Model answer

M.Sc. (Semester I)

Paper-LZT-102: Entomology and Fish Biology

SECTION-A (Multiple choice question)

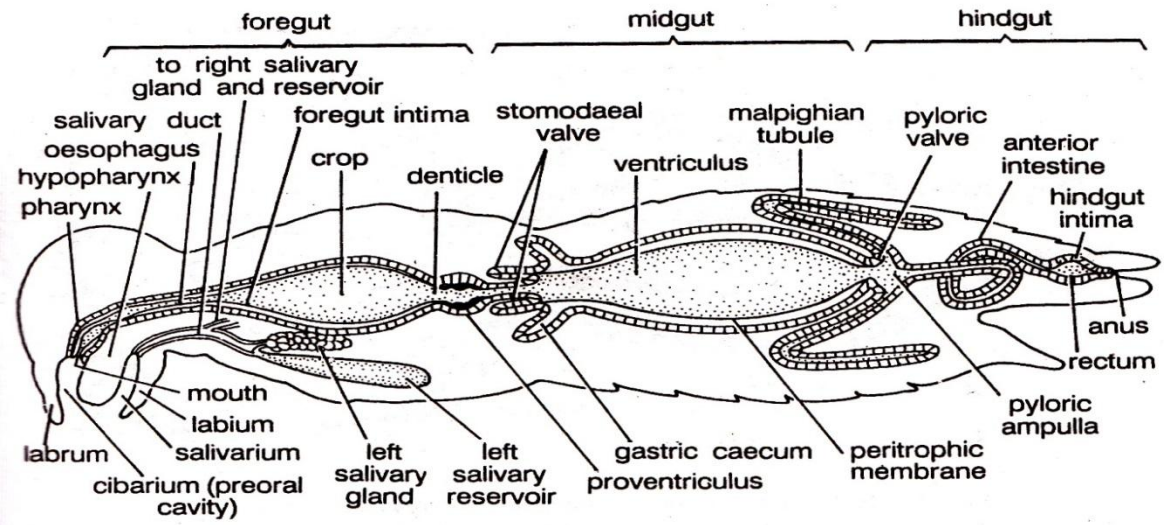
Answer No. 1

i. **b**
ii. **a**
iii. **b**
iv. **b**
v. **c**
vi. **c**
vii. **c**
viii. **d**
ix. **a**
x. **c**

SECTION-B

Answer No. 2

In insects, digestive system is a straight tube of epithelium running from mouth to anus. It has three regions, the foregut or stomodeum, the midgut or mesentrom and the hindgut or prostodeum.



Digestive system of insect

Foregut: It is the anterior part of the digestive tract and is composed of three parts buccal or mouth cavity, the pharynx and oesophagus. The oral aperture opens into the mouth cavity, the anterior part of which is bounded by mandibles, the dorsal part by labrum, the ventral side by

labium and two lateral sides by maxillae. The mouth cavity opens into a narrow pharynx and flask shaped oesophagus having two pair of muscles, the contractions of which enables the larvae to swallow the food. At the end of the foregut is a cardiac valve which helps in retaining the chewed leaves in the crop for some time and prevents backward motion of food midgut to foregut. The wall of foregut is made up of three layers: 1) tunica intima, secreted by the ectodermal cells, 2) epithelial layer having glands with digestive function and 3) muscle layer composed of longitudinal and circular muscles.

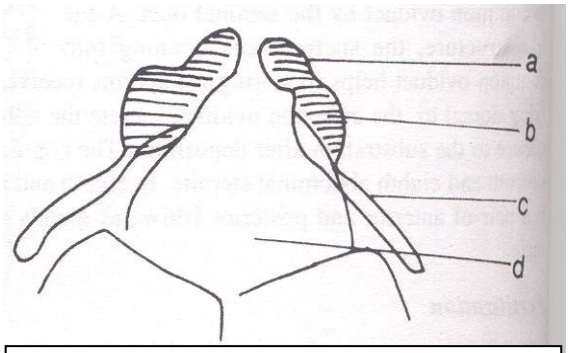
Midgut: It is largest part of digestive system and lies between the second and the ninth body segment. Digestion and assimilation of food takes place mainly in the midgut. While the midgut has endodermal lining, the fore and hindgut have lining continuous with the cuticular lining of the body wall. The wall of the midgut is composed of muscular layer, basal membrane, epithelium and peritrophic membrane. The epithelium is composed of cylindrical, goblet and intestinal cells. The cytoplasm of cylindrical and goblet cells has mitochondria and Golgi bodies. The digestive enzymes which hydrolyze the food into products capable of absorption are secreted partly by salivary glands and chiefly by goblet cells, whereas the cylindrical cells absorb the assimilated food. The midgut is alkaline in nature with pH 9.5. It is separated from hindgut by a pyloric sphincter which opens from time to time to allow the passage of digested food in fluid form into hindgut.

