DISTANCE LEARNING MATERIAL

VIDYASAGAR UNIVERSITY

DIRECTORATE OF DISTANCE EDUCATION

MIDNAPORE - 721 102

M. Sc. in Zoology

PART - I

Paper - I - Group : A & B

Module No. - 01, 02, 03, 04, 05, 06, 07, 08, 09, 10, 11 & 12

CONTENT

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M. Sc.

in

ZOOLOGY

Part – I : Paper - I : Group – A : Unit – I

Module – 01

Topic –1 : Origin and Evolution of Metazoa; Phylogenetic overview of major invertebrate phyla.

Topic – 6 : Conservation of invertebrates: approaches and setting priorities.

Topic – 1 Origin and Evolution of Metazoa.

What are Metazoans ?

Metazoans are multicellular, motile, heterotrofic organisms that develop from embryos. The gamets never form within unicellular structures but are rather preduced within multicellular sex organs or at least within surrounding somatic cells. Besides, they possess the following characteristic features.

1. The surface layer (epithelial cells) exposed to external conditions specializes first into protective functions, then into sensory and nervous structures while the internal layer comes digestive.
2. Cells and layers in an intermediate situation tend to assume supporting an contractile roles.
3. The layered construction also favours the fomation of different organs at different depths.
4. Collagen fibers are distinctive product of metazoans.
5. Metazoan sperms which are monoflagellated uniformly, occured in all eukaryotic organisms.
6. The body tissue of metazoa is differentiated in a somatic part which carries on the regular life activities and eventually dies and a germinal p which is immortal by means of sexual reproduction.
7. The diversity in metazoa is significant with 29 phyla (of which only one, the chordata, contains animals that are not invertebrates).

The Figure –1 illustrating the phylogeny of Animal Kingdom reflecting the different ways of grouping which are most widely accepted by Zoologists.

Appearance of different anatomical structur he course of metazoan evolution :

The different stages of anatomical ela ora i n actually represent in a general way the steps by which the higher animals evolved from the lower ones.

The first true metazoa were diplobastic animals, devoid of organs, consisting of an outer ectodermal epithelium and an inner endodermal mass. Soon, however, both layers gave off glands, muscles and primit connective tissue cells; sensory and nerve cells were apparently of later origin. Connective tissue of ectodermal origin came to lie between the ectoderm and endoderm forming a mesenchyma.

The next step in the metazoan evolution is the appearance of mesoderm, replacing connective tissue in between ectoderm and endoderm forming triploblastic stage.

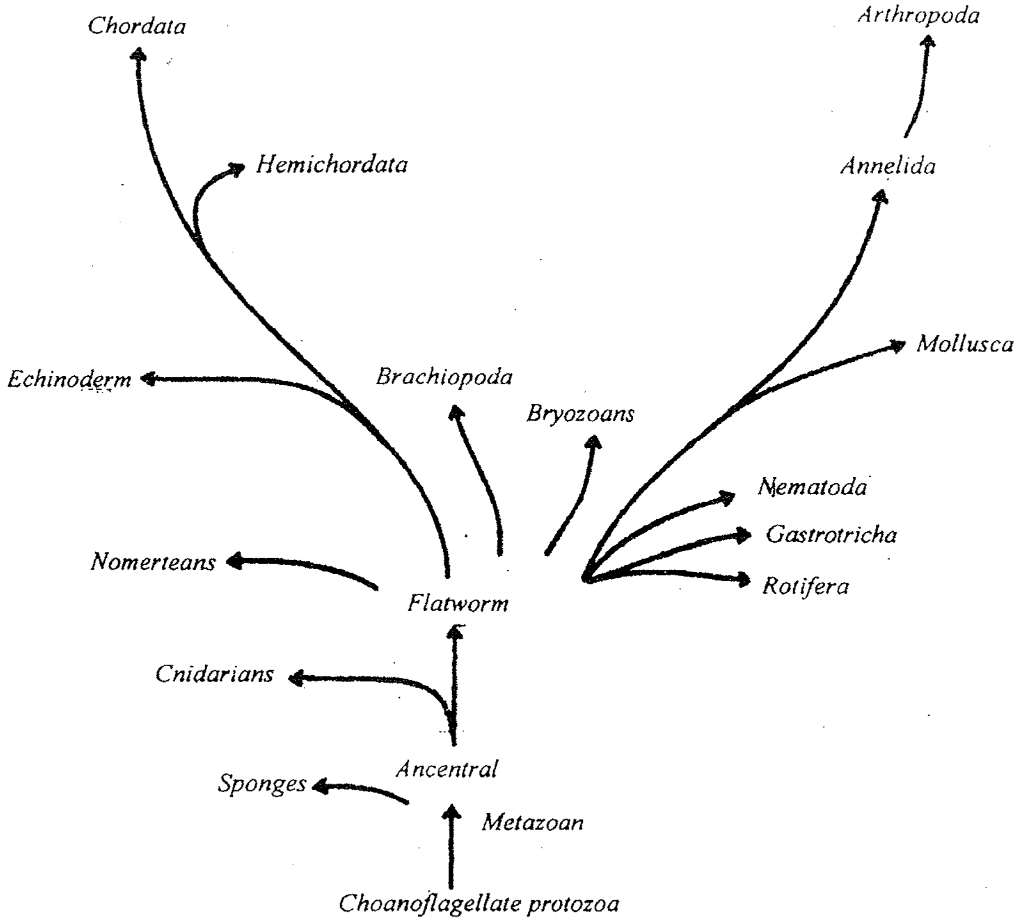


Fig. 1 : A possible phylogeny of the Animal kingdom

The mesoderm furnished space and materials for the formation of many organs like muscular, reproductive, supporting and circulatory system. The ectoderm specialised in skin and nervous structure, the endoderm in the digestive tract and its various elaboration.

With the appearance of the mesoderm, the metazoan body became coelomate i.e., a space developed in the mesoderm. The coelom apparently facilitates the reproductive and excretory functions and provides space for other organs to carry on their activities.

The final step on anatomical elaboration in the evolution of metazoa is the segmentation of the body. This is to be noted that evolution does not proceed in a straight line but rather as a branching tree. Any particular structure may represent several variations with some features in one group of animals and other in another.

Characteristics of the first Metazoans :

Radial or Bilateral :

Three phyla of animals – sponges, cnidarians and ctenophorans exihibiting a radial symmetry are grouped as radiata. Many species of these groups have become irregular, such as sponges or have become biradial such as sea anemones and ctenophores, but the primitive symmetry for each group is radial.

All of the remaining animal phyla are bilateral or if radial, like starfishes, the radial symmetry has clearly been secondarily derived from bilateral ancestors. Thus radiality in the three "lower" phyla preceded the evolution of bilaterality, implying that the first metazoans were radially symmetrical.

Pelagic benthic :

The different form of symmetry when is considered on ecological perspective, may give rise the idea that either form of symmetry may be appropriate for either pelagic or benthic forms. It correlates on the mode of living rather than where they live. Radiality is appropriate for a planktonic drifting form where they move in any direction depending on the nature of current of water or for a sessile form. It is reported that a pelagic radial form gave rise to a bilateral phase on becoming benthic. Again within the established bilateria groups, a secondary trend towards radiality on becoming sessile is very common (bryozoans, tunicates etc., the echinoderms, once included in the radiata, now firmly recognized as secondarily pentaradial). From the lifehistory patterns, it is apparent that the newly evolved benthic adults retain a pelagic larval stage.

The ciliate forms from which a syncytial metazoan might have originated are not noticiably benthic whilst many small pelagic larvae may perhaps be primitive. Either type of ancestry seems equally possible, considering different biological and ecological criteria for benthic and pelagic forms.

Flagellate or ciliate :

It is assumed that there were two separate origins for the metazoa, some phyla deriving from a flagellate ancestor and some from a ciliate form. It may be concluded that ancestral metazoans may have been just flagellate, are rather unlikely to have been just ciliate but could have possibly been of both types independently.

Metazoan Embrogency :

The embryonic development of bilateral metazoans provides the principal basis for the division of these phyla into rather well defined groups. One division embraces flatworms, annelids, mollusks and arthropods as well as a number of smaller allied phyla. These groups constitute the protostomia. The other division includes echinoderms, chordates and several smaller phyla, the members of this division are known as the deuterostomia.

There are many examples of modification and deviation in every phylum, largely through changes in the distribution and the amount of yolk materials. But each line does display certain characteristic features.

The period of embryonic development may again be divided into the following stages.

1. The period of cleavage or segmentation.
2. The period of formation of the germ layers.
3. The period of formation of organs i.e., organogenesis.
4. The period of histological differentiation – histogenesis.

Cleavage : Types of cleavage :

Indeterminate Cleavage :

The late establishment of the embryonic fate of blastomeres is known as indeterminate cleavage e.g., deuterostomes (here the blastopore is transformed into anus). If a starfish egg is allowed to cleave to the four cell stage and the cells are then separated, each cell is capable of forming a complete gastrula and then a larva. Here the blastomeres in their early stages of development are with unfixed fates and thus represent an example of indeterminate cleavage.

Determinate cleavage :

The blastomeres in their early stages of embryonic development with determined fates are a part of determinate cleavage e.g., protostome (where the blastopore of the developing embryos are transformed into mouth aperture). If a marine annelid egg is allowed to undergo two cleavage divisions and the resulting four blastomeres after being separated develop into a fixed part of the gastrula and then into a larva.

Holoblastic cleavage :

The eggs containing little yolk are completely divided into blastomeres and called holoblastic.

Meroblastic cleavage :

The eggs containing good amount of yolk materials are not completely divided i.e., the cleavage furrow never reach to the vegetal pole, so the vegetal hemisphere of the egg remains uncleaved – known as meroblastic cleavage.

Radial cleavage :

The axes of the early cleavage spindles are either parallel or at right to the polar axis (the axis between animal and vegetal poles). The resulting blastomeres are thus always situated directly above or below one another. This is radial cleavage e.g., deuterostome.

Spiral cleavage :

Cleavage is total but the axes of the cleavage spindles are oblique to the polar axis, rather than as right angles or parallel e.g., protostome.

Coelom, its origin and development :

Coelom is a space within the body covered by mesoderm. In protostomes all the endomesoderm arises form a single cell, the messentoblast cell formed at the sixth cleavage. Located originally at the posterior end of the animal in front of the site of the future anus, each cell proliferates to form two masses of mesodermal cells, one on either side of the body. In metameric (segmented) protostomes, the mesodermal masses form a linear series of segmented blocks of cells. Subsequently, a split forms within each mesodermal mass and the resulting cavity enlarges to form the coelom. This mode of coelom formation is termed schizocoely and coelomate protostomes are therefore often referred to as schizocoelous coelomates.

In deuterostomes, the mesoderm arises by a process called enterocoelic pouching, in which the wall of the archenterons evaginates to form pouches. The pouches separate from the archenterons, either as a pair or in the case of metameric deuterostomes as a series of lateral pairs. The cavity of the evaginate and later pouch become the coelom and the wall becomes the mesoderm. Because of this mode of coelom formation, the deuterostomes are known as enterocoelous coelomates. (Fig.2)

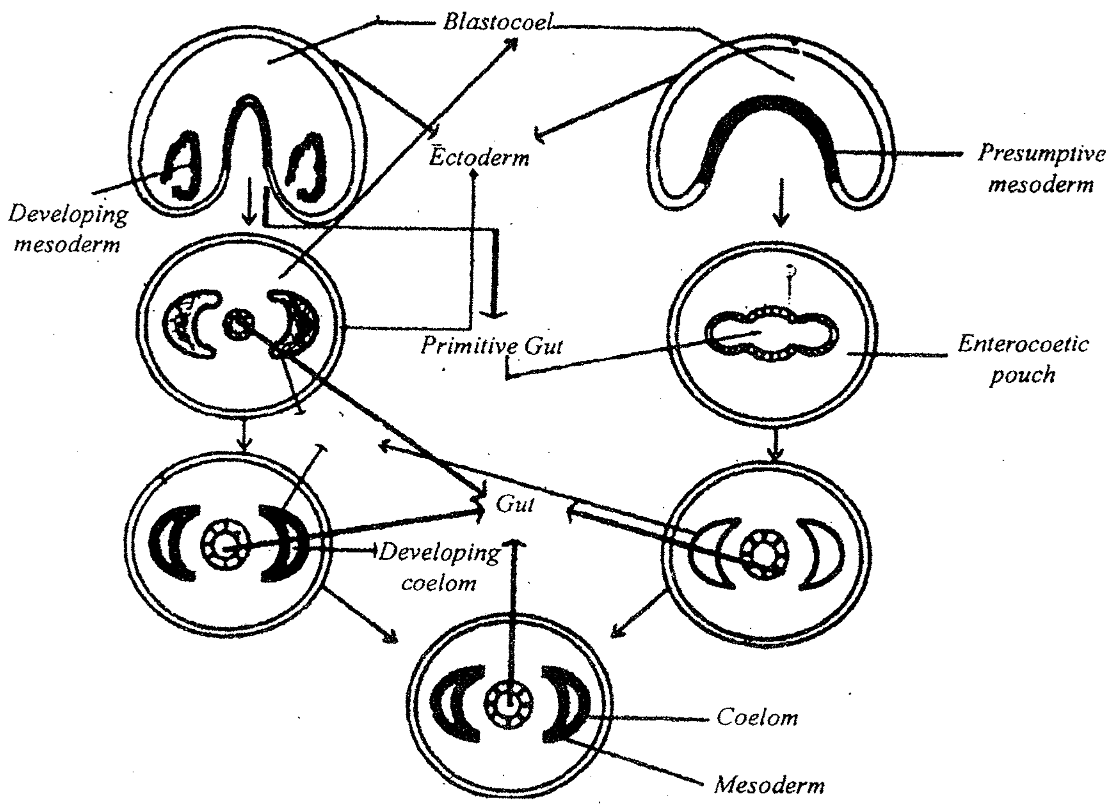


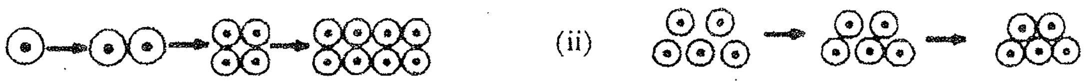
Fig. – 2 : Mesoderm and Coelom formation in Animals

A survey of different theories to explain the origin of metezoa :

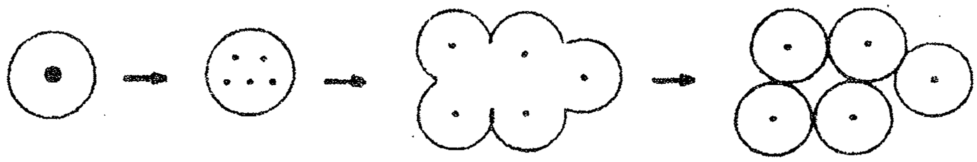
Many theories have been put forward to explain the origin of metazoa. Most of these have been compounded with views on subsequent evolution from the earliest metazoan to the groups of existing lower metazoa.

All the theories are of only two kinds.

1. The first possibility is that metazoan status was achieved by the coming together of two or more cells, forming a colony – whether by incomplete separation of daughter cells after mitosis or by independent aggregation of formerly sepatated cells in a symbiotic fashion. This colonial theory is the most frequently encountered and classic theory of the origin of multicelluler animals.



2. The second major possibility called the syncytial theory which holds that animals arose from a single cell which became multinucleated without divisions of the cytoplasm and the cell boundaries were established later to give rise to multicellular animals.



