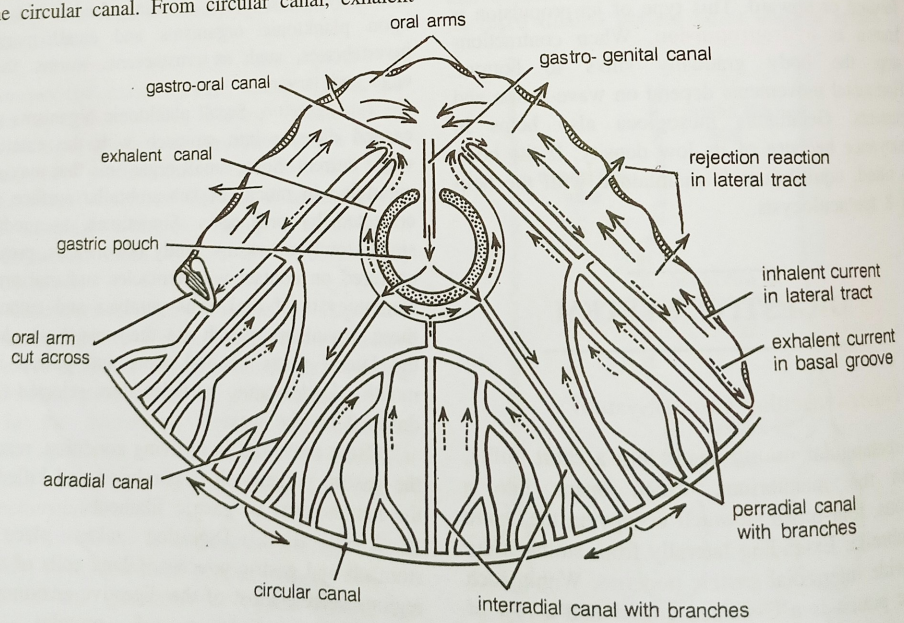

Fig. 5. *Aurelia.* Diagrammatic representation of gastrovascular canal system. Only one quadrant and two arms shown. Circulation of water shown by arrows.

Carbon dioxide and nitrogenous wastes diffuse out into surrounding water. Some workers are of the opinion that the subgenital pits facilitate gaseous exchange. This is based on the observation that, at the time of swimming, foul water constantly leaves the pits and fresh water (with dissolved oxygen) enters into them.

Water forms up to 99% of the weight of jelly-fish. Thus, compared to its weight, the oxygen requirement of *Aurelia* is quite insignificant. Almost nothing is known about the nature of excretory products.

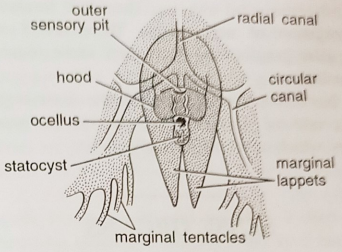

Fig. 6. *Aurelia. A.* portion of umbrella edge showing one rhopalium with its related parts.

NERVOUS SYSTEM

It consists of (i) a **main nerve net**, (ii) a **diffuse nerve net**, and (iii) eight **rhopalial ganglia**.

1. Main nerve net. Each nerve net or plexus consists of nerve cells and fibres. The main nerve net is more developed. It lies on the subumbrellar surface and extends into tentacles, rhopalia, manubrium and oral arms. Presence of main nerve net on subumbrellar side is correlated with the presence of well-developed musculature on that side; the former co-ordinates muscular movements during locomotion. Its nerve elements form a sort of **nerve ring** along the margin of umbrella near circular canal. Along per- and interradii, main nerve net is somewhat thickened due to the concentration of its nerve elements along these radii. Each radial thickening, near the margin of umbrella, is connected with the **rhopalial ganglion**, situated near the rhopalium on that radius.