Hindgut: It is the posterior part of alimentary canal and comprises of small intestine or ileum, colon and rectum. The small intestine has a membranous valve at its junction with the midgut. This valve regulates the flow of the content from the midgut to the small intestine and at the same time prevents their backflow into the midgut. The malpighian tubules open at the junction between the small intestine and the colon. The colon continues into the rectum and terminates at the anus. On the surface of the rectum there are six longitudinal ridges. Associated anterolaterally with the rectum there are six malpighian tubules, three on each side. The residual feed after digestion in the midgut passes through the small intestine and become consolidated in the colon. Inside the rectum the undigested food become solidified into hexagonal pellets and extricated as faeces.

Digestive enzymes: The paired salivary glands are small, tubular and light yellow in colour located on either side of oesophagus. The salivary gland secretes, saliva, a weak alkaline solution, which contains an enzyme known as amylase. The midgut is the place of secreting major digestive enzyme, the gastric juice, which is a string alkaline solution with pH ranging from 9.2-10.3. The principal components of gastric juice are protease, hydrolyzing proteins, lipase, hydrolyzing fats, amylase, hydrolyzing starch, invertase, hydrolyzing cane sugars and maltase hydrolyzing maltose. Besides these the gastric juice also contains trypsin, glucogenase and tyrosinase.

Digestion and assimilation of food: Digestion is the process of changing insoluble substances and also impermeable substances into permeable ones. The midgut is the major site of secreting

digestive enzymes as well as making food soluble to absorb. The foregut only ingests food and mixes with saliva, whereas the hindgut absorbs the water content and hardens the undigested material to expel. The insect digests and absorbs 41-46% of chlorophyll and 29-34% keratenoids of leaves. Ingredients of leaves such as water, glucose, soluble salts are absorbed by mid intestine as such but proteins are too large to pass through cell membrane are converted into amino acids and peptones by proteinase, and then absorbed. While these are being taken into various organs these get converted into glycerine and glycerol by lipase. The essential amino acids, formed after the digeston of proteins are arginine, histidine, isoleucine, leucine, lysine, methionine, phenylalanine, threonine, tryptophan, valine, aspartic acid and glutamic acid. In addition semi essential amino acid (praline) and non – essential amino acids cystine, tyrosine, alanine, glycine and serine are also formed.



Salivary glands
a: Mandible, b: Mandibular flexor,
c: Salivary gland, d: Oesophagus

Answer No. 3

Mouth parts are attached ventrally to the head surrounding the preoral cavity and are of chewing or mandibulate type which enables the insect to bite and chew vegetable matter. The following are the various parts:

i. Labrum: Upper lip or labrum is a broad, somewhat rectangular plate attached to the ventral edge of clypeus.

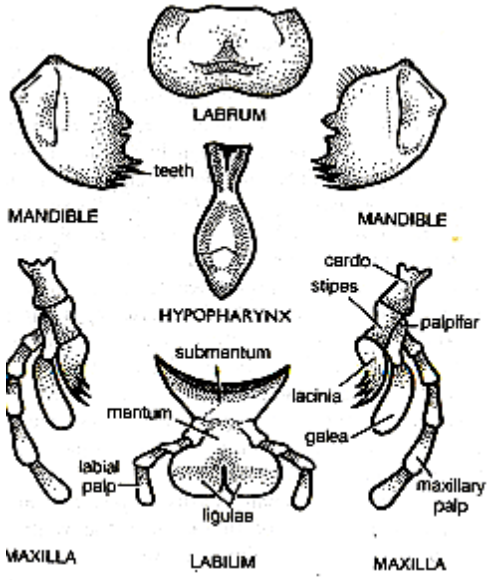
ii. Hypopharynx: It is a median, membranous, tongue-like structure lying beneath labrum.