Colonial "blastaea/ gastrea" theories :

The version of this theory proposed in the Nineteenth Century by Haeckel (1874-75) was heavily dependent on recapitulation theories suggesting that the blastula of modern embryos recapitulate their ancestry as "blastea" organism succeeding a phase of aggregation of protistan flagellates. The basic metazoan was thus a pelagic, radialy symmetrical aggregation of protistan flagellates as currently represented by forms like Volvox. A "gastrea" stage which the gastrula of modern embryos recapitulates would arise from the blastea by a separation of locomotory and digestive regions. The "gastrea" form, a simple two layered sac like organisms readily gave rise to the similarly constructed asepitate cnidarans, from which other metazoans subsequently evoeved.

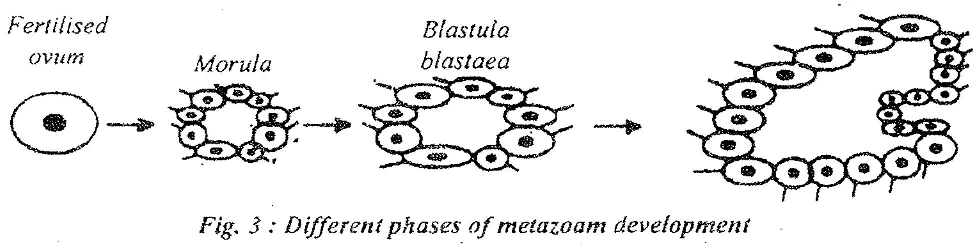


Fig. 3 : Different phases of metazoam development

Remark :

Haeckel's theory has the great merits of simplicity and elegance but there are many opinions in favour and against this theory.

Barnes (1987) :

The colonial theory maintains that the flagellates are the ancestors of the metazoans and in support of such an ancestry the following facts are cited as evidence.

1. Flagellated sperm cells commonly occur throughout the metazoans.
2. Flagellate body cells commonly occur among lower metazoans, particularly among sponges and cnidarians.
3. This theory holds that the ancestral metazoan probably arose from a spherical, colonial flagellate. This stage like the volvox colony, was called the blastaea by Haeckel which subsequently invaginated to form a double-walled saclike organism, the gastrea. This gastrea was the hypothetical metazoan ancestors, equivalent to the gastrula stage in the embryonic development of living metazoans. In addition to embryological evidence, Haeckel noted the close structural similarities between gastraea and some lower metazoans, such as the hydrozoan cnidarians and certain sponges. (Fig. 3).
4. The body of this hypothetical ancestral metazoan is believed to have been ovoid and radially symmetrical which simulate the planula larva of cnidarians and is called as planuloid ancestor. From such a free swimming, radially symmetrical planuloid ancestor the lower metazoans are belived to have arisen. On the basis of this theory, the primary radial symmetry of the cnidarians was supposed to have been derived directly form the planuoid ancestor. The bilateral symmetry of the flatworms would then represent a later modification in symmetry.

Trochea theory by Nielsen & Norrevang (1985) :

They suggest that a common monociliate gastrea stock gave rise directly to cnidaria and also via a "trochea" stage with an equatorial ring of multiciliate cells, to the remaning bilateral phyla. This occurred through trochophore larvae on the spiralian side and through a 'tornea' larva on the deuterostome side, the latter form losing its multicilliation again. (Fig. 4).

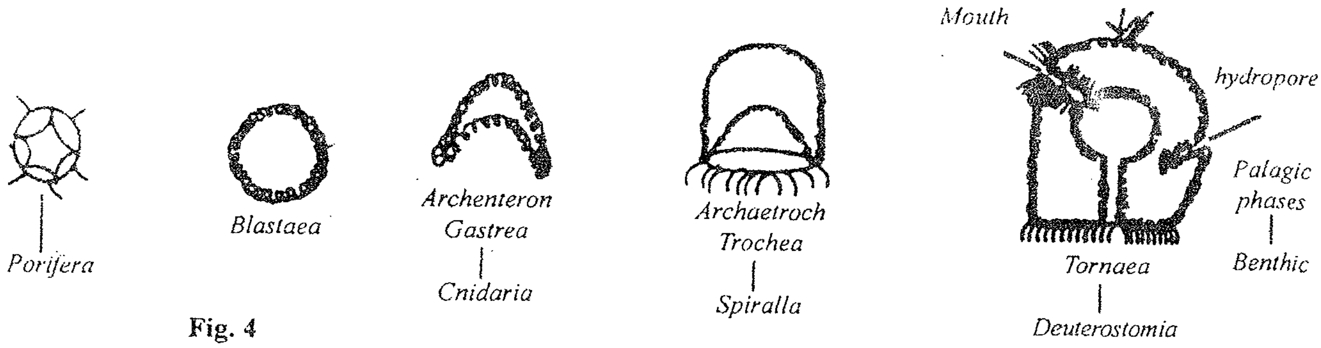


Fig. 4

Colonial 'blastula–planula' Theories (Hyman1940, Hand 1963, Reisinger 1970).

The planula ancestor is taken to be small, pelagic, ovoid but radially symmetrical solid mass cells, the internal cells acquired by immigration from the blastula stage. From it radiated the cnidarian and cenophoran lines and when it became benthic and differentiated its dorsal – ventral and anterior – posterior axes, it gave rise to the primitive bilateria such as flatworms. It embraces both pelagic and benthic forms and radial and bilateral forms in a single theory, permitting all the metazoa to be monophyletic from flagellate ancestors.

This theory also establishes the platyhelmenthis firmly near the rootstock of the bilateral phyla. All that is required to complete their transformation from planula is the increasing potency of the endoderm to form mesodermal parenchyma and actual gut tissues leading from a new ventral mouth and the acquisition of a reproductive system.

Salvini – Plawen's (1974) review of the colonial Blastaea Planula Theories (Fig. 5) which emphasised that a Planula with a single pair of tentacles is considered as the first critarian as well as the starting point of biradial polyps which is evident in the embryology of scyphozoa and some hydrozoan polyps. As a theory, it explains the difference between the medusae in these two groups proposing that their pelagic medusoid phases must have arisen convergently.

Remark :

Controvercies on above mentioned views centered over two points. Firstly, the 'planula' is an extremely simple architectural construct and is almost an obligate stage in any metazoan's embryology developed independently several times due to cell aggregations. Secondly, monociliated cells as derived from a flagellate are represented amongst lower metazoans in cnidarians, placozoans and sponges but multiciliated cells occur in ctenophores and platyhelminthes. If the whole origin of metazoa is monophyletic from flagellates, the presence of monosomal multiciliation in early planula leading to the turbellarians and other spiralian animals is somewhat difficult to account for.

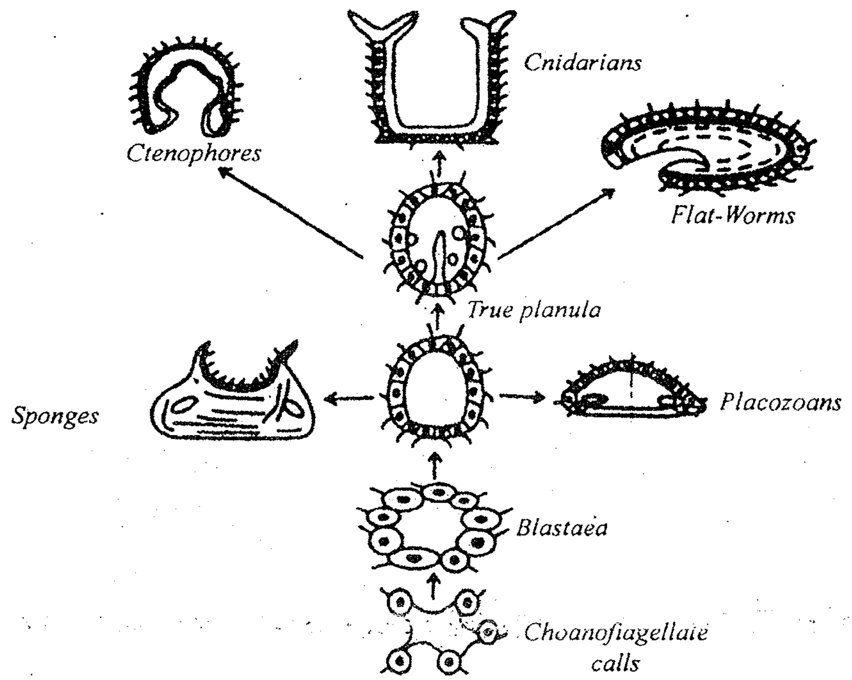


Fig. 5: A scheme of invertebrate origin in which the planula is central to all further development beyond the first acquisition of multicellularity.

Colonial amoeboid / acoeloid theories :

Reutterer (1969) proposed an archemetazoan origin amongst the amoeboid protozoans that exhibit some tendency to aggregate and are essentially diploid. The ancestral metazoan would therefore be benthic with nutrition by ingestion of surface deposits lacking primary surface ciliation, such acoeloid ancestors could perhaps readily give rise to either modern multiciliated groups like the acoela or the monociliated lineages like the cnidarians.

Hanson (1977) also advocated a colonial amoeboid form as the likely ancestor of cnidarians as part of his effectively polyphyletic theory on metazoan origins.

Syncytial ciliate / Acoeloid theories :

The main proponent of these theories, was Hadzi (1953,1963) and subsequently supported/ and elaborated by steinbock (1958, 1963) and partly by Hanson (1958, 1963, 1977).

Hadzi (1953, 1963) highlighted the possibility of metazoan origins through growth, nuclear division and cellularisation of a single protozoan, rather, than by aggregation of several. His theory also explained that a bilateral ancestor of metazoa i.e. ciliated protozoa (Paramecium or Opalina) could very directly gave rise to the acoel turbellarians which lack any gut lumen. In particular, Hadzi, believed the midgut tissue in Acoela to be premitive syncytial in nature, standing as testimony to a genuine link with plasmodial protists. Acoels would then be ancestral to all other metazoans considering many features as to be homologous with one another. Much emphasis on homologies was criticized by Remane (1952). Hadzi's views of the later evolution of the metazoans in linear pathways with all phyla derived from a single stem (Fig. 6) has certainly not been widely accepted. But Hadzi's ideas on archemetazoam origin's have been accorded some serious consideration. The planuloid /acoeloid form leads readily to flatworms which gave rise to ctenophores in one hand and cnidarians on the other. Alternatively, Steinbock (1963) suggested that cnidarians branched off from very acoel form similar to the planula invoked by other theories; the acoel preceded the planula rather than vice-versa.

Hanson's theory (1977) invoking a plasmodial/syncytial ciliate origin for platyhelminthes and the spiralians but a choanoflagellate origin for sponges and an amoeboid origin for cnidarians received wide acceptance.

Evolution of the lower Metazoa :

It is widely accepted that metazoans evolved from protozoans though there is a dispute as to the ancestral type. The first significant advance towards metazoans must have been the development of a multicellular organism. In order to maintain definite shape and size of the multicellular aggregation or colony, specified growth patterns and morphogenetic movements controlled by a definite set of genome was required. To accomplish this, the regulatory mechanism would have to develop from control of individual cell functions to the integration of many genetically identical cells. Evolution of multicellular control could proceed through the intercellular exchange of substances, such as hormones, enzymes etc. Once some genetic multicellular integration was achieved, variations in the shapes of cell aggregation could have arisen through recombination, and mutation and natural selection would establish an array of shapes in accordance with the adaptation of different ranges of habitats. During the evolution of intercellular communication, regulation and differentiation, a point is reached where the cells no longer form a colony/multicellular aggregation but an integrated individual organism.

The three living multicellular animal groups with especially primitive features viz. porifera, coelentera (cnidaria and ctenophora) and platyhelminthes are considered as lower metazoa.

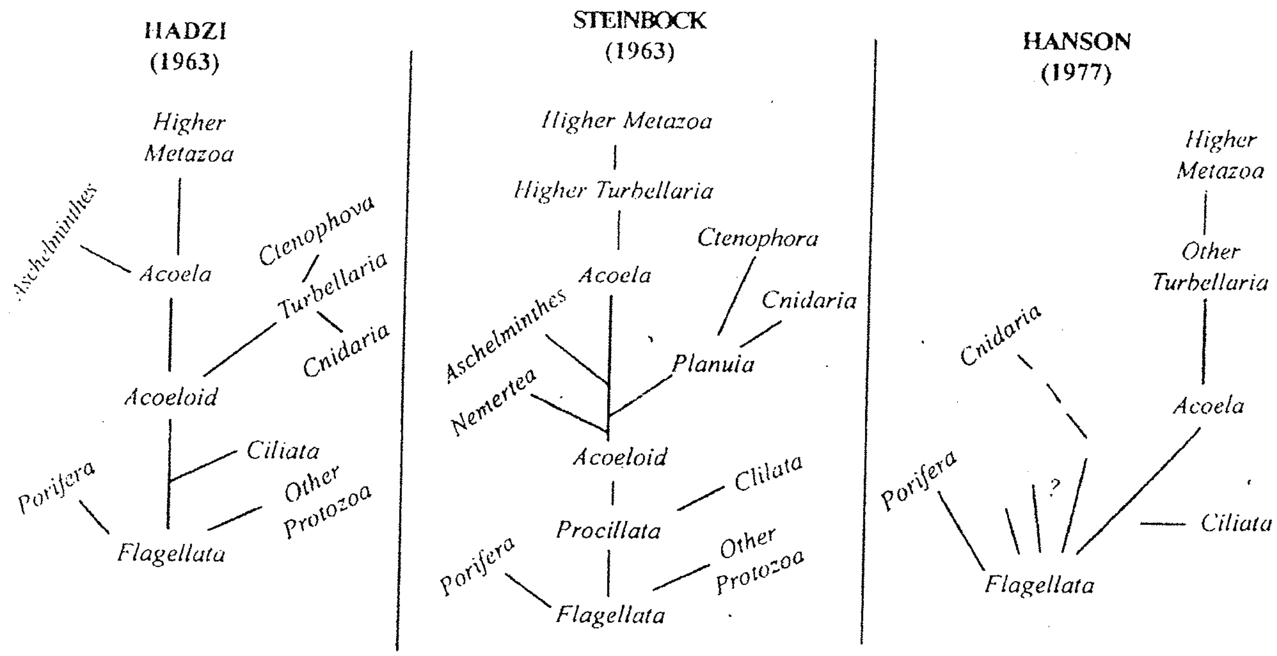


Fig. 6: Evolutionary pathways of metozoa.

Porifera :

Sponges furnish some idea of the construction of the early Metazoa. The sponges are lowly organized aggregations of the cells that are slightly differentiated into several sorts. Tissue formation is limited on free surfaces which does not reveal any differentiation. Instead differentiation proceeds in the mesenchyma. Although definite head is absent, osculum has some of the physiological characteristics of a controlling region. No definite digestive tract is present, and the protozoan mode of food intake and digestion has been retained by most. Presence of choanocytes in sponges led many zoologists to believe that sponges are derived from choanoflagellate protozoans. Colonid choanoflagellates. Such as proterospongia represent an obvious intermediate position, lacking the cellular differentiation and limited consideration of a complex sponges but differing very little from the simplest ascon – type poriferans. The question therefore comes down to whether the sponges are a separate evolutionary line making the metazoans at least diphyletic. Sponges have evolved very little beyond the stage of colonial protozoans possibly through their early adoption of a sessile mode of life. and the inability of their cells to give up their protozoan habits. The failure to develop a mouth and digestive sac and the retention of the original flagellate cells as food getters and current producers lead to the evolution of a unique anatomical type permeated with water channels. Evolutionary changes of sponge has been concerned chiefly with the perfecting of the water system and the development of a skeleton.