2. Diffuse nerve net. Diffuse nerve net lies in the epidermis of subumbrella as well as exumbrella. Its nerve elements consist of smaller cell bodies. It is also connected with rhopalial ganglia. It controls local responses, like feeding, and can inhibit contractions of the umbrella.

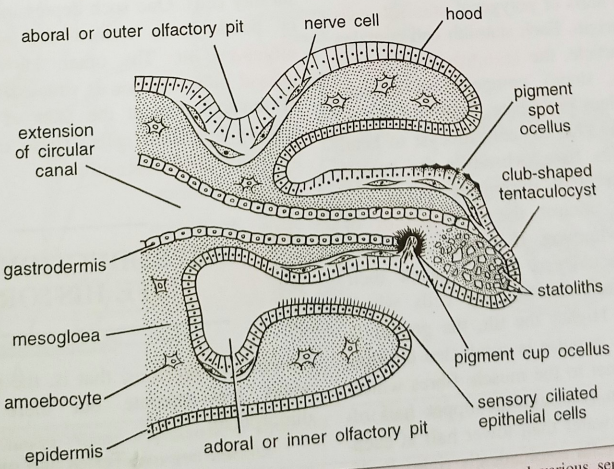

Fig. 7. *Aurelia.* Vertical section through a rhopalium showing the hood and various sensory areas.

3. **Rhopalial ganglia.** These are formed by aggregation of nerve cells. There are 8 such rhopalial ganglia, one near each sense organ or rhopalium.

Nerve impulses received by the sense organs, are conducted through nerve nets to the muscle fibres which react accordingly.

SENSE ORGANS

Sense organs of *Aurelia* are eight **rhopalia**, situated one in each of the per- and interadial marginal notches. Each rhopalium comprises **tentaculocyst** or **statocyst**, two **ocelli** and two **olfactory pits**.

1. **Tentaculocyst or Statocyst.** It is a hollow club-shaped structure, situated in the marginal notch between two **marginal lappets**. It is covered on the outer side by a process of bell margin, termed **hood**, which also connects the bases of two marginal lappets. Just below the club is a pad of tall ciliated **sensory epithelial cells** which are connected with the subumbrellar nerve net lying below epidermis. Tentaculocyst is a specialized hollow tentacle. Projecting into tentaculocyst is an extension of circular canal lined by gastrodermis. Lying in the distal part of tentaculocyst is a mass of polygonal **statolith cells** of gastrodermal origin. Each statolith cell contains a self-secreted particle, the **statolith** (Gr., **statos**, standing + **lithos**, stone), composed of calcium sulphate and calcium phosphate. Statoliths act as weight, causing the club of tentaculocyst to bend up and down at its base, whenever the animal tilts to one side or other, during swimming.

Tentaculocysts control the **equilibrium** of umbrella during swimming. If umbrella is tilted, the clubs of tentaculocysts press against their sensory pads beneath, the sensory cells which become stimulated. Higher the tilt, the greater is the stimulation. The impulse is conducted through subumbrellar nerve net to the muscle fibres which react accordingly. In response the upper half of umbrella drives less water than lower half at each beat, so that the umbrella automatically rights itself (Fig. 8).

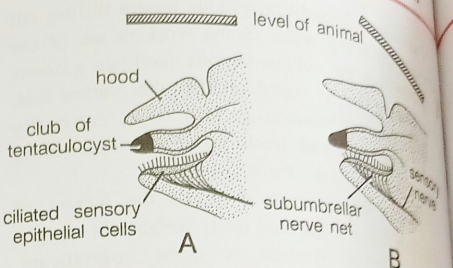

Fig. 8. *Aurelia.* Diagrams showing working of a tentaculocyst. **A.** Bell or umbrella in horizontal position. **B.** Bell tilted so that club of tentaculocyst presses down on pad of sensory epithelial cells.