iii. Mandibles: On either side below cheek is a large, heavy, somewhat triangular and dark-coloured jaw or mandible. It is hard, horny and with toothed inner margin for chewing food.

iv. Maxillae: Lying behind mandibles are a pair of maxillae. Each maxilla consists of several parts basal cardo, middle stipes, distal elongated curved lacinia and rounded galea and a slender

five segmented sensory maxillary palp which arises from palpifer. Maxillae are used in manipulating food as enters mouth.

v. Labium: The broad, median lower lip or labium is considered as a fused second pair of maxillae. It consists of a basal submentum, a central mentum, two movable flaps, the ligulae, and a three segmented sensory labial palp on either side. Labrum and labium serve to hold food between the mandibles and maxillae which move laterally to grind it.



Mouth parts of grasshopper

Answer No. 3

All insects have sense organs that allow them to see, smell, taste, hear and touch their environment. There are organs connected with these sense that take in information that is sent to the brain so that the body can act on it. All sense organs (receptors) act as transducers -- converting light energy, chemical energy, or mechanical energy from the environment into electrical energy of nerve impulses in sensory neurons. Signals generated by insect sensory receptors travel to the brain or ventral nerve cord where they stimulate appropriate behavioral responses: finding resources (e.g. food, mate, etc.), avoiding danger, or reacting to changes in the environment. All sensory receptors are derived from embryonic ectoderm and are integral parts of the insect's exoskeleton. They can be grouped into one of three categories, depending on function.

Photoreceptors: Arthropods have compound eyes, which have greater depth of focus than refracting eyes, but which sacrifice resolving power or acuity. A pair of compound eyes are the principle visual organs of most insects; they are found in nearly all adults and in many immatures of ametabolous and hemimetabolous orders. As the name suggests, compound eyes are

composed of many similar, closely-packed facets (called ommatidia) which are the structural and functional units of vision. The number of ommatidia varies considerably from species.
Externally, each ommatidium is marked by a convex thickening of transparent cuticle, the corneal lens. Beneath the lens, there is often a crystalline cone secreted by a pair of semper cells. Together, the lens and the crystalline cone form a dioptric apparatus that refracts incoming light down into a receptor region containing visual pigment.
Since insects cannot form a true (i.e. focused) image of the environment, their visual acuity is relatively poor compared to that of vertebrates. On the other hand, their ability to sense movement, by tracking objects from ommatidium to ommatidium, is superior to most other animals.
Temporal resolution of flicker is as high as 200 images/second in some bees and flies (in humans, still images blur into constant motion at about 30 images/second). They can detect polarization patterns in sunlight, and discriminate wavelengths in a range from ultraviolet to yellow.
Ocelli (Simple eyes): Two types of "simple eyes" can be found in the class Insecta: dorsal ocelli and lateral ocelli (stemmata). Although both types of ocelli are similar in structure, they are believed to have separate phylogenetic and embryological origins.
Dorsal ocelli are commonly found in adults and in the immature stages (nymphs) of many hemimetabolous species. They are not independent visual organs and never occur in species that lack compound eyes. Whenever present, dorsal ocelli appear as two or three small, convex swellings on the dorsal or facial regions of the head. They differ from compound eyes in having only a single corneal lens covering an array of several dozen rhabdom-like sensory rods. These simple eyes do not form an image or perceive objects in the environment, but they are sensitive to a wide range of wavelengths, react to the polarization of light, and respond quickly to changes in light intensity
Mechanoreceptors
Insect mechanoreceptors can be found almost anywhere on the surface of an insect's body. They may act as tactile receptors, detecting movement of objects in the environment, or they may provide proprioceptive cues (sensory input about the position or orientation of the body and its appendages). These receptors are innervated by one or more sensory neurons that fire in response to stretching, bending, compression, vibration, or other mechanical disturbance. Some mechanoreceptors produce a phasic response when stimulated i.e., they fire once when activated and again when deactivated. Other receptors generate a tonic response, firing repeatedly as long as a stimulus persists. Neural processing centers in the brain or segmental ganglia interpret the combinations of tonic and phasic signals sent from nearby receptors.
Trichoform sensilla are probably the simplest mechanoreceptors. Hair beds (clusters of tactile setae) are often found behind the head, on the legs, or near joints where they respond to movements of the body.
Pressure receptors provide sensory information about an aquatic insect's depth in the water. These receptors are usually associated with a cushion of air against the body or within the

tracheal system. Increasing water pressure deflects hair-like processes within the receptor and stimulates tonic and phasic impulses.