Cnidaria and Ctenophona :

Cnidarians form a clearly defined phylum because of their unique cnidoblasts and this phylum is supposed to have been derived either from a conventional gastrea stage or from a solid planula. Hyman (1950) strongly advocated that the coelenterate stock arose from the gastraea by the attachment of the later at the aboral pole and its development into a hydra like polyp. This by asexual budding gave rise to hydroid colonies which through division of labor became polymorphic and some polyps were modified into medusae specialised for sexual reproduction and lead a pelagic mode of life. Hadzi (1963) opined that anthozoans are the most primitive group of cnidarians and the hydrozoans were derived from them.

Platyhelminthes :

The phylum platyhelminthes embraces four classes of worms – three are entirely parasitic (monogenea, trematoda and cestoda) and the fourth class, the turbellaria are free living and are certainly the ancestors of the three parasitic classes.

Members of the phylum justify their name as flatworm because of their dorsoventrally flattened body shape Psuedocoelomate – loose parenchyma of mesenchymal origin fills the space between the internal organs and body wall. The mouth is only opening to the digestive tract. Protonephridia are present and the reproductive system is hermaphroditic.

A Phylogenetic overview of invertebrates :

Phylogenetic study is important in order to find out the right answer to the question of how all the familiar living animals are related to one another. On analysing the relationship of animals with the forms of some phylum and that of members of other phyla, it is noticed that some types of animals seem to be very isolated with little resemblance to and so convincing homologies with any other known forms. Other types of animals appear to be part of fairly clearcut super-phyletic group though members of these are restricted to a rather small number of phyla. Phylogeny gives a structure and context to the rapidly advancing intricacies of molecular biology on the one hand and the equally fashionable overviews of behavioural, ecological and evolutionary theory on the other.

Invertebrate Phylogenetic Schemes :

Traditional Schemes :

This scheme considers 'Planula' as ancestor for the metazoans, with diploblasts preceeding triploblasts and acoelomates giving rise to pseudocoelomates and coelomates. The latter are split into two major groups, the protostomia including the three large phyla annelida, mollusca and arthropoda and the Deuterostomia incrorporating Echinoderms and a few minor phyla together with the Chordates.

Archecoelomate Views :

Proponents of this scheme believe that rather than taking an acoelomate 'Planula' – type creature as the ancestral metazoan, the archemetazoan to have coelomate organisation and is supposed to have been derived from something like cnidarian and three pairs of body cavity pouches budded off from the gut.

Spiralian ancestry schemes :

This scheme considers that the protostomes or spiralians to be the more primitive of the super phyletic groupings and are derived from acoelomates and in their turn give rise to non-spiralian groups.

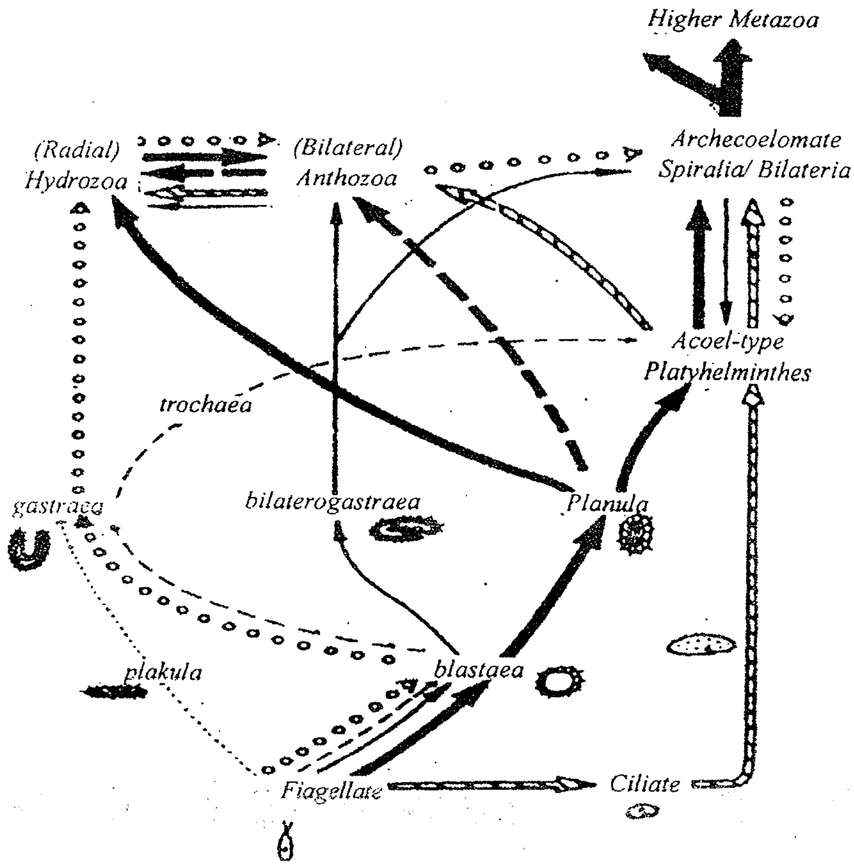


Fig. 7: A summary of different theories of matazoan origin. Solid black arrows - The planula theory of Hyman, Salvini-Plawen; circles - 'gastrea' theory of Haeckel; continuous narrow lines - Jagersten's bilaterogastrea version; Dotted line - Nielsen's trochea theory; Diagonaly barred arrows - syncitial theory of Hadzi.

Division of metazoans based on morphological features :

Certain features of basic animal design contribute to hierarchical plan of animals viz. the planes of symmetry that distinguish radiate phyla from higher bilateral groups, the diploblastic nature of lower animals and the added mesoderm giving triploblasty and the presence of varying types of body cavities.

Patterns of symmetry :

Based on the patterns of symmetry of the animals are divided into two broad groups – Radiata (possession of radial symmetry) and Bilateria (possession of bilateral symmetry).

Germ layers :

The three basic germ layers of animal tissue and homology of these layers throughout the animal kingdom allows direct comparisons among the tissues of all animals. In the lower metazoa (porifera, cnidaria, ctenophora, platyhelminthes) two primary germ layers are formed by the process of gastrulation an outer ectoderm and an inner endoderm – and that the mesoderm is subsequently derived from one or both of these layers and lies in an intermidiate position to give the typical triptoblastic condition (Fig. 8). Each layer has characteristic properties and gives rise to a characteristic set of tissues or organs as follows.

(a) **Ectoderm** : It is usually derived from the upper (animal) pole in the embryo. It surrounds the outer surface of all organisms and may line the fore and hind guts and certain other ducts. It has protective function and also gives rise to the nervous system and sense organs and performs role in ciliary flagellar locomotion or in producing hydrokinetic effects.

(b) Endoderm, deriving from the lower (vegetal) pole in most embryos, forms the gut lining and certain organs are derived from the gut.

(c) Mesoderm, after being derived from endoderm (usually), comes to lie in between two germ layers. Based on the absence or presence of mesoderm, animals are grouped into diploblasts and triploblasts.

Body cavities :

The body cavity of any metazoan is a fluid filled cavity that takes up a relatively large space within any animal's body and within which fluids move and circulate. This cavity may serve a number of functions such as distribution of nutrients, respiratory gases, acts as a storage area for different organs viz excretory, respiratory etc; may allow greater coordination by use of circulatory hormone, again important is growth, metamorphosis and reproduction. The body cavity fluids serve as an efficient hydrostatic skeleton.

Body cavity and its further modification :

The archenterons and its derivatives formed by intucking during embryological gastrulation opens to the outside via the blastopore. In radiate groups, this cavity is commonly termed the coelenteron whereas in the bilateral phyla it is the gut.

The blastocoel and its derivatives, the primary body cavity formed within the hollow embryo at the blastula stage. This cavity may persist directly as a spacious pseudocoel, in those animals where only limited mesoderm is produced to invade the embryologicl space viz. nematode.

And a good real acoelomate is the turbellarian flatworm, with fairly densely packed cellular mesoderm and little evidence of residual primary body cavity.

The coelom, the secondary body cavity formed within the developing mesoderm.

Body Cavities in Metazoa :

Acoelomale	Porifera, Cnidaria, Cetenophora, Platyhelmentes, Placozoa, Musozoa Nemurator
Pseudocoelomate	Rotifera, Gastrotricha, Entoproc, Priapulida, Nematoda, Kinorhynca
Coelomate	Annelida, Arthropoda, Molluscs, Echinodermata, Chordata

Body divisions :

Different phyla of metazoans show a tendency towards repitition of structure along their axis, a phenomenon generally known as metamerism. The metamerism of annelids, arthropods and chordates, are different in kind from that of other animals and these animals are often dignified with the term 'Segmented' instead. This implies a precise and definite repetition of all structures in each segment (called somites) particularly involving the mesoderm and with new somites added at the back end of the animal.

Evidence in invertebrate phylogeny :

The following scheme (Fig. 8) depicts the possible types of evidence that might be used in drawing phylogenetic relationships among different groups of invertebrates.

A. Evidence from the fossil record :

A knowledge of fossil remains is generally regarded as an important tool in drawing relationships of different groups of metazoa. From the Cambrian period, complex mineral skeletons were secreted and fossilization of animal remains became much more evident. As a general rule, the tougher the skeleton, the better fossil record of a group leaves behind. Molluscs and brachiopods have more complete records, Cnidarians the poorest and echinoderms and arthropods with intermediate. Throughout the Cambrian, the trilobites and other thin shelled brachiopods were the most abundant preserved animals in the fossil strata. At the end of this era, the fauna changed dramatically within a few million years and some other Cambrian groups appeared. During Ordovician period there was a considerable radiation of animals from many phyla having calcareous skeletons. Brachiopods, mollsucs, corals, echinoderms and new trilobite forms, together with early bryozoans are assumed to be forerunners of hemichordate deuterostomes. This radiation established the marine faunal pattern of the succeeding Devonian and Carboniferous eras. One important message the fossil records holds is the trend of decrease in diversity of species throughout past geological periods, despite a general increase in species number. Study of fossil records in time and space although throw some light on diversification of species, emergence of super phyla, sequence of evolution of class within, the relatively well preserved phyla (Mollusc, brachiopods, Echinoderms, Crustaceans) but does not reveal very much of our understanding of invertebrate relationships especially with regard to the sequence of appearance of body plans.

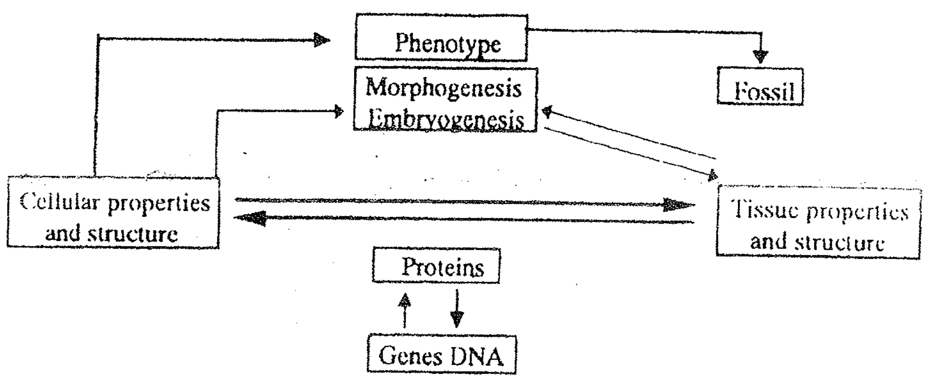


Fig. 8

Evidence from chemistry and genetics :

Phylogenetic relationship can be drawn on molecular structures and their distribution among different groups of animals. The base sequence of DNA molecule determines the ultimate form and properties of the organisms.

A . Skeletal molecules :

These include the proteins, namely collagen and number of polysaccharide derivatives (cellulose, chitin). Cholagens are recognized by their amino acid compositions (about one third glycine, with high percentage of proline and hydroxyproline) , their wide angle. X-ray diffraction pattern and their characteristic 60 - 70 mm banding when analysed by Electron – microscopy. Colagens are found in all the metazoa and is normally produced mesodermally but ectodermally in the cuticle of nematodes and annelids. A variety of fibrous protein of non-collagenous nature occur throughout the animal kingdom. In chordates, these proteins are termed keratins and these molecules are supposed to be restricted to terrestrial vertebrates. Another major of structural proteins, the elastins, are subject to convergent and divergent occurrence arising from ecological and mechanical requirements. Chitin (Nitrogenous polysaceharide) has long been considered for molecular phylogenies. Three types are known to occur in different animals with differing chain orientations and also may occur in different parts of the same animal.

Concluding remark on origin, evolution and phylogenetic relationship among Metazoa :

In respect of complexity of organisation, the lowest groups of Metazoa are traditionally the sponges, cnidarians and ctenophores, together with the placozoans and mesozoans.

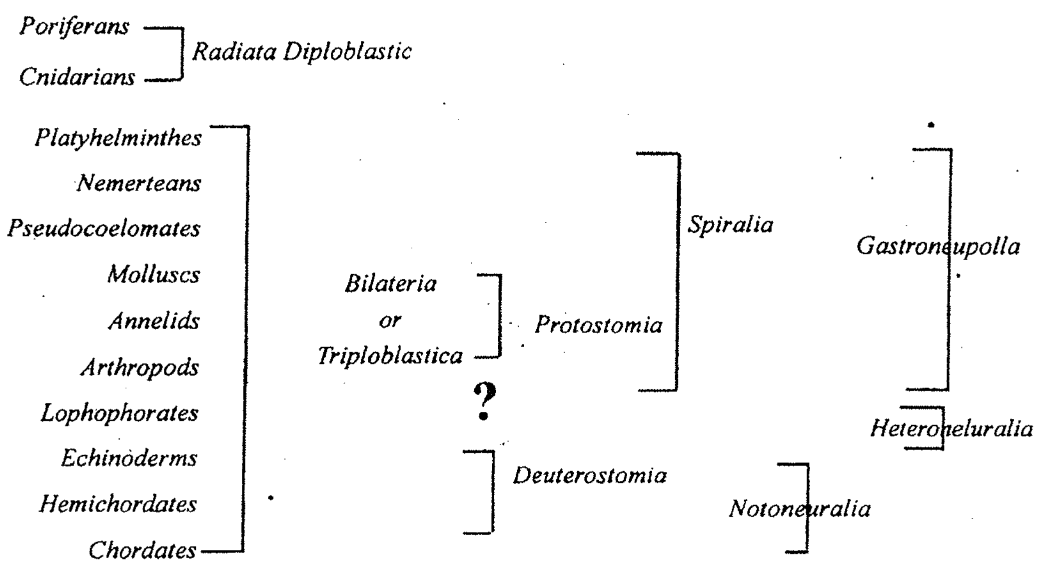
Sponges are certainly rather primitive in their design and are organized with limited coordination between. They differ not very much from other metazoa since their embryology has been interpreted to accord with conventional patterns and their choanocytes have been associated with the microvillar monociliate cells found in many other phyla. However, their links with all other groups are slight and independent origin from flagellate protists (choanoflagellates) seems beyond doubt.

Cnidarians may have a fossil record right back in the pre-cambrian that would indicate a position near the base of the metazoan kingdom. Scheme that derives cnidarians from a form like the present planula larva is most acceptable.