2. **Ocelli.** There are two ocelli, one of ectodermal and other of endodermal origin. The former, known as **pigment spot ocellus**, consists of a patch of pigmented and sensory epidermal cells on the outer side of the club of tentaculocyst. The latter, known as **pigment cup ocellus**, consists of a cup-shaped cavity lined by pigmented and sensory gastrodermal cells and is situated on the inner side of tentaculocyst, in association with statoliths. Sensory cells of both the ocelli are connected with their respective underlying nerve nets. Ocelli are **photoreceptors**.

3. **Olfactory pits.** These are in the form of depressions of thickened epidermis containing sensory cells. One such depression lies at the base of hood. It is termed the **outer** or **aboral olfactory pit**. The other, known as **inner** or **adoral olfactory pit**, is situated on the inner side of tentaculocyst at the base of pad of ciliated sensory epithelial cells. These olfactory pits are probably **chemoreceptors**.

REPRODUCTION AND LIFE HISTORY

Aurelia is **dioecious**, that is, the male and female sexes are separate but there is no sexual dimorphism.

1. **Sex organs.** Testes and ovaries are similar in appearance. A medusa has 4 horseshoe-shaped gonads lying on the floor of stomach periphery,

that is, one in each gastric pouch. They are reddish violet in colour. They are visible through the semitransparent jelly of umbrella as frilled organs with their concavities facing inwards. On maturity, ova and sperms break into the gastrovascular cavity and pass out of mouth with the outgoing water current. The ova or eggs are lodged in the frills of oral arms.

2. Fertilization. Spermatozoa, swimming about in water, reach the ova and fertilize them either in stomach of female or in the frills of oral arms. Thus, fertilization is either **internal** or **external**.

3. Formation of planula larva. Frills of oral arms serve as temporary brooding members. Here each fertilised egg or zygote undergoes early development into a ciliated larval stage, called **planula**. The zygote undergoes holoblastic and equal segmentation to produce a solid ball-like **morula**. Soon it is transformed into a single-layered **blastula**, enclosing a central fluid-filled cavity or **blastocoel**. Two-layered **gastrula** develops by invagination, having an outer ectoderm and an inner endoderm lining an enteron cavity, with its **blastopore** or **gastral mouth** not completely closed. Thus, it differs from the gastrula of Hydrozoa (*e.g., Obelia)* which develops by a process of delamination and multipolar ingression of cells into blastocoel having no blastopore. The embryo now elongates, its outer cells become ciliated, blastopore closes and the typical **planula** larva is formed. At this stage, masses of planulae are visible as minute opaque patches on the oral arms of female individual.

4. Formation of scyphistoma. The ciliated planula eventually escapes and after a short free-swimming existence, attaches itself to a stone or seaweed by its broad anterior, aboral end. Cilia are lost and a **mouth** opens at its free distal end where blastopore had closed. The larva now becomes elongated and metamorphosed into a small trumpet-shaped or *Hydra*-like polyp, about 5 mm high. Its proximal part is narrowed into a stalk-like organ, attached to the substratum by an adhesive **basal disc**. **Tentacles** bud out around the mouth. First 4 tentacles are perradial, subsequent 4 interradial and then 8 adradial in position. Thus, 16 long and slender tentacles are formed. Mouth becomes square in outline and its edges become elongated to form a short **manubrium**. The larva now looks like a trumpet-shaped polyp or *Hydra,* and is called **hydratuba**