Chordotonal organs include several types of mechanoreceptors in which one or more bipolar neurons bridge a gap between two internal surfaces of the exoskeleton.

Each neuron is usually accompanied by two other cells which form a sheath (the scolopale cell) and a point of attachment (the cap cell). Together, these three cells create a unit (called a scolopidia) that may occur singly or in groups. Common types of chordotonal organs include:

Tympanal organs lie beneath a drum-like membrane (the tympanum) where they respond to sound vibrations. These "ears" may be located on the thorax (in some Hemiptera), on the abdomen (in grasshoppers, cicadas, and some moths), or on the front tibia (in crickets and katydids).

Johnston's organ found within the pedicel of each antenna. In some insects, they function as proprioceptors, supplying information on position or orientation of the antennae. In mosquitoes and midges, they respond to certain frequencies of airborne sound by detecting resonant vibrations in antennal hairs.

Chemoreceptors

Insects have the ability to sense various chemical substances in their environment. When these chemicals are present in gaseous form (at relatively low concentrations), they may be detected as odors (smells) by olfactory receptors. When they are in solid or liquid form (usually at higher concentrations) they are perceived as tastes by gustatory receptors. In general, the sense of taste involves direct contact with a substrate (contact chemoreception) whereas olfaction usually implies detection of compounds in gaseous or airborne form (remote chemoreception).

Gustatory receptors are commonly described as thick-walled hairs, pegs, or pits where the dendrites of several (usually up to five) sensory neurons are exposed to the environment through a single opening (pore) in the cuticle. Each neuron appears to respond to a different range of compounds (e.g. sugar, salt, water, protein, acid, etc.). Taste receptors are most abundant on the mouthparts, but may also be found on the antennae, tarsi, and genitalia (especially near the tip of the female's ovipositor).

Olfactory receptors are usually thin-walled pegs, cones, or plates with numerous pores through which airborne molecules diffuse. Dendrites of sensory neurons branch profusely within these pores and may respond to very low concentrations of detectable compounds (e.g. sex pheromones). Some receptors respond to a wide range of substances while others are highly specific. Olfactory receptors are most abundant on the antennae, but may also be associated with the mouthparts or external genitalia.

Answer No. 5

Structure of the integument: The outer covering of body is composed of three layers, viz. cuticle, epidermis (hypodermis) and basement membrane.

Cuticle: It is the outermost non cellular layer and gives support, protection and restricts water loss. It is secreted by underlying epidermis and oenocytes as a soft and flexible layer which

subsequently hardens by a process of sclerotisation. Cuticle is composed of two layers, primary cuticle or epicuticle and secondary cuticle or inner epicuticle or procuticle.

Epicuticle: It is non-chitinous layer, made up of protein and lipids. It bears numerous nodules and pores. It composed of four layers: cement layer, wax layer, polyphenol layer or protein epicuticle and cuticulin or lipoprotein epicuticle.

Procuticle: It is chitinous nature. It composed of exocuticle, endocuticle and mesocuticle. The exocuticle is hard and dark, the endocuticle is soft, light, made up of horizontal lamellar which provide flexibility to the insect and chitin is the main constituent.

Expansion of the cuticle: Soon after ecdysis, the soft new cuticle expands and stretches gradually to accommodate the larger size of the new instar. The expansion of cuticle is brought to an end by a process of sclerotization. In most insects, the new cuticle is tanned soon after ecdysis and becomes hard and inextensible. However, in Bombyx mori tanning does not take place after larval ecdysis. Tanning is a process by which cuticular structures are made stiffer, inextensible, darker and more resistant to adaptation.

Lines of weakness: The exocuticle is absent along the ecdysal line and this place consists of endocuticle only which constitutes the lines of weakness. Moulting hormone acts on endocuticle and split occurs along the lines of weakness at ecdysis. The procuticle in insects cosist of numerous vertical lines which run from epidermis to the inner layer of epicuticle are called pore canals. These pore canals involved with the transport of cuticular materials like moulting fluids, proteins, etc. during the formation of cuticle.