Ctenophore can only be derived with any degree of conviction from a planula form, possibly entirely independently or perhaps as an offshoot of an early, non-spiral multiciliate proto-platyhelminth stock. Placozoans and mesozoans probably both represent further independent attempts at a multicellular condition. Placozoans appeared to be a close descendant of one of several planuloid ancestors, mesozoans require a multiciliate ancestral stock.

Every one of the 'lower phyla' is therefore best derived separately and uniquely from protozoans via planula or gastrula stages. From the early protozoan stock. Cnidarians and Ctenophores originated followed by the appearance of the acoelomate flatworms and nemerteans. With nematodes and their relatives as sideline, then came annelids, molluscs, arthropods and echinoderms. These phyla are not necessarily closely related to each other. They may be broadly divided into two guoups – Radiata as opposed to Bilateria and of Diploblastica as opposed to Triploblastica. The sequence of phylogenetic origin may be from, 'planula' type ancestor for the metazoans, with diploblasts preceding triploblasts and acoelomates giving rise to psendocoelomates and coelomates. The latter as divided into two major groups – the protostomia including the three large phyla Annelida, Mollusca and Arthropoda while Deuterostomia incorporates echinoderms and a few minor phyla together with chordates.

Scheme of Invertebrate 'Super Phyla' :



Such schemes originated in the late nineteenth and early twentieth century, with Zoologists such as Haeckel, Grobben and Hatschek but more recently they impart enormous influence on the works of Hyman (1940, 1951, 1954) by reviewing most of the animal kingdom in terms of structure and function and giving the most recent intensive analysis of the phylogenetic status of each invertebrate phylum.(Fig.-8 and Fig.-9)

Embryological and larvel features of Protostomes and Deuterostomes :

Features	Protostome	Deuterostome
Cleavage	Spiral/ Determinate	Radial/ Indeterminate
Blastopore	Forms mouth	Forms Anus
Coelom	Schizocollic	Enterocoelic
Larval type	Trochophore	Dipleurula

A phylogenetic scheme for the invertebrates based on all the evidence, can be drawn as bellow (Part-Willmer, 1990) which established the prevalence convergent evolution. (Fig. 10).

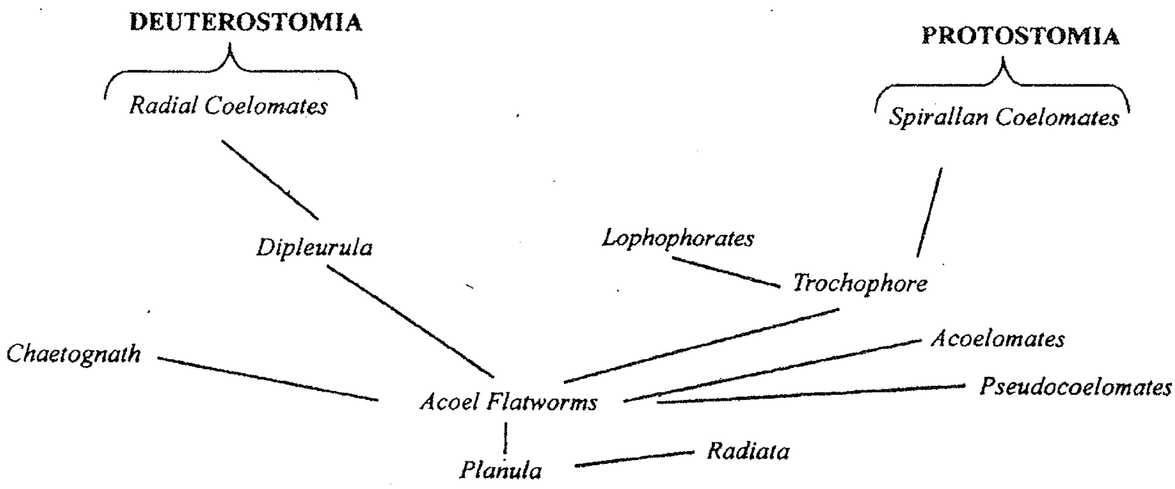


Fig. 8 : Traditional dichotomous phylogenetic trees of the invertebrates. (Hyman, 1940).

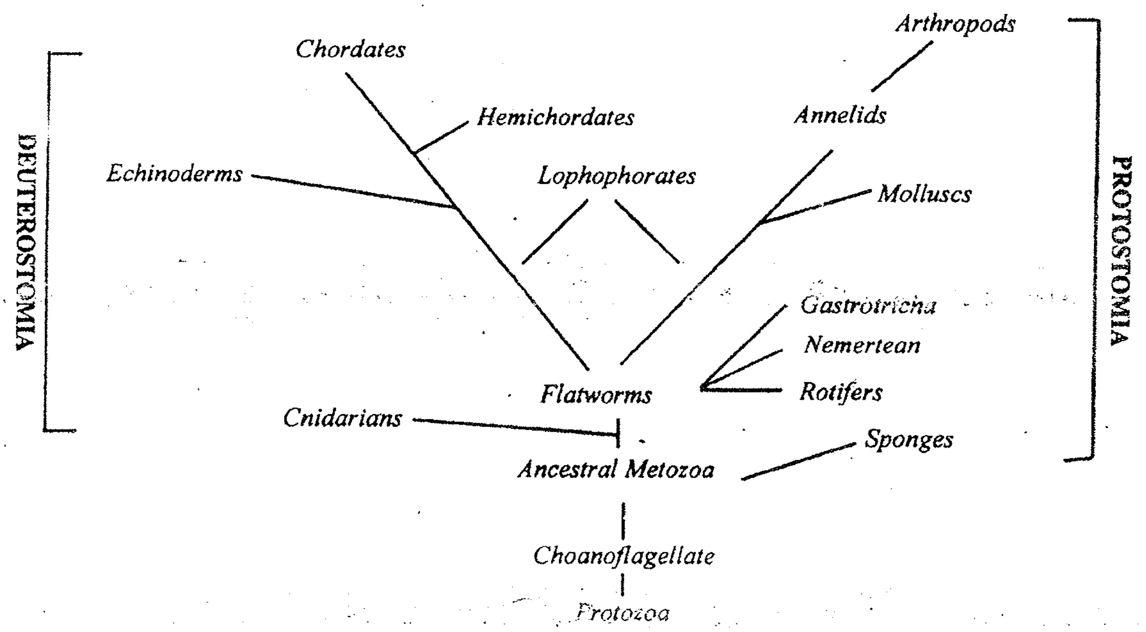
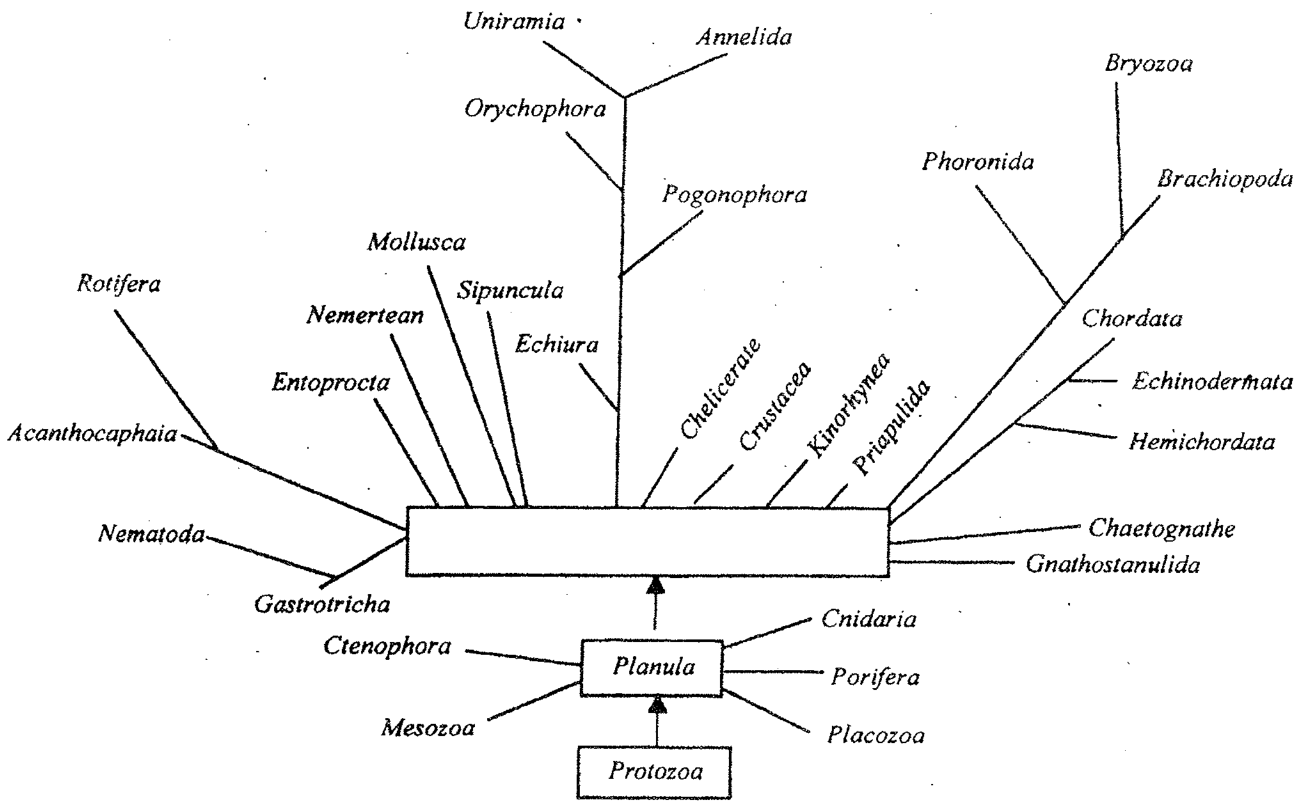


Fig. 9 : Traditional dichotomous phylogenetic trees of the invertebrates (Barnes, 1987).



Conservation of invertebrates, approaches and setting priorities

Invertebrates constitute the most diverse and abundant animals in most natural ecosystems but their importance in sustaining those systems is usually underestimated. Conservation in usually misunderstoods simply with the saving of notable species rather than with broad and less tangible aims such as maintaining natural communities or whole ecosystems. Much emphasis has so for been laid on the conservation of higher vertebrate many reptiles, birds and mammals which certainly play a vital role in popularising the conservations issues. On the other hand, the well-being of natural ecosystems may depend on a galaxy of less-heralded animals, most of them are invertebrates whose collective ecological role and influences predominate in the diverse community they largely constitute. In order to ensure proper conservation of the whole environment in general and target biotic community in particular, the main needs are to seek and adopt methods for rapid detection and assessment of biota, to rank the species or faunas in some logical ways for conservation importance or priority and to implement management and practical conservation from incomplete data.

Biodiversity with special reference to invertebrate during :

The term biodiversity encompasses all levels of biological variations from the level of genes, to ecosystems; it is usually defined as the totality of genes, species and ecosystem.

The agreements for conserving biodiversity (Mc Neely et. al. 1989) include.

i) That each species is part of a holistic ecosystem and the loss of any part (species, population etc.) may lead to instability and collapse of the whole system.

ii) That each species is part of a holistic ecosystem and the boss of any part (species, population etc.) may lead to instability and collapse for the whole system.

iii) That species are to be used in future as an important commodity for maintenance of life i.e. for food, shelter, clothings and medicine.

iv) That diversity has scientific and cultural values, as well as aesthetic appeal.

Any of these considerations applies significantly to invertebrates and they are substantiated by Wilson's (1987) statement that "if invertebrates become extinct, the world as we know it would cease to exist".

Invertebrate Diversity :

The vertebrates (fishes, amphibians, reptiles, birds and mammals) are included only under one phylum, chordata and may comprise of thousand of different species whereas 'invertebrates unites a great diversity of life forms and unrelated animal groups by the single condition of lacking a backbone. More than Thirty phyla are there to accommodate this diverse arrays of non-chordates which are immensely varied and occupy collectively the totality of global ecosystems and represent virtually all life styles and trophic roles.

The two important considerations for the conservation of invertebrates are:

i) as target for conservation .

ii) as tools used to monitor the 'health' of natural environments, to indicate the effects of various anthropogenic and other intrusions and to show the success (or otherwise) of remedial management procedures.

The diversity of invertebrate life forms is summarised in Table –1.

Reasons behind conservation of invertebrates :

Conservation of invertebrates does not include only collection and preservation of those groups of animals, instead documenting, followed by their habitat restoration. Pragmatic reasons for conserving invertebrates encourages their integrating roles in ecosystems, so that without them most natural biotic systems would not function properly. Slightly less tangible values are exemplified by the importance of invertebrates as study materials and also their use as ecological monitors.

Many positive values of invertebrates have been set out clearly by European Community, 1986 which are considered as the compelling points for their conservation. These are mentioned below:

i) Invertebrates are the most important component of wild fauna, both in number and biomass.

ii) Invertebrates are an important source of food for animals.

iii) Invertebrates may also constitute a source of food for mankind.

iv) Invertebrates are vital to the fertility and to the fertilization and production of the vast majority of cultivated plants.

v) Invertebrates are useful in protecting farming, forestry, animal husbandary, human health and water purity.

vi) Invertebrates are valuable aids for medicine, industry and crafts.

vii) Many invertebrates are of great aesthetic value.

viii) Some invertebrates may harm human activities but their populations may be controlled naturally by other invertebrates.

ix) Mankind can benefit greatly from enhanced knowledge of invertebrates.

x) Terrestrial, aquatic and aerial invertebrates, should be protected from possible causes of damage, impairment or destruction.

Table -1 : Diversity of invertebrats (after Meglitsch and Schram 1991)

Phylum	Common names	Major habitat(s)	Number of species known/estimated
Mesozoa	(Mesozoans)	Microsopic Parasites	85/500+
*Porifera	Sponges	Aquatic mainly marine	c.5000/?
*Cnidaria	Corals, polyps, Sea anemones	Aquatic mainly marine	c. 10000/?
* Ctenophora	Comb jellies	Marine	80/130-500
Gnathostumulida	(Gnathostomulids)	Microscopic; Interstitial in sand, marine	80/1000
* Platyhelminthes	Flatworms, flukes, tapeworms	Aquatic or terrestrial; many parasitic forms	/many 1000s
Gastrotrichas	(Gastrotrichs)	Aquatic, interstitial	450/1000+1800/2500-3000
Rotifera	Rotifers, wheel animalcules		
Acanthocephala	Thorny-headed worms	Intestinal parasites	c. 1000/?
Loricifera	(Loriciferans)	Marine sediments	?/?
Kinorchyncha	(Kinorhynchs)	Aquatic, interstitial	125/500
Priapulida		Marine bottom dwellers	15/25
Nematomorpha	Horsehair worms	Aquatic, parasites	275/?
Nematoda	Roundworms	[All]	1x10⁶/?
Chaetognatha	Arrow worms	Marine	70/100
*Mollusca	Snails, clacms, Calms octopus	[All]	100-150000/?
Nemertinca	Ribbon worms	Mainly marine	800/3000
Sipuncula	Peanut worms	Marine	320/330
Echiurs	Spoon worms	Marine	130/140
Pogenophora	Beard worms	Marine	120/500
*Annelida	Earth worms, leeches (Pentastomids)	[All]	12000/?
Pentastomida	(Pentastomids)	Parasites of vertebrates	c. 100/?
Tardigrada	Water bears	Mainly semiaquatic	500/1000+
*Onychophora	*Peripatus*	Terrestrial	100/300
Arthropoda	Insects, crustaceans, arachnids, and their relatives	[All]	$1x10^6$/?10=$30x10^6$ (or more)
Phoronida	[Phoronids]	Marine	13/20
Bryozoa	Entoprocts, ectoprocts	Mainly marine	4000/?
Brachiopoda	Lamp shells	Marine	330/500
*Echinodermata	Starfish, sea urchins	Marine	8000/?
Hemichordata	Acorn worms	Marine	1200/150+

* indicates major thrust has been given on the conservation of these groups.