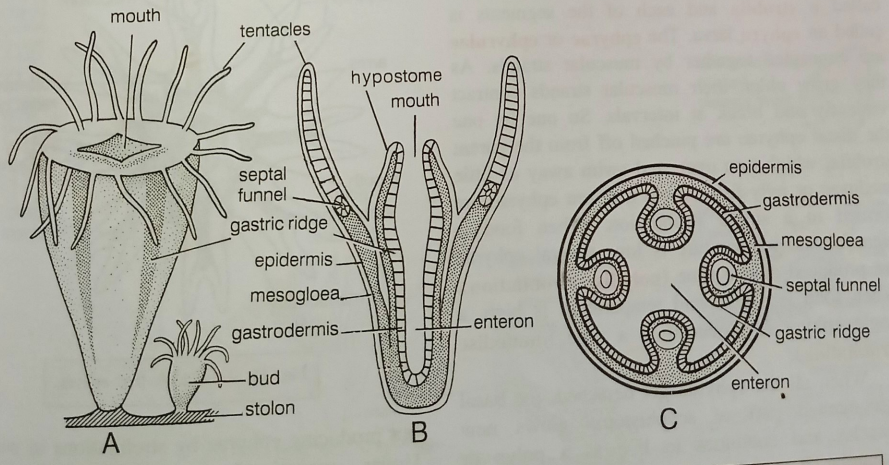

Fig. 9. *Aurelia.* Young scyphistoma or hydratuba. **A.** Outer view. **B.** Vertical section passing through an interradius. **C.** T.S. through septal funnels.

or **young scyphistoma** (Gr., **skyphos, cup** + **stoma**, mouth).

Endoderm of its enteric cavity is raised into four interradial longitudinal **gastric ridges** or **taenioles**, characteristic of **Scyphozoa**, which divides the enteric cavity into four perradial diverticula or pouches. Simultaneously, the ectoderm between mouth and tentacles also becomes invaginated as four interradial funnel-like depressions, known as **septal funnels** or **infundibula**, which sink into the four gastric ridges.

Scyphistoma feeds and grows up to 12 mm in height and may survive in this stage for several months. Sometimes, it multiplies either by lateral budding or by growing horizontal creeping stolons, which bud off fresh hydratubae. These buds eventually separate from the parent, as in *Hydra*.

5. Formation of ephyrae (strobilation). In autumn and winter, scyphistoma undergoes a remarkable process of budding or transverse fission of oral end, called **strobilation**. Distally, body develops a series of ring-like transverse constrictions or furrows which gradually deepens so that the organism resembles a pile of minute saucers or discs, placed one above the other. At this stage, scyphistoma with a segmented body is called a **strobila** and each of the segments is called an **ephyra** larva. The **ephyrae** or **ephyrulae** are connected together by muscular strands. As they grow older, their muscular strands contract violently and break at intervals. So one by one the distal ephyrae are pinched off from the parent strobila, which turn over, and swim away as little medusae or jelly-fish. About a dozen ephyrae are formed in a single strobilation. When food is plentiful and temperature is low, several ephyrae are produced at one time (**polydisc strobilation**). When food is scarce and temperature is high, a single ephyra is produced at a time (**monodisc strobilation**).

When all the ephyrae get detached, the basal unsegmented part of scyphistoma grows new tentacles and continues to live as a polyp or hydratuba. It may live for several years, feeding, growing and multiplying by budding in summers, but producing ephyrae by strobilations in winters. Under exceptional circumstances the whole scyphistoma may be metamorphosed into a single adult *Aurelia*, without forming ephyrae.

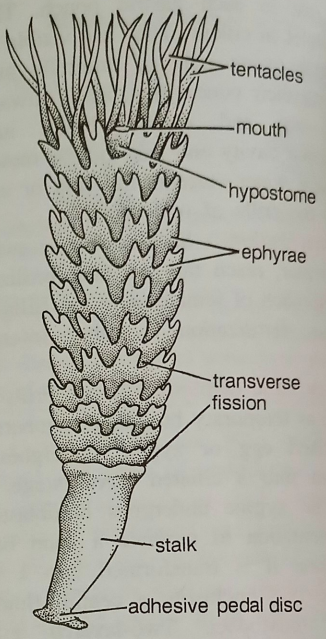

Fig. 10. *Aurelia.* A strobila.