Chitin: It is a colourless polymer, insoluble in water, alcohol, ether and dilute alkaline. It is a high molecular weight nitrogenous polysaccharide, $C_8H_{13}O_5N$. This polysaccharide is made up of N–acetylglucosamine which are attached to one another by 1, 4 β glucoside linkages. The bulk of the non chitinous material in the cuticle (0.5 – 37% w) is the protein.

Glycoprotein complex: The proteins of cuticle are three types, water soluble tyrosine and glycine, water insoluble sclerotin and resilin and colourless rubber like protein.

Epidermis: It is a single continous layer of cells composed of cytoplasmic membranes. Secretory in nature, the epidermal cells become flattened during moult and as well as absorb the endocuticle at the time of ecdysis. The epidermis also bears several tricogenous cells.

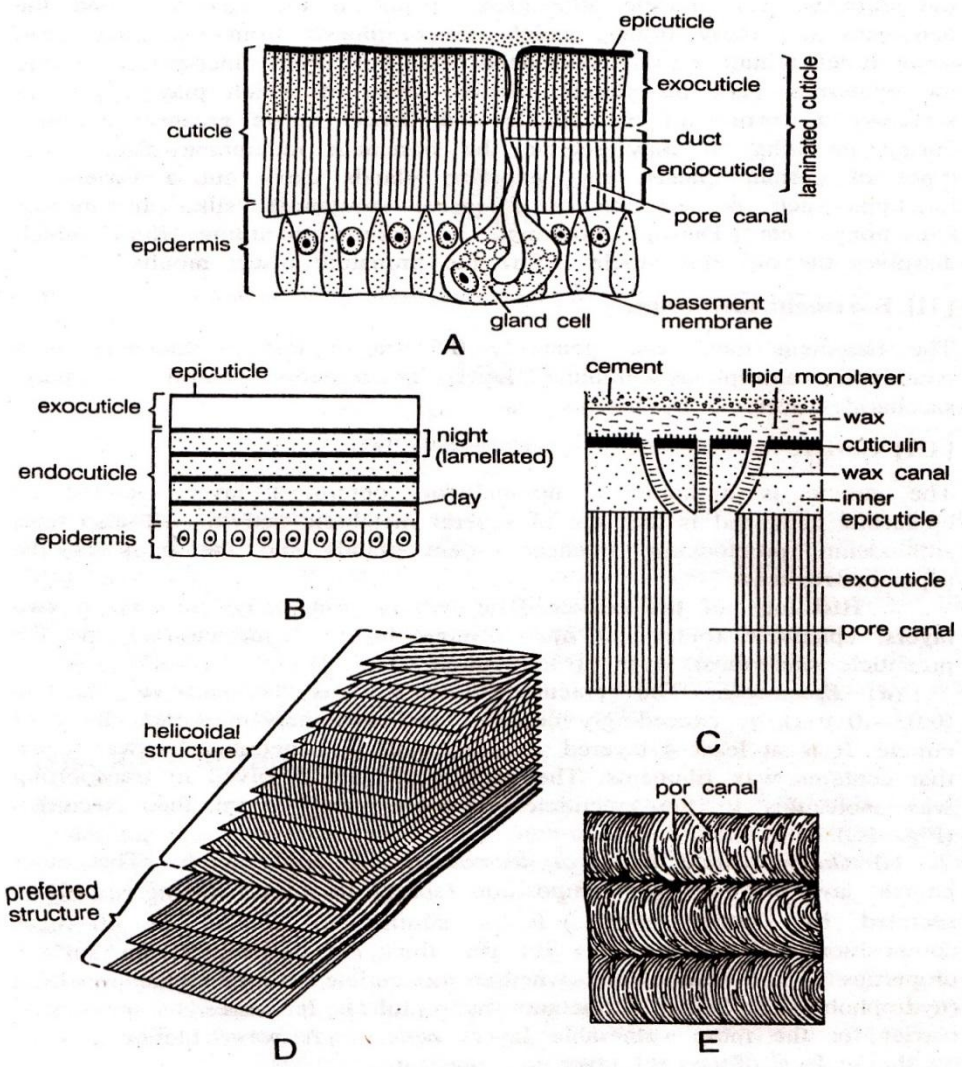


Fig. 1. Structure of the integument (diagrammatic). (A) section of generalised integument, (B) daily growth layers and lamellar pattern, (C) generalised epicuticle, (D) helicoidal and preferred structure of layers of endocuticle, (E) transverse section of endocuticle showing parabolic effect.