Detailed account of ecological importance :

1. **Ecological importance:**

   The understanding for the intricate relationships between biodiversity and ecosystem function is critical to understanding how to manage habitats to conserve the greatest number of taxa. Invertebrates play predominant roles in most ecosystem processes and are necessary links of food webs in any community. Many organisms, depend entirely on particular invertebrates for their own sustained existence, many flowering plants for pollination and other carnivores for their food. The role of earthworms and other invertebrates in soil aeration and litter decomposition and thereby enhance soil fertility. Decomposition of plant and animal material is achieved predominantly by invertebrates action in many places and in all major ecosystems. Major ecological structures, the basis for diverse communities such as coral reefs derive directly from invertebrates activity.

2. **Use of invertebrates as foods :**

   Traditional use of invertebrates and their products as human food is widespread. Among others, molluscs, and crustaceans constitute major component of food industries vis-à-vis fisheries. The best known terrestrial invertebrate food industry is bee-keeping with honey and other live products. Consumption of grassophers; termites and a wide range of other taxa is widespread in many developing and also developed countries.

3. **Utilisation for invertebrates for biological control :**

   Mass production for nature enemies (e.g. arthropods & nematode) in the form of predators or parasites for the control of pests constitute an important aspect of integrated pest management. Biological control measures enable to restore a balance in an environmentally acceptable manner, substituting for pesticide use.

4. **Application of invertebrates as useful commodity :**

   A great diversity of other uses of invertebrates helps human being profusely which are being mentioned below:

   i) ***Sericulture :*** Silk fibres are being used as an important fibres for human clothings.

   ii) ***Marine sponges:*** Besides their use as showpiece in the house, recently they are being screened for cancer – curing drugs. Many invertebrates have got pharmaceutical potential. Many invertebrates are sources of potentially exploitable bio-compounds different from those of their close relatives, emphasizing further the wisdom of conserving species rather than just representatives for higher taxonomic categories.

   iii) ***Dyestuffs:*** Since the time of Romans and Greeks, molluscs are being used for the production of dyestuffs.

   iv) Molluscan shells and corals are being used for jewelary and ornaments, mothers of pearls, household showpieces and building materials.

   v) Local hunting of earthworms, marine worms and molluscs, various insects, tunicates and others for fishing bait and as a food in agriculture.

   vi) Earthworm protein, produced through intensive mass rearing or vermiculture, is a valuable ford supplement for farm animals.

   viii) Use of leeches in medicinal treatments to reduce bruising and swelling after surgery.

5. Cultural aspects of invertebrates :

Aesthetic appreciation has led to some groups, particularly some insects and molluscs, playing significant roles in human culture. Dragon files have long been important in the culture of Japan as have cicadas in China and butterflies in Greeks. Dance (1996) noted that molluscan shells are associated with the cultures of pre-dynastic Egypt, prehistoric Europe, pre-collumbian Ecuador and prehistoric Maxico.

6. Invertebrates as research and practical tools :

Earthworms, cockroaches etc. are being used as an important tool for practical classes in biological sciences. The vinegar fly, Drosophila are still an important vehicle for research and teaching in genetics. Any commercial use of invertebrates depends in the long term on the sustainability for the species being exploited or harvested.

Ecological priorities for invertebrates conservation :

Four kinds of invertebrates have been discussed as priorities irrespective of their taxonomic status. These groups are:

i) Keystone species,
ii) Umbrella species,
iii) Flagship species,
iv) Indicator species.

Keystone species :

It is defined as those species on which the local biotic community entirely depends for its functioning. An example in this category is Krill in Antarctic ocean water. Krills, an euphaused crustaceans feed mainly on diatoms and constitute an important food for vertebrates especially for penguins, seals and whales. Fishing for Krills for use as stock food, fertilizer or human consumption has been seen as a major opportunity for commercial enterprise. Overexploitation of this group could lead to disrupt the balance of ecosystem functioning.

Umbrella species :

'Notable' species characteristic of a particular community whose safety can assure that of many less conspicuous or less known taxa in the places where they live. They need not play any major integrating role in the functioning of the community and differ thus from key-stone species.

One example of this category is velvet worms (Onychophora) in humid forest and cave habitats in the tropics and also in southern temperate regions. Measures for the protection of this worms in turn facilitate the protection of the multitude of other taxa living in wet forest litter or in caves by reducing the incidence of threats and degradation of their environment.

Flagship species :

They serve to increase awareness of conservation need by helping to gain public and political sympathy, based on their appeal to people. Particular species can be involved but whole groups of 'charismatic' invertebrates may also constitute flagship taxa.

The paramount invertebrate group utilized so far as flagships are the butterflies. The following features are useful for promoting flagship groups of invertebrates.

i) Taxonomy well known, with many species easy to recognize without being captured.
ii) Ability to engender public sympathy for their well-being, either based on aesthetic value or commodity value.
iii) The groups should be relatively diverse and widespread but with localized or narrowly endemic taxa which can be used to monitor local community health.
iv) This should frequent an array of different habitats and contain specialist species which respond to habitat change with their responses.

Indicator species :

'Any species' which can throw light on the particular suite for environmental condition is known as indicator species. The most frequent application is to indicate pollution in various ways and there are five major contexts in which this is done (Spellerberg, 1993), reflecting different kinds of indicator species.

i) ***Sentinels*** – Species introduced to an environment as early 'warning devices' or to determine the effect of a pollutant.
ii) ***Detectors*** – Species occurring naturally in an area and which show a measurable response to environmental change.
iii) ***Exploiters*** – Species whose presence indicates disturbance or pollution and which can then become abundant because their components have been eliminated.
iv) ***Accumulators*** – Organisms which take up and accumulate chemical from their environment in measurable quantities.
v) ***Bioassay organisms*** – Those used in laboratory tests to detect pollutants or to rank levels of toxicity.

Threats to invertebrates :

The major threatening processes to invertebrates can be grouped into four broad categories (Wells *et al* 1983).

i) Effects of habitat destruction,
ii) Effects of pollution and pesticides,
iii) Effects of exotic species,
iv) Effect of overexploitation and over collecting.

Approaches and setting priorities to invertebrate conservation :

Two major approaches have played important roles in attempts to conserve the animals.

i) The 'species level' where particular species or other taxa have been the primary conservation target.

ii) The 'habitat level' where representing habitats have been the primary target for reservation or protection, with the assumption that the taxa present will thereby be conserved effectively. The sequence of steps involved in practical conservation targeting a given species is summarized in Fig. – 1. There are several major steps in this general sequence.

i) Establishing the status of the species gives a strong foundation for all subsequent management. The components of status include the taxonomic and biological integrity of the species, its rarity and how its abundance and distribution are changing.

ii) Establishing the nature of threats and the time scales over which they operate is needed to counter them.

iii) Determining or anticipating the effects of these on the organisms themselves or their environment leads to the next step.

iv) Defining the kind of management strategy needed, probably with an action plan formalizing the steps in a logical sequence over a given period.

v) Implementation of management is then needed to achieve one or more of threat abatement, habitat protection and species conservation.

vi) Any management should be monitored carefully, leading to continually refining details or approaches as the programme proceeds.

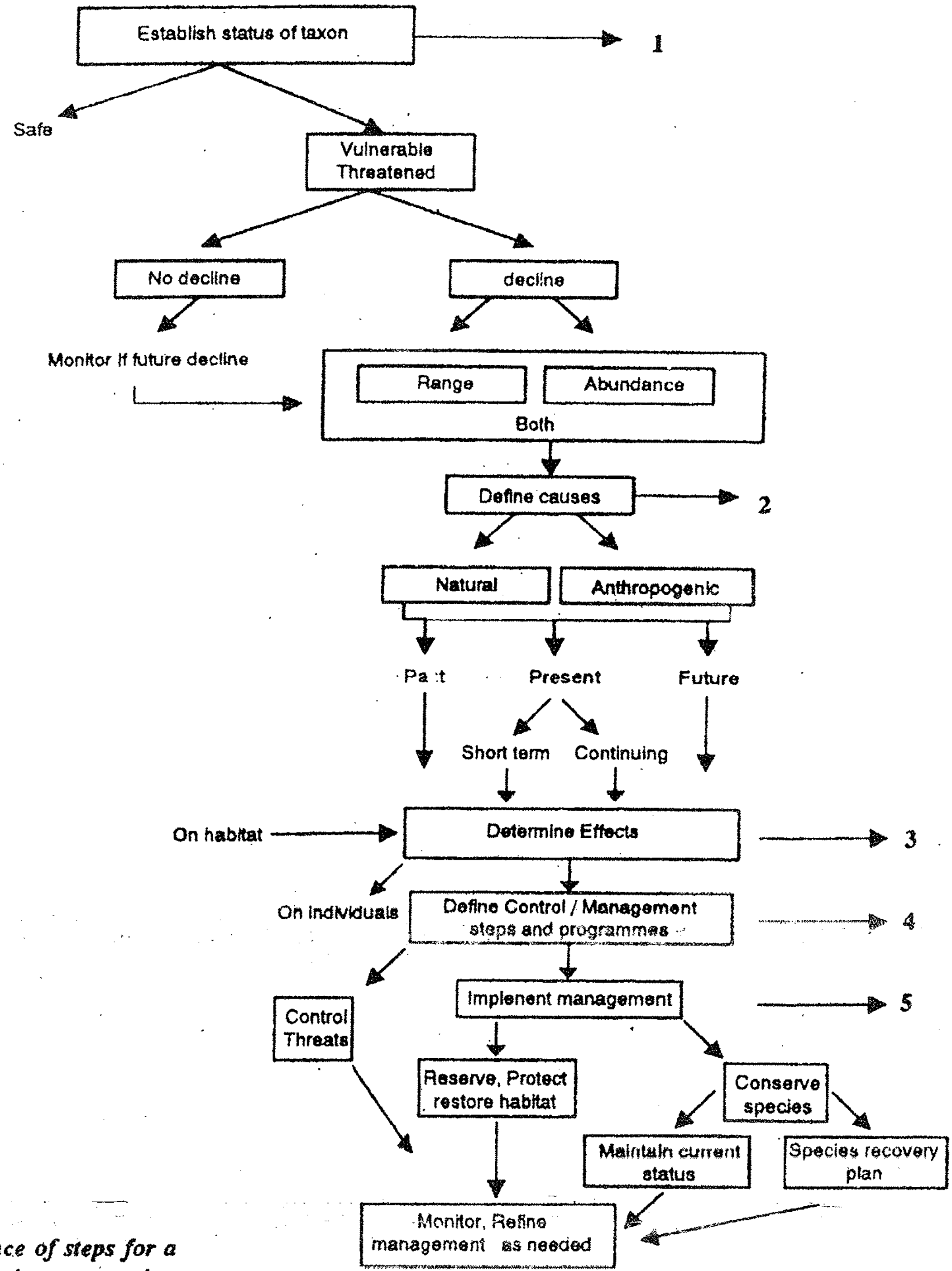


Fig.-11:
A sequence of steps for a single species conservation

VIDYASAGAR UNIVERSITY

DIRECTORATE OF DISTANCE EDUCATION
MIDNAPORE - 721 102

M.Sc. in ZOOLOGY

Part – I : Paper - I : Group – A : Unit – I

Module – 2

Topic – 2 : Comparative account about different larval forms of coelomate non-chordates

What is larva :

The embryonic life leads in most cases to the emergence of a larva. The larva is a feeding, free, young, individual. In oviparous animals, the eggs are either released or may be retained in temporary brood pouches and at some stage of embryonic development or soon after its termination, the young ones escape as in polychaetes, crustaceans etc.

The larva is a nearly well completed embryo, which is on its way to adult development. The larva is endowed with some of its unique features which get modified or lost in course of development to the adult e.g. trochophore, caterpillar etc.

Types of larvae :

Lecithotropic (Thorson, 1950) : This type of larva derives nourishment from the yolk originally provided in the egg and released with the larva. Thorson (1950) found that 10% of the temparate and tropical larvae fall into this category.

Planktotrophic (Thorson, 1950) : This type is actively swimming over prolonged periods and larva feeds on plankton. This form constitutes about 55-65% of marine froms, nearly covering upto 85% of the tropical species.

Teleplanic (Secheltema, 1986) : This type of larvae developed from external fertilization and enjoy maximum pelagic existence.

Demersal (Mileikovsky, 1971) : This type of larvae are bottom dwellers and spend mostly benthic life.

Importance of larval forms :

i) The increased interest in autecology as a key to a better understanding of complex ecological systems implies the need for a deeper knowledge of life-cycle and life-history stages vis-a-vis larval forms and their onward development.
ii) The larva is valuable to the species in effecting dispersal by its locomotor abilities and exploiting the environment by even taking on different modes of feeding. This has a far reaching effect on

community dynamics, especially considering larval mortality, succesful recruitment and settlement.

iii) Identification of species should not be based only on morphological and functional features of adult but larval features should be taken into consideration.

iv) The larvae of invertebrates have been used by different phylogeneticists seeking support for their favourite theories. Whole edifices of invertebrates relationships have been errected on the basis of larval similarities and complex transformation sequences between dissimilar larvae and between similar larval and adult forms have been derived.

Larval development & resource utilization :

Reproductive strategies are defined on the basis of the morphological, physiological and behavioural traits conditioning reproductive efforts. These traits are extremely vairable, not only among different taxa but also at population level and determine when and how often reproduction occurs. Traits in larval development are fundamental in determining life-history strategies.

The advantages for different larval forms are expressed in terms of resource utilisation, reproductive effort of parents and dispersal. The length of pelagic existence increases from lecithotropic to teleplanic larvae. Planktotrophy appears to be the original condition, to which some other 'primitive' features of reproduction are linked such as free spawning, external fertilization, spermatozoa with rounded head, alecithal eggs and so on (Jagersten, 1972). Egg size (which in marine invertebrates ranges from about 30 μm to 2mm) to be considered to be related to the energy stored for further development. Small eggs generally produce planktotrophic larvae and large eggs undergo direct development, usually associated with brood care (Chia, 1974). The link between eggs size and type of development is different in several taxa, due to the presence of different constraints on development. In cirripeds, the eggs size is related to the length of embryonic development rather than to the length of larval development (Barnes, 1989). The variability of eggs size may be due to causes other than energy (nutrient) content, such as size at metamorphosis or eggs hydration (Strathmann & Vedder, 1977). Moreover, secondary planktotrophy may be often obtained by feeding mechanisms different from the original ones and sometimes this does not allow a decrease in egg size (Strathmann, 1978).

Planktotrophic larvae generally derived from small eggs, reach a size suitable for metamorphosis utilizing different resource compartments than that of the parents. Therefore, production of a planktorophic larva requires a low parental energy investment, instead they depend on the planktonic blooms (Star *et al*, 1990). On the contrary, the energy allocation to produce a lecithotrophic larva depends entirely on the parents. This also explains the higher abundance of former groups in tropical regions where abundance and diversity of plankton are more in comparison to polar regions. Besides, in polar areas and in deep sea, low temperature and scarce food supply reduces survival of larvae by increasing duration of development and the risk of losses by predation (Thorson, 1950). But opposite trend is also evident in some groups (Prosobranchs) which experience direct development in tropical areas (Spight, 1981). It may be concluded that sizes of eggs and resource availability are not solely responsible for different types of development but may be a co-factor in determining the strategy used.