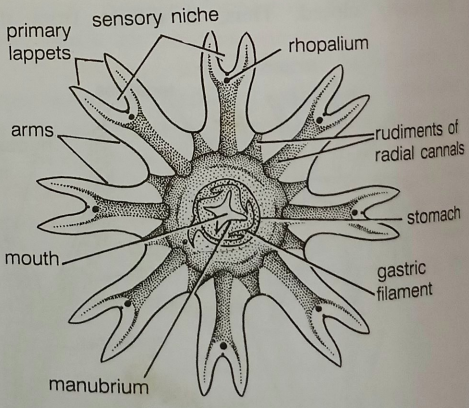

Fig. 11. *Aurelia.* A free ephyra.

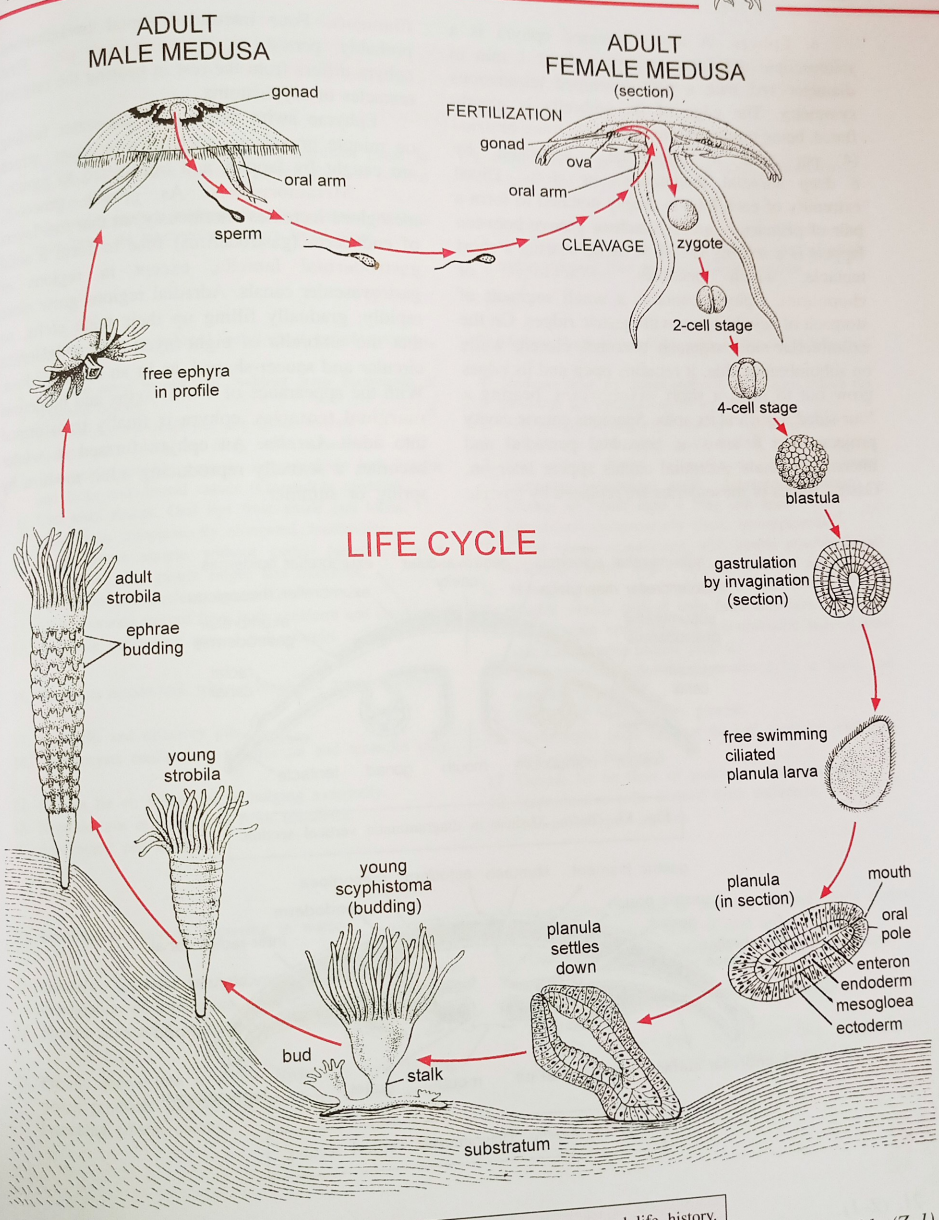

Fig. 12. *Aurelia.* Stages in development and life history.