Basement membrane: It is a non cellular sheath on which epidermal cells rest. It formed by the secretions from haemocytes. In insects, unlike other insects, when the integument gets injured, regeneration does not occur by the multiplication of the epidermal cells but by accumulation of haemocytes which become transformed into epidermal cells and form a layer. Further insect integument playing important role in various process which is as follows:

Apolysis: Towards the end of instar, larvae stop feeding and remain immobile. However, the rhythmic peristaltic movements of the gut continue due to its emptying. The rigid cuticle becomes unable to accommodate the body which has grown in size. As a result of changes in the epidermal cells, a tension is generated at the surface of the epidermal cells which results in the separation of cuticle, forming a subcuticular space. The inactive moulting fluid, secreted by the

moulting glands, is discharged into the subcuticular space just before or at apolysis. The moulting fluid contains enzymes, proteinase and chitinase.

The moulting fluid gets activated and digests the chitin and proteins of the endocuticle for resorption and utilization. The hydrolysis products of the old cuticle are apparently transferred across the new cuticle into the haemolymh. Once the cuticulin is produced, the epidermal cells begin to deposit procuticle underneath it. While moulting fluid is digesting the endocuticle, it does not attack the epidermis. Since, before the activation of moulting fluid the epidermis immediately after separating from the cuticle secretes on its surface a layer of epicuticle which is resistant to moulting fluid, thereby giving protection to the epidermis. The undigested material (10-20) of the endocuticle becomes the ecdysal membrane, which persists and continues to receive stimuli from the environment till ecdysis takes place.

Answer No. 6

Mucous Gland

Mucous glands, which aid in maintaining the water balance and offer protection from bacteria, are extremely numerous in fish skin, especially in cyclostomes and teleosts. Numerous tubular or flask shaped cells are scattered among the epithelial cells and may even extend into dermis. Mucous cells develop from the stratum germinativum and migrate to the surface. They vary in number, size and kind in different species of fishes. These cells secrete mucin, a glycoprotein, which mixes with water to form thick, slimy mucus covering the whole body.

Functions

The mucus covering the body of the fish performs several important functions.

1. It lubricates the fish so as to reduce body friction in water while swimming thus enabling the fish to move with a greater speed.
2. It protects the body from parasites, fungus, bacteria and other micro-organisms.
3. In turbid or muddy water mucus has the power to precipitate the particles in suspension especially in contact with the gills and thus prevents the fish from suffocation and helps in its survival.
4. The skin and the mucus secreted by its glands help the fish in regulating to some extent, the osmotic exchanges of water and ions between the body fluids and the surrounding medium.
5. The African lung fish, *Protopterus*, makes use of the mucus secreted by the skin, in preparing the hard cocoon for its summer sleep.
6. Certain species utilise the sticky mucus for preparing nests for egg laying.

7. The skin performs an important function in repairing the surface wounds. Immediately after an injury, the wound is closed by the mucus containing a large number of lymphocytes. The marginal cells of the wound, then multiply rapidly to form a thin protective layer and gradually healing of the wound is completed.

Poison Gland

Poisonous glands are present in many fishes as skin derivatives and they are considered as modified mucous gland. Poisonous gland secrete venom that is when injected in other animal may be painful or lethal. Study of these glands and their secretions is a part of the field of Ichthyotoxism. Venom from stings of certain fishes may be fatal as well as having painful symptoms to the human that is rays, chimaeras, scorpion fishes etc. Not fatal but painful to humans are sting of venomous shark, toad fishes, catfishes etc.

Significance

Nothing is known of the biological significance of the venom apparatus in fishes although it is easy to postulate their role in food getting, offense or defense.