Table : 1. Larval categories and correlated strategies.

Reproductive efforts of parents : (RE)

Category	Resource Utilization	Egg Number per single spawning	RE per single egg	Mortality	Dispersal
Teleplanic	high (1)	very high	low	very high	very high
Pelagic planktotrophic	high	very high	low	high	high
Pelagic lecithotrophic	low or absent	low	medium	medium	medium
Demersal	high	medium	high	medium absent	low or

Diversity of larval forms in non-chordates :

It has long been held that there are two basic types of invertebrate larvae corresponding to two super-phyletic divisions - protostome and deuterostome. A comparison between these tow groups with regard to their embryology reveals their larval forms and other striking features (Table - 2).

Table : 2. Comparison of embryological/larval features of Protostome and Deuterostome

Features	Protostome	Deuterostome
Cleavage	Spiral/ Determinate	Radial/ Indeterminate
Blastopore	Forms mouth	Forms anus
Mesoderm	Form 4d cells proliferation	From gut walls infolding.
Coelom	Schizocoelic (split within mesodermal bands)	Entercoelic (pouch off from gut wall)

Generalised larval form of Protostome :

By far the best known of these larvae is the trochophore that is deemed to be characteristics of the protostome /spiralian phyla.

This larva, found in its most generalised form in certain polychaete families, is approximately biconical. It has an outer single layer of ectoderm and an equally simple complete endodermal digestive tract leading from the anterior mouth to a roughly ventral anus. Few organs are present in the larva -

1. There is one pair of protonephridia terminating internally in flame cells or solenocytes.
2. an apical organ consisting of a dorsal tuft of cilia.
3. schizocoelic mode of coelom formation.
4. pressence of external ciliated bands that provide both the motile system and food trapping

device - the principal one is the prototroch running as a pronounced ridge around the larval equator just above the mouth - it may involve one or more rows of ciliated cells. Another band- metatroch encircles the larva in its equatorial region, but below the mouth and a third, the telotroch (or paratroch) surrounds terminal portion of the larva (Fig. 1). From this trochophore larva, other larval forms of protostome developed and diversified in different groups.

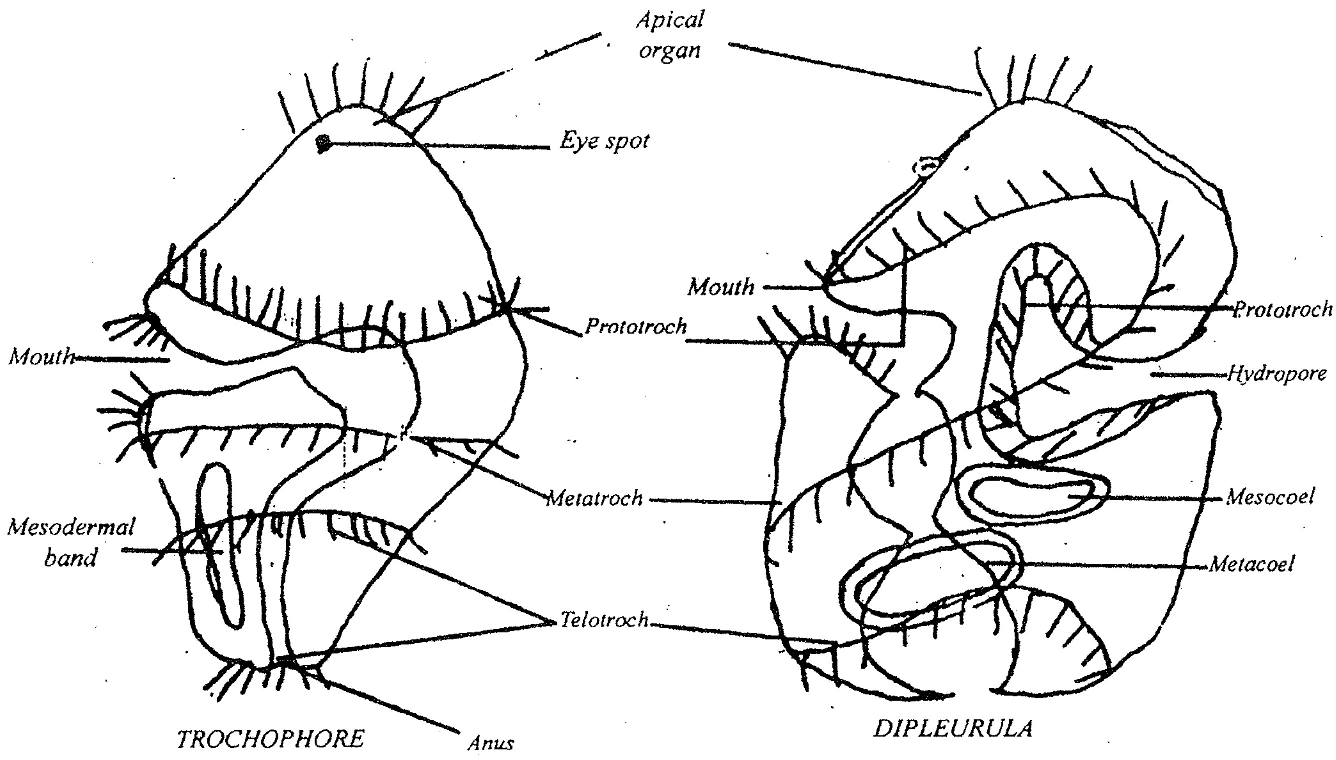


Fig. 1

Remarks :

This larval organisation, with varying degrees of modifications is described very commonly in lower invertebrates, including annelids, molluscs, flatworms, sipunculans, echiurans and much more dubiously - the lophophorate phyla. It is also somewhat similar to adult form in the ctenophores and in particular in rotifers, both sometimes thought to be neotenous derivation from it.

Generalised larval form of Deuterostomes :

The characteristic larval form of deuterostomia is diplurala. This is characterised by -

1. Bilaterally symmetrical body with simple ectoderm and complete digestive tract with mouth and anus both somewhat anterior.
2. Enterocoelic coelom formation.
3. One continuous ciliated band passes above and below the mouth and laterally along the sides of the body.

Strathman (1978) regarded this single band as a vital link uniting deuterostomes and lophophrates in both larval and adult forms. He compared it with the opposed band system of most spiralian larvae (and rotifers) where the prototroch and metatroch work together to trap food and transfer the same to an intervening food groove.

In other groups of deuterostomes, larval forms have been developed from this generalised dipleural larval form as in bipinnaria of starfish, the pluteus of brittle stars, the auricularia of sea cucumbers, or tornaria of hemichordates.

Interrelationships among different larval forms :

Although all the larvae of invertebrates are supposed to be the modifed forms of two hypothetical larval groups - Trochophore for protostome and Dipleurula for deuterostome.

The generalised form of trochophore is the larva of *Polygordius sp.* Variation in the morphological features are found in other groups of phylum Annelida or even in the individuals belonging to the same family in which *Polygordius sp.* belongs. The ciliated bands show differences in the absence of prototroch forming the mesotrochal larva as in *Phyllodoce sp.* or represented by series of bands as in polytrocha larva seen in *Eunice sp.* or without any bands forming the atrochal larva of *Lumbriconeries.* In *Neries* sp., the larva emerges at an earlier stage without mouth and anus, this being the protrochophore. In *Polynoe* sp., more advanced form of larvae is nechochaetus larva where the posterior part of the body is metamerically segmented and have setae bearing parapodia.

In Platyhelminthes, the characteristic larval form is Muller's larva which possesses multiple bands of cilia and eight posterior ciliated lobes and larval form of nemerteans is pilidium which is helmet shaped with ciliation around the rim. Neither form as an anus and their likeness to the polychaete larva is limited.

In Phoronids, the larval form is the actinotroch - characterised by a complete gut, a hood shaped preoral ciliated lobe and an apical non-ciliated sense organ. A metatroch is present on hollow, ciliated and downwardly directed tentacles and there is a telotroch. The ectoproct larva is very much similar to that of phoronids.

The brachiopod larva has another ciliated preoral region and bearing an apical sense organ which is ciliated, with middle mantle lobe with ciliated folds (dorsal and ventral) and the hind lobe which is not ciliated forming a foot lobe.

Arthropods never do have a trochophore most uniramians and chelicerates undertake direct development but even in crustancean groups that generally do produce pelagic larva there is no real trace of a trochophore. The simplest crustacean larva is a nauplius with a cuticular covering and three pairs of appendages for swimming in place of cilia.

Smaller phyla such as echiurans and sipunculans whose larvae are actinotroch and the cyphonautes respectively are not clearly trochophore having aberant features of a large pre-oral hood, a ring of tentacles and a highly developed locomotary telotroch - no real prototroch (Neilson, 1977).

The typical trochophore organisation, well defined as the ciliated larvae of Annelida and other groups has given way to a ciliated larval type in molluscs. In Scaphopoda, Aplacophore and Polyplacophore, the trochophore is practically of the generalised type. In gastropods and Lamellibrachiata such a stage passes on to a veliger - which is characterised by the possession of an elevated dorsal region - a prototroch, apical plate and telotroch like trochophore. Thus, it represents a more developed stage.

For deuterostome larvae there is even less cohesion and variation can be extreme within one phylum, accentuating the issue of functional adaptation in pre-adult forms. Echinodermata show free swimming ciliated larvae. The gastrulae which can swim about, are minute organisms, externally with cilia. In the early dipleural phase, the cilia get confined to a single continuous band, the mouth and the anus get well defined and the coelom appears vasicular. From this type, the bipinnaria, the larval form of asteroids, the plutei of ophiuroids and echinoids, the auricularia of holothuroids, the doliolaria of some holothuriods and crinoids are supposed to have been derived (Grasse, 1948). Amongh all deuterostome larvae, tornaria larva of hemichordata enjoys very strong position with regard to the phylogenetic relationship among different groups of deuterostome because establishing a clear link between echinoderms and the rest of the deuterostomes would have been more harder without this larva.

Functional modifications of different larval forms

Modifications of larvae are accomplished according to their functional need. They have very precise task to accomplish and the selective pressure on them may be intense. The marine pelagic larvae must primarily achieve dispersal and habitat selection, establishing new populations where competition with the parents and or with siblings is reduced and outbreeding promoted. Planktotrophic feeding and locomotory systems and suitable sensory modalities are therefore required.

For marine larvae, there is a profound morphological convergence in virtually all phyla in the early stages of larval life, since they are of similar sizes and perform such similar functions. When the larvae are somewhat older they often become more distinctive in form, as they begin to acquire adult features. A larva can more easily lose the feeding capacity than re-acquire it beoause the loss of the feeding capacity implies the loss of the original feeding apparatus. Spirala show more flexibility in this trait than Radialia and this difference could be linked to the original food filtration mechanisms, to the degree of reorganisation at metamorphosis to the adult structures (Strathnum, 1978).

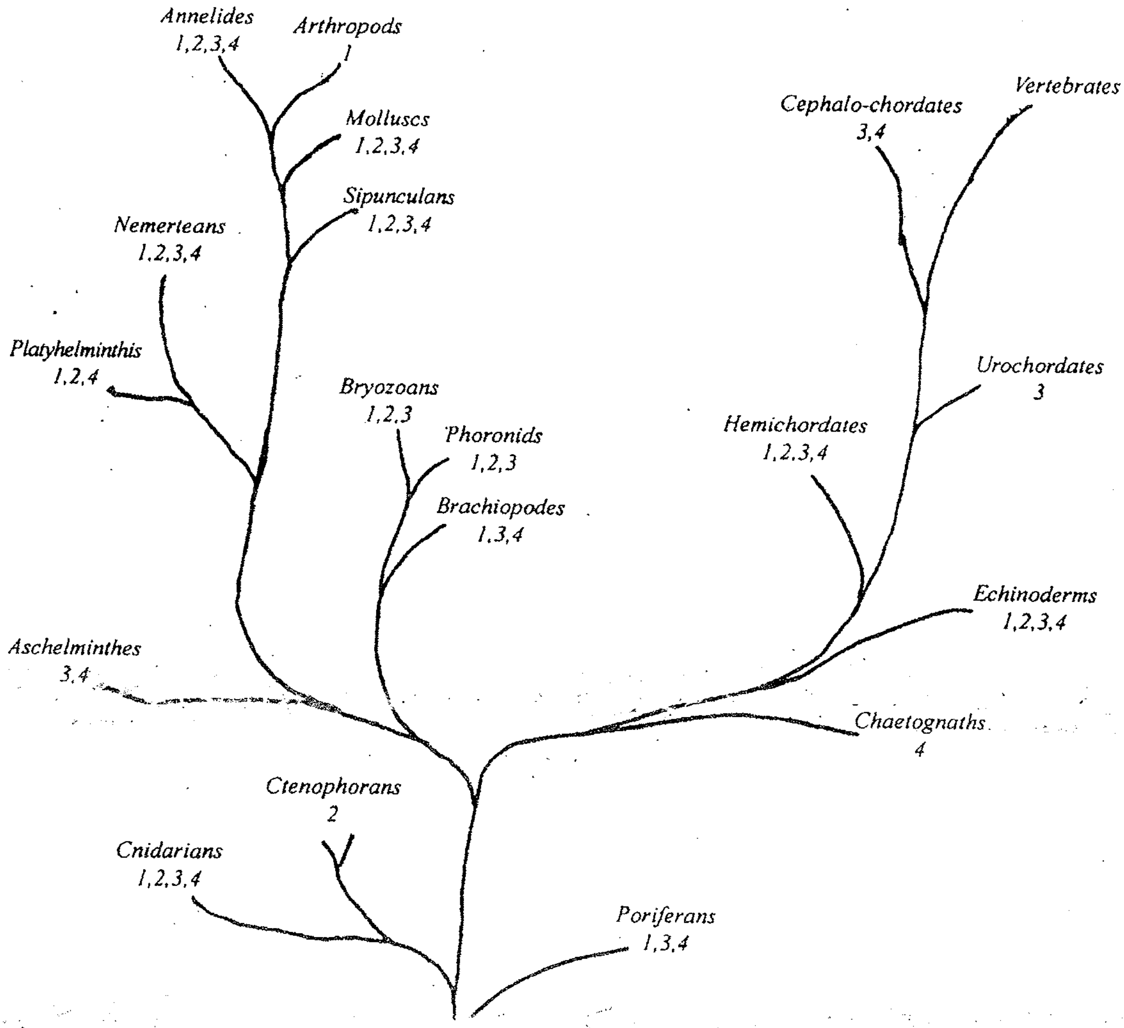
The larvae begin to resemble their adult stage with the appearance of new features such as in molluscan veliger - appearance of shell, head and foot; in hemichordate, tornaria elongates and grows a tail. This 'adultation' may be an important source of potential evolutionary change, by varying the temporal relation of larval and adult features (Freeman, 1982).

Larval Evolution :

Marked similarity of so many early larval forms may throw some light on the existence of a primitive common ancestral larval type. Jagersten (1972) has strongly advocated this view point and put forward his bilaterogastraea theory.