6. Ephyra. A newly released ephyra is a microscopic gelatinous creature, about 1 mm in diameter and with a well-developed tetramerous symmetry. The edge of its umbrella is greatly fluted, being produced into eight **bifid lobes** or **arms** (4 per and 4 interradial), separated by 8 deep adradial indentations or **clefts**. Distal extremity of each lobe is deeply notched to form a pair of primary **lappets**. Notch or groove between lappets is a sensory recess or niche bearing a short tentacle, which becomes **tentaculocyst** or **rhopalium**. Ephyra contains a small segment of stomach of scyphistoma with gastric ridges. On the exumbrellar side, stomach becomes closed, while on subumbrellar side, it remains open and its edges grow out to form a short **manubrium**, bearing a four-sided **mouth** at its apex. Spacious enteric cavity projects into 8 arms as branched perradial and interradial canals. Adradial canals appear later on. Gastric ridges or mesenteries are replaced by **gastric filaments**. Four interradial septal invaginations probably persist as 4 **subgenital pits**. First ephyra differs from the rest in bearing the original tentacles of scyphistoma.

Ephyrae swim actively in sea-water feeding on minute organisms, such as protozoans, which are caught by lappets and transferred to mouth.

7. Metamorphosis. As growth proceeds, mesogloea increases enormously, so that two layers of endoderm (gastrodermis) fuse to form a solid **gastrodermal lamella**, except in regions of gastrovascular canals. Adradial regions grow more rapidly, gradually filling up their wide clefts, so that the umbrella of eight-rayed ephyra becomes circular and saucer-shaped, as in an adult medusa. With the appearance of 4 **oral arms** and numerous **marginal tentacles**, ephyra is finally transformed into adult *Aurelia*. An ephyra formed in winter becomes a sexually reproducing adult medusa by spring or summer.

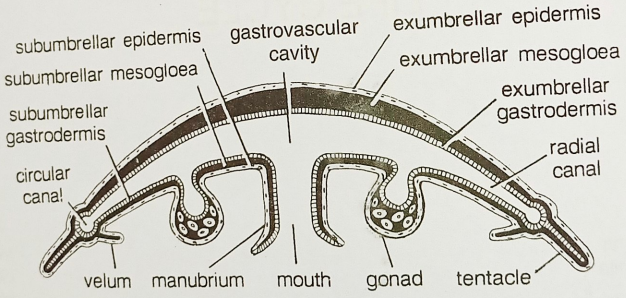

Fig. 13. *Obelia.* Medusa in diagrammatic vertical section.

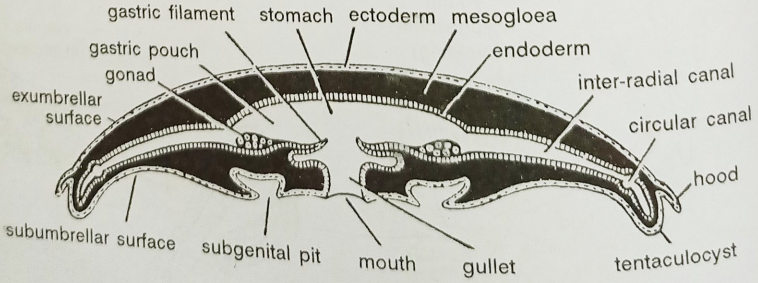

Fig. 14. *Aurelia.* Diagrammatic vertical section.