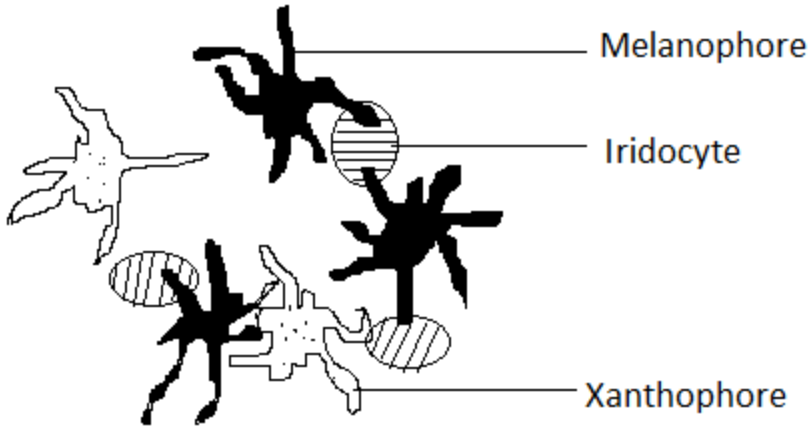
Answer No. 7

Large number of teleosten fishes are brightly and brilliantly colored. Colouration in fishes is primarily due to skin pigments. Background color is due to underlying tissues, body fluids or gut content.

Source of Coloration

Coloration is due to presence of two types of special cells-

1. Chromatophores
2. Iridocytes



Chromatophores of the skin

Chromatophores are branched connective tissue cells situated in the dermis either above or below the scales. The various kinds of pigment granules that impart color to fish are-

i. Carotenoids (yellow and red)
ii. Melanins (black)
iii. Flavines (yellow)
iv. Purines (white and silvery)

Depending upon the color of pigment, the chromatophores are designated as-

- Erythrophores (red or orange)
- Xanthophores (yellow)
- Melanophores (black)

The iridocytes contain a crystalline substance guanine which is opaque, whitish or silvery. It is waste product and is deposited in the form of granules or rounded, polygonal or stellate bodies, or in the form of plates. Iridocytes are also called mirror cells as they contain great reflection power. They give white or silvery appearance to the fish.

Significance of coloration

Functions of coloration are for intraspecific and interspecific signals.

Intraspecific – social (recognition, threat, warning)

Sexual

Interspecific – warning and masking (either for prey or predator)

Cott (1940) grouped principal functions into three heads

1. Concealment
   i. Obliterative shading
   ii. Disruptive coloration
   iii. Coincident disruptive coloration
2. Disguise (for securing prey)
3. Advertisement (Advertisement)

Control of color change

1. Hormonal control
2. Neural control

1. Hormonal

Pituitary gland exercises control over the distribution of pigments in the chromatophores. Most important pituitary hormone, intermedin, causes dispersion of the melanophores pigment resulting in the darker color of the animal. Besides pituitary hormones, adrenaline also exerts a powerful concentrating effect on the melanophores. Some fishes show color change during reproductive period which may be due to gonadal hormones. Thyroxine also influences color change by acting on the melanophores.

2. Neural control

Chromatophores of some fishes are abundantly supplied with nerves. It is believed that neurohumors secreted by neurons activate chromatophores. One type of fibres produce neurohumor that cause dispersion and other cause aggregation.

Answer No. 8

Methods of determining age and growth

1. **Rearing the fish in a controlled environment**

This is one of the direct methods for determining the growth of fish. A fish or egg or larva of known age is placed in a tank. Its lengths and body weight is measured at intervals of time for calculating growth rate. This method is useful for cultured fishes.

2. **Tagging**

Fishes are marked or tagged and released after recording initial measurements of length and weight. The fish are recaptured after an interval of a few months and measured again. The growth rate is calculated from the change in size over the time period. Marking should be done in such a way that it does not affect the behavior or feeding rate. Marking can be done by-

a. Clipping fin rays
b. Coloring epidermis
c. Spraying
d. Providing fluorescent rings on scales

Tagging is more popular. Tag may be attached to the body by means of a thin wire without actually piercing it. Magnetic tags are also used that can be detected in magnetic field. The marked or tagged fish provide more realistic data. But these fishes are difficult to recapture hence a very large number of fish must be used in this method.