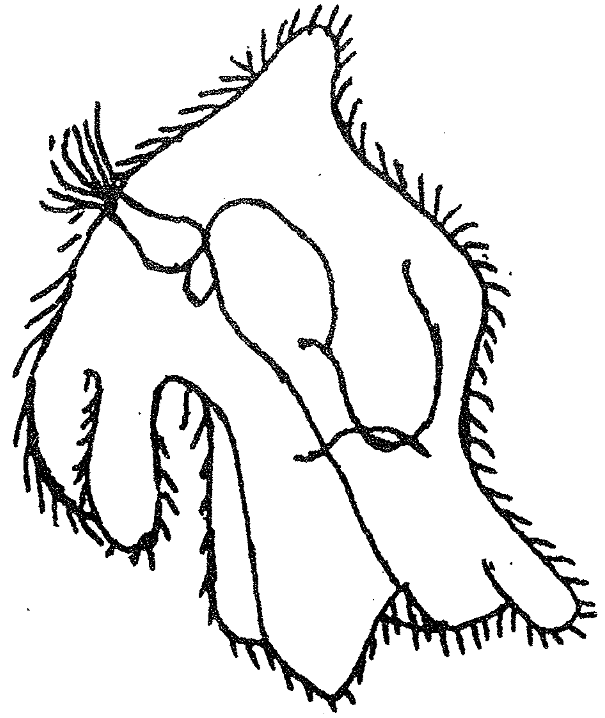
Jagersten argues for a primary alteration of pelagic larvae and benthic adults in the metazoan life-cycle, assuming that when the original blastaea-type ancestor (as hypothesised by Haeckel's blastea-gastrea theory, 1875) settled on the bottom as a bilaterogastrea, the juveniles remained in the pelagic zone. The two developmental stages thereafter diverged to different extents in different groups. Jagersten maintains that there is no evidence in favour of a primitively holobenthic life with direct development and this is supported by the occurrence of the pelago-benthic lifestyle together with primitive sperm, external fertilization and gastrulation thoughout metazoa.

Extensions of Jagersten's lead to complex views of life-style evolution as recently proposed by Nie... on (1985), where all larval forms are seen as interrelated, the primitive blastaea and gastraea being the forerunners of the trochaea, which in turn gave rise to the true trochophore on the one hand and to a tornea, ancestral to deuterostomes on the other.

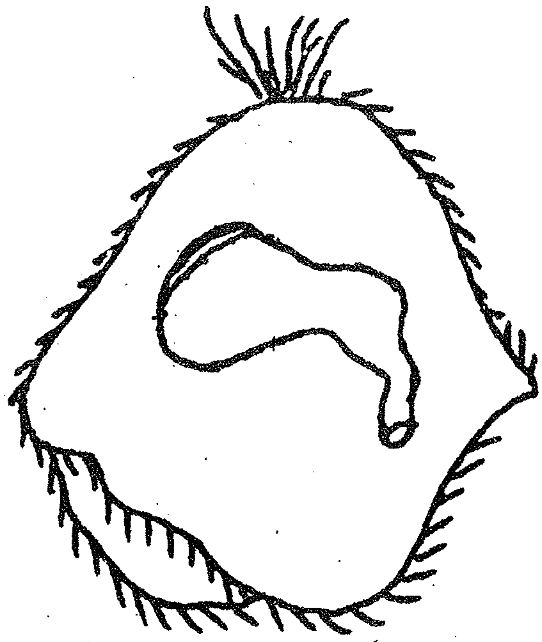


Schematic representation of the occurrence of supposedly primitive life-cycle characteristics in invertebrate groups, based on Jagersten (1972).

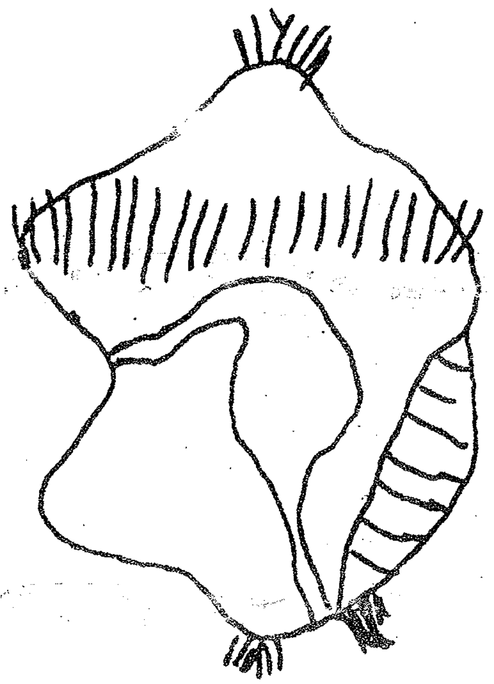
1. Pelago-benthic life-cycle.
2. Planktotrophic primary larva.
3. External fertilisation.
4. Gastrulation by invagination.



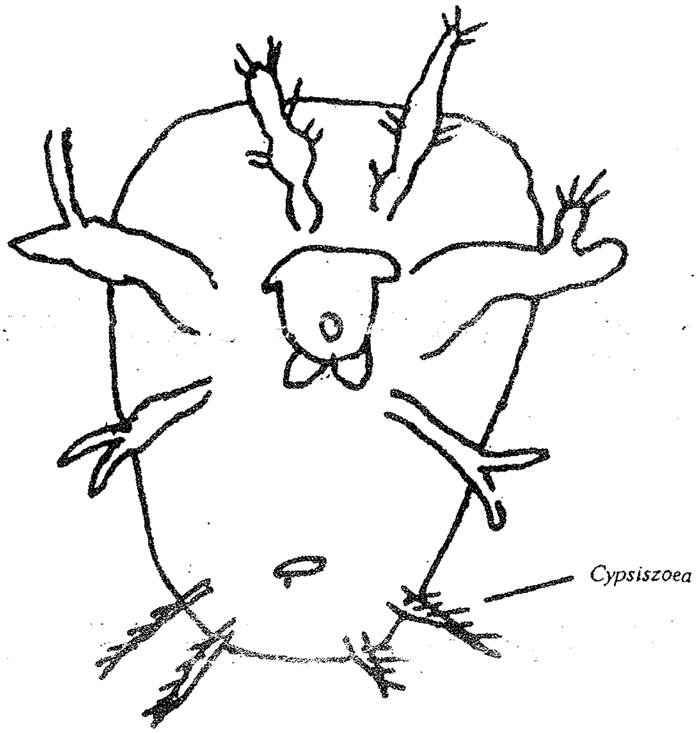
Platyhelminth - Mullers Larva



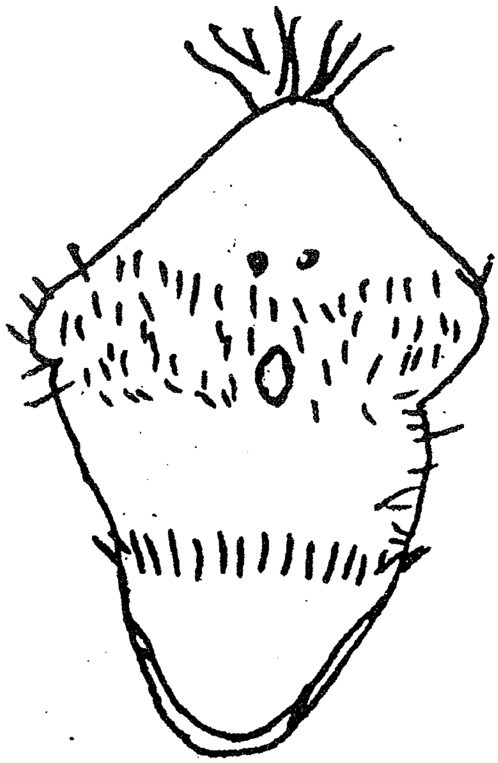
Nemertean - pilidium



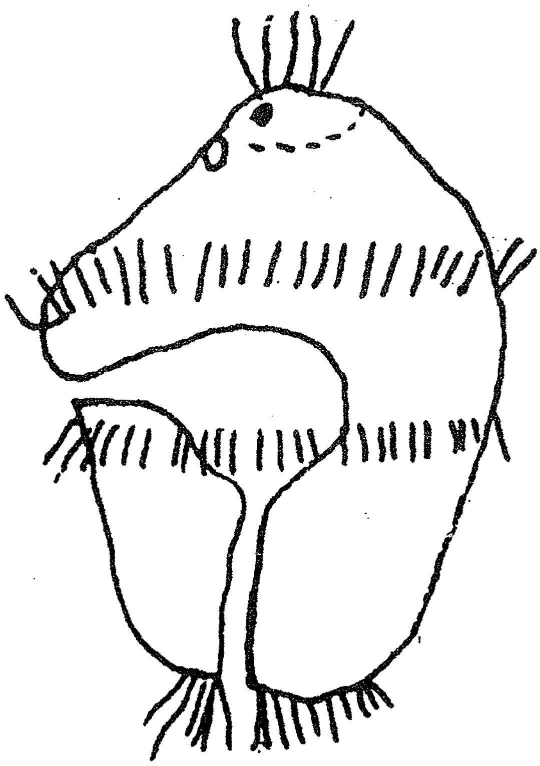
Molluscan - trochophase



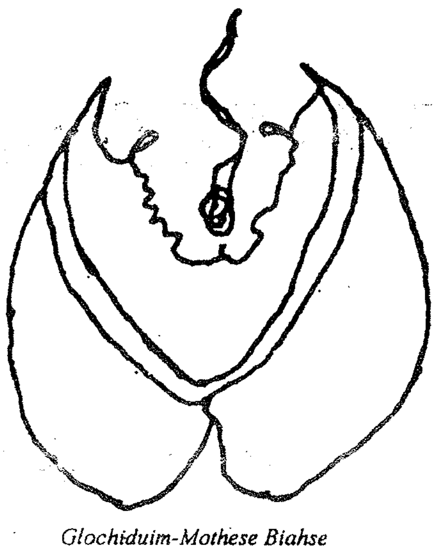
Crustacean-nauplius



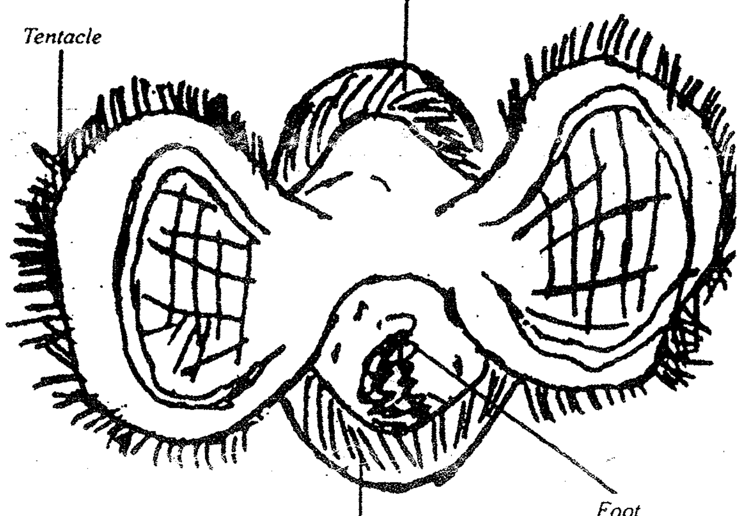
Sipunculan larva - Actinotroch



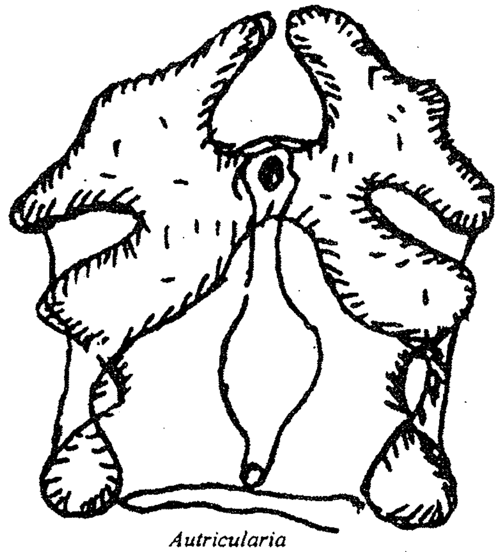
Echiuran trochophore (cyphotautes)



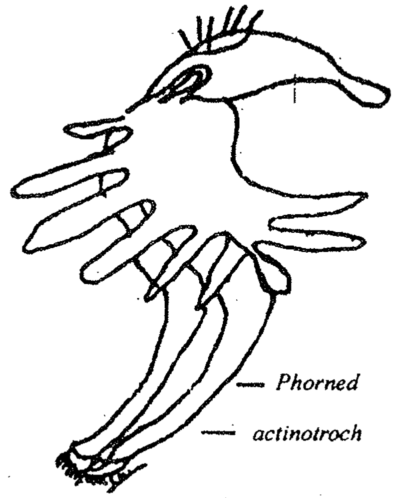
Glochiduim-Mothese Biahse



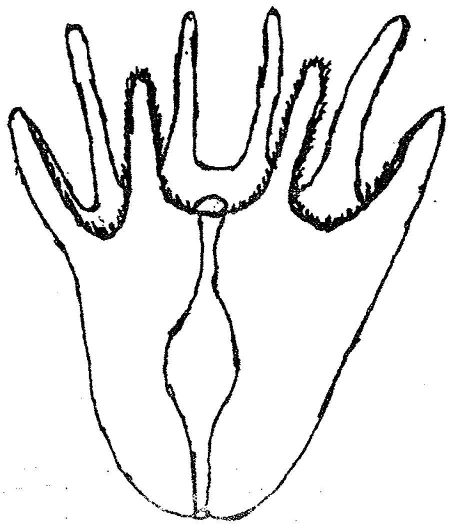
Veliger



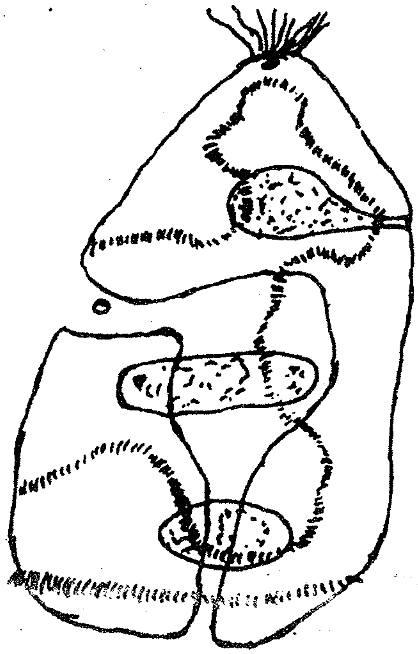
Autricularia (helothuroids)



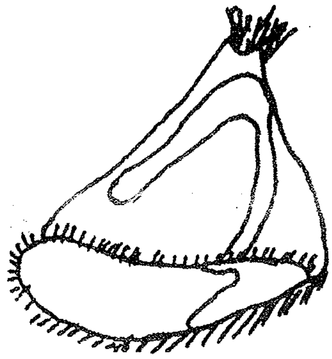
Phorned actinotroch



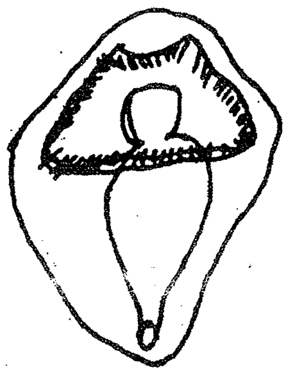
Pluteis-Ophiuropcis



Tornaria



Bryozoan cyphonautes



Dipleurula

Topic 3 : Biology of free living Nematods feeding mechanisms and life-cycle; role of nematodes in ecosystem.

Nematodes are generally defined as appendageless, unsegmented, worm like invertebrates possessing a body cavity and a complete digestive tract. Over 15,000 Nematodes have been described and it has been estimated that there are at least 5,00,000 species of these animals in the world.

Taxonomic status :

Previously Nematodes were placed under the phylum Aschelminthes but owing to its wide differences with other constitutent groups of Aschelminthes, Nematodes have been given a separate status of a phylum.

Origin :

Many theories have so far been put forward on the origin of Nematodes. Some scientists are with the opinion that round worms arose from arthropods by degeneration and neotony (retention of juvenile characters); others claim they are related to annelids or more remote groups such as echinoderms, chaetognathus etc.

The fossil records of nematodes are very sparse and those fossils that do exist are not old enough to tell us anything about the origin of specific nematode groups. Therefore, the comparative morphology may throw some light on the origin of nematodes. One of the most plossible explanations expressed by Paramonov (1982) is that, nematodes arose from the Gastrotricha during the Pre-cambrian or Cambrian Period. Morphological affinitis between the two groups especially in the digestive and reproductive systems, support this belief.

Andrassy (1976) listed some of the basic characters of primitive nematodes viz. bilateral symmetry, three lips, four head setae, simple mouth cavity, three glanded pharynx with a bulb, single celled excretory gland, specialised musculature, tail opens into a cloaca in both sexes, paired spicules and absence of a bursa.

Classification :

The phylum Nematoda is divided into 2 classes and 14 orders. The class Adenophorea (Aphasmida) contains nematodes that have variably shapped amphids behind the lips. There are both free living and parasitic members. The free living species include terrestrial forms and almost all of the marine forms. The class Secernentea (Phasmida) contains nematodes that usually possess porelike amphids in the lateral lips. Many parasitic forms are members of the class, and the free living species are largely soil inhabitants.

Free living Nematodes :

Habitat :

Free living nematodes are found in the sea, in fresh water and in the soil. They occur from the polar regions to the tropics in all types of environments; including deserts, hot springs, high mountain elevations and great ocean depths. Nematodes are benthic animals and live in intertidial spaces of algal mats and especially in aquatic sediments and soils.

External features :

1. The size and form of nematodes are important adaptations for living in interstitial spaces. The body of a typical nematode consists of a flexible cylinder which tapers at both ends - a pointed tail and a blunt head. The majority of free living nematodes are less than 2.5mm. in length while some soil nematodes are as long as 7 mm. and some marine species attain a length of 5 cm.

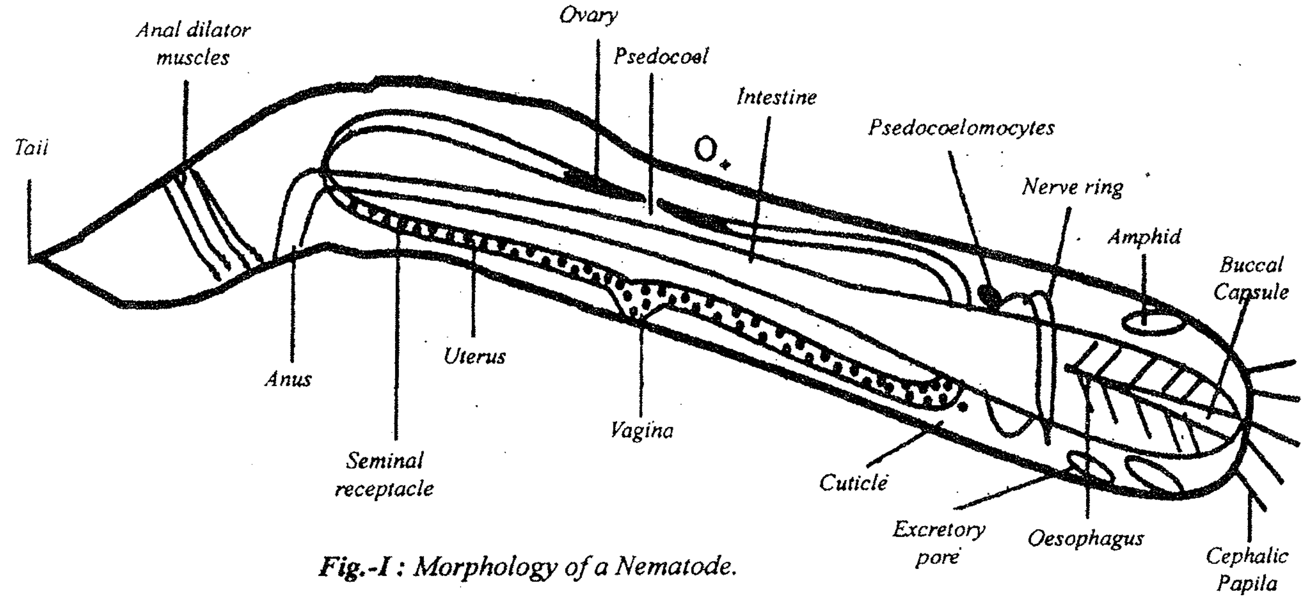


Fig.-I : Morphology of a Nematode.

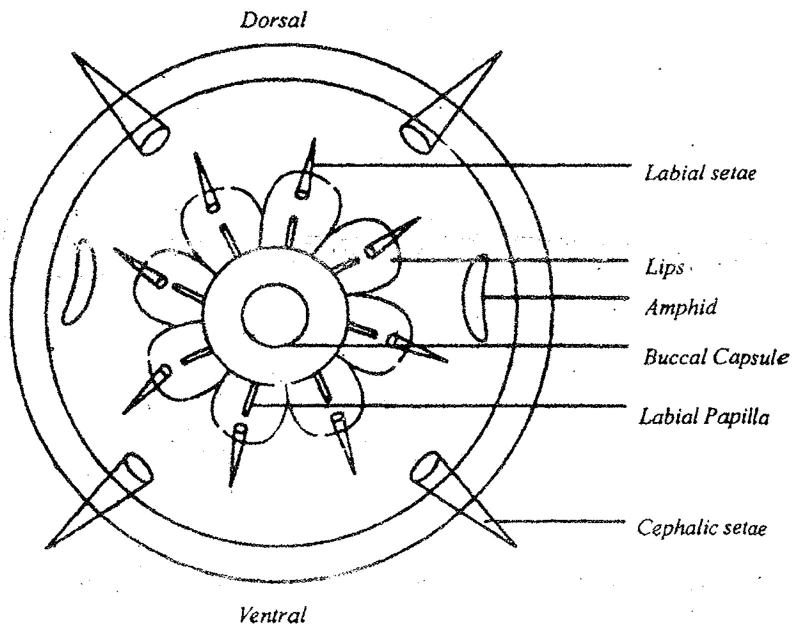


Fig. 2 : Cross sectional view of frontal end of free-living nematode.

2. The mouth is located at the somewhat rounded anterior end and is surrounded by lips and sensory papillae or bristles.

3. The body is bounded by a flexible but tough collagenous cuticle which is a non-cellular flexible, multilayered structure, secreted by a layer of underlying hypodermal cells. It serves as a barrier both to physical obstacles such as soil particles and to biotic agents such as predators, parasites and pathogens.
4. The cuticle of the general body surface is often sculptured and ornamented in different ways. Members of the marine interstitial nematodes under the family Stilbonematodae have body surfaces clothed with a symbiotic blue green alga and appear to be hairy. Normally, cuticle is shed 4 times during nematodes development.
5. Beneath the cuticle is epidermis (=hypodermis) which is cellular or syncytial. The cytoplasm of the epidermis bulges out into the pseudocoel along the middorsal, midventral and midlateral lines of the body, forming longitudinal cords that extends the length of the body.
6. The muscle layer of the body wall is composed entirely of longitudinal, obliquely striated fibres arranged in bands. The muscular system can be divided in two broad types :
   a) The general body musculature;
   b) The specialised muscle;

   Body muscles fall into two main types, although intermediary forms also occur.
   i) Coelomyarian muscles - are those where the fibres occur on three sides, so that only the side facing into the cavity is devoid of fibres.
   ii) Platymyarian muscles - are those in which the muscle fibres are restricted to the basic layers joining the hypodermis.

   Specialised muscles are those which are used for movement of particular parts of the body i.e. labial muscles for prehenson of food, pharyngeal muscles for swallowing, rectal muscle for defecation and copulatory muscles associated with the spicules and vulva.
7. The nematode's pseudocoel is spacious and filled with fluid. No free cells are present, but fixed cells, located either against the inner side of the muscles layers or against the wall of the gut and the internal organs are characteristics of many nematodes.

The Turgor Pressure System (Hydrostatic Skeleton) and Locomotion :

In order to produce movements, muscular contraction needs something to act against.

Nematodes lack a regid skeleton and most species collapse due to water loss when exposed to air. The pseudocoel, in conjunction with the limitations on expansion imposed by the cuticle, acts as a hydrostatic skeleton which maintains body shape and provides the reaction to the contraction of the longitudinal muscles (Harris and Croften, 1957). The turgor pressure recorded in nematodes is higher (Average 70 mm. of Hg) than most of the invertebrates and is very effective because it lacks circular body wall muscles.

The hydrostatic skeleton gives regidity and being incompressible, an increase in pressure will be directly transmitted thoughout the system. Contraction in one part of the system in turn result in expansion elsewhere. The high internal turgor pressure may be responsible for the remarkable constancy of nametode body form.

Locomotion :

Undulatory propulsion is the basic pattern of locomotion in nematodes. The hydrostatic skeleton of pseudocoel fluid and the elasticity of the cuticle are antagonistic to the bending of the body produced by muscles contraction. The undulatory movements of nematodes are for progression through soil pores of 15 to 45 μm in diameter.

Digestive System of Nemetodes (Food, feeding habits, alimentary canal, food capturing devices, digestion, absorption and defication) :

Food and feeding habits :

Glycogen appears to be the chief food reserve in animal - parasitic nematodes, but lipids constitute the major stored food in free living microbotropic and plant parasitic nematodes. Lipids may be oxidised directly or converted into carbohydrate and metabolised via the TCA cycle. Little is known about protein metabolism in nematodes, even though proteins make up over half the dry weight of nematode tissue.

Based on food and feeding habits, many types of nematodes as mentioned below are encountered -

i) Many free-living nematodes are carnivorous and feed on small metazoan animals including other nematodes; other species are diatomes.
ii) Many marine and freshwater species feed on diatoms, algae and fungi.
iii) A large number of terrestrial nematodes pierce the cells of plant roots and suck out the contents.
iv) There are also many deposit - feeding marine, freshwater and terrestrial species which ingest substratum particles.
v) Many deposit feeders (living on dead organic matter/dung) feed on associated bacteria and fungi.

The Alimentary Canal :

The majority of nematodes possess a well developed alimentary tract composed of three regions - the stomodaeum (mouth, buccal capsule and oesphagus); the intestine and the proctodaeum (retum and anus).

Stoma :

the most anterior portion of the alimentary tract is the mouth, which is commonly refered to as the stoma. These structures are complex and variable, reflecting the different feeding habits of the species concerned.

In a free-living, microbotrophic nematodes of the Secernentea, the stoma is composed of several sections (Fig. III). It is considered that five basic sections are representative of primitive nematodes and that during the evolutionary process, these sections became modified. Each section includes a ring of cuticle (rhabdium) surrounding a portion of the mouth cavity. These portions of the stoma starting from the mouth opening, are cheilostom, prostom, mesostom, metastom, and telostom. They are surrounding by the corresponding rhabdions - cheilorhadions, prorhabdions, mesorhabdions, metarhabdions and telorhabdions respectively. In some groups, the rhabdions have become modified into teeth, hooks or stylets.

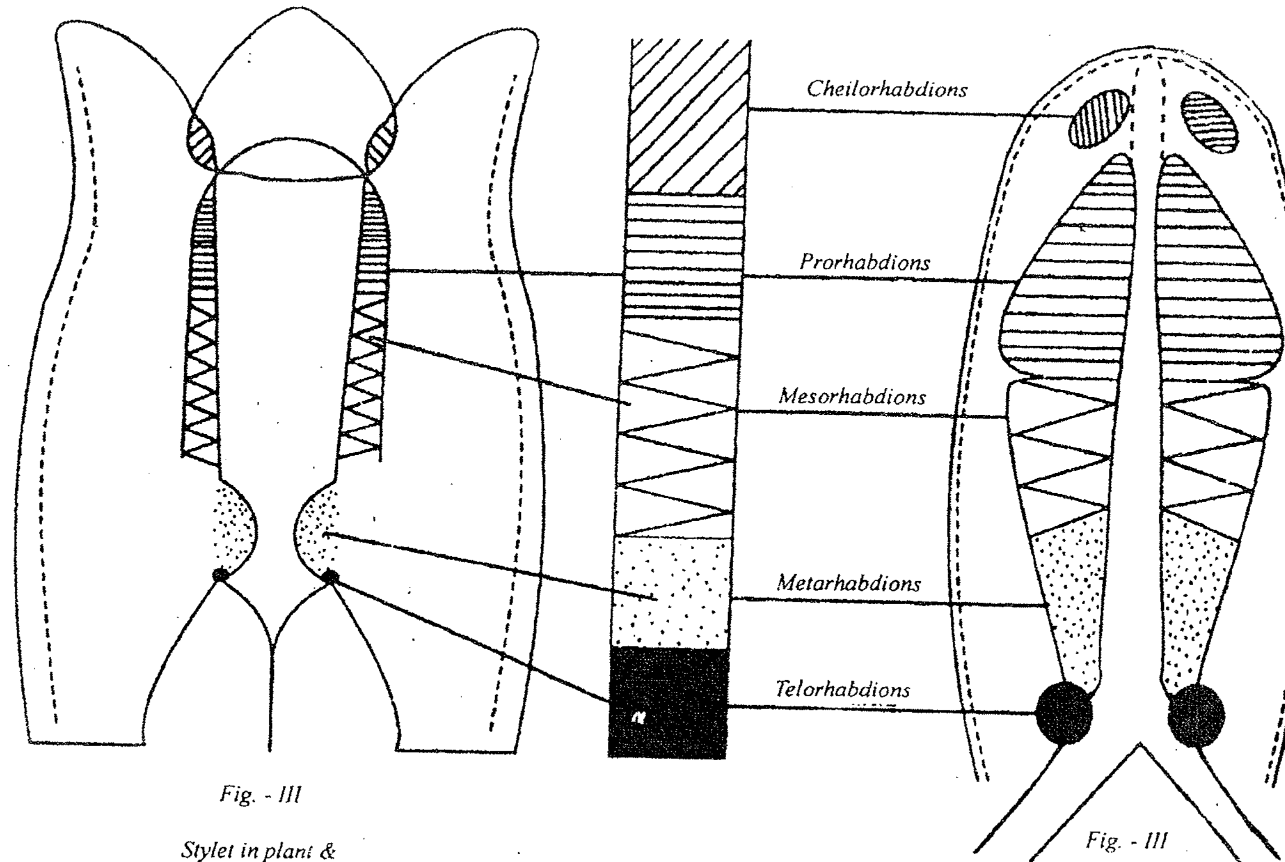


Fig. - III

Stylet in plant & invertebrate nematodes

Fig. - III

A primitive soil nematodes

Buccal Cavity :

The mouth of the nematodes opens into a buccal cavity which is somewhat tubular and lined with cuticle. The cuticular surface is often strengthened with ridges, rods or plates or it may bear a large number of teeth. The structural details of the buccal cavity are correlated with feeding habits. Teeth in carnivorous nematodes may be small and numerous or limited to a few, large, jaw like process in some carnivorous as well as in many species that feed on the contents of plant cells. The buccal