3. **Length frequency distribution method**

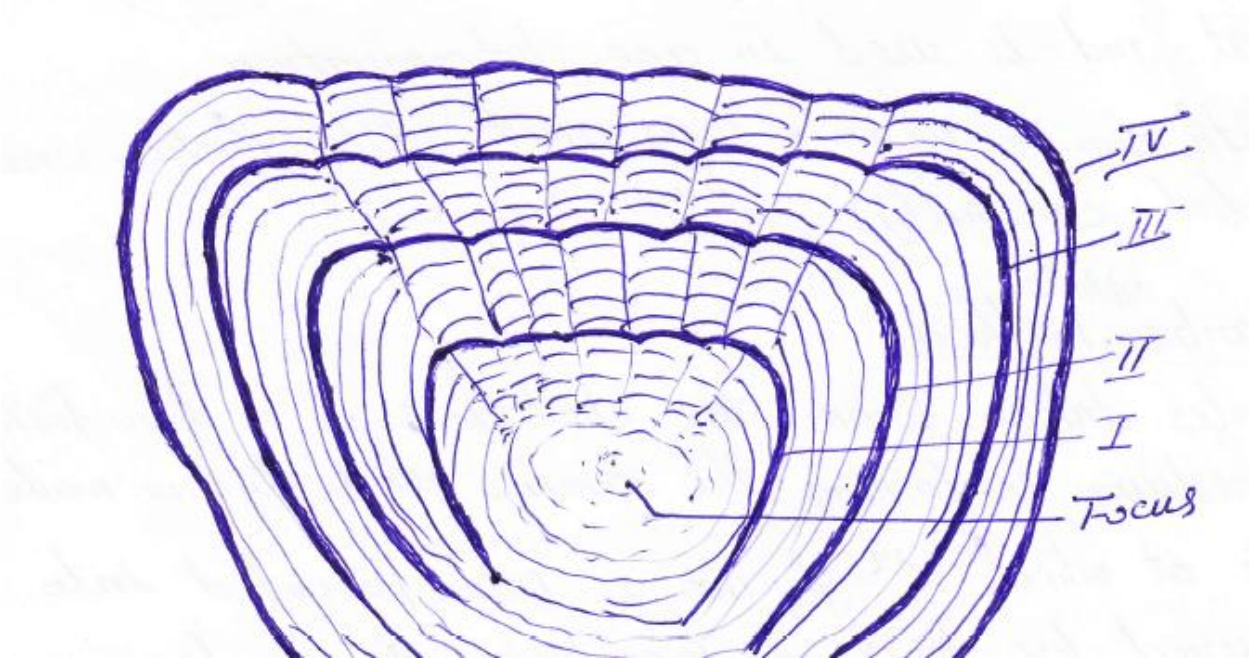
This method is based on the expectation that length frequency analysis of individuals of any age group will show variation around the mean length. In this method, length of 300-500 fish from a population is measured in a month. The data are distributed in frequencies. The modes are then traced after plotting the data, to determine the age and rate of growth. By comparing the mean length between age classes one can determine approximate growth rate at various ages. For reliable result sample should consists a large number of individual, collected preferably on a single day and should include representative of all sizes and age groups.

4. **Rings or annuli on hard substances**

In many fishes rate of growth in the diameter of the bones, spines and scales is proportional the growth of fish. the hard parts that can be studied for age determination are the otoliths, vertebral centra, scales, dorsal and pectoral spines, opercular spines etc. age determination with the help of

scales is simplest and most accurate method. About 10 scales are taken, usually from below the origin of the dorsal fin just above the lateral line, these are called key scales. The scales are cleared, mounted and then examined. The focus of the scale is the first part to develop and is usually located in the centre. An annulus is usually marked by a clear, narrow streak, encircling the focus. One annulus represents one year, and addition of successive annuli indicates the number of the years the fish has attained. Rings formed in summer and autumn are widely spaced because plenty of food is available. The number of annuli on the scale gives the age of the fish.

Otoliths are formed in embryo as soon as the inner ear is formed, and are located on either side of skull. Of the three otoliths (lapillus, asteriscus, and sagitta) the sagitta is the largest and is used in age determination.



A scale showing four annuli

5. **Radio-carbon uptake method**

Fish scales taken from the epidermis of a live fish are incubated in a medium containing the amino acid glycine made radiolabeled. The rate at which C^{14}-glycine is incorporated into the scale is measured by level of β emission by scale. In creased incorporation of C^{14} means faster growth rate.

6. **RNA-DNA ratio method**

This is a method to measure protein synthesis rate, giving an index of growth rate. DNA content is constant per cell, but RNA content is a function of the cell's protein synthesis rate. Thus RNA-DNA ratio shows this rate per number of cells in a tissue sample. This ratio correlates with measured weight gains in some fishes.

Growth in animals is not constant for all the years. The young grow at a faster rate and this goes on decreasing as the animal advances in age. Age and growth rate determination are useful while comparing growth rates of species. Observation on growth rate suggest about the favorable conditions, season, onset of sexual maturity etc. Such studies are extremely useful in the fishery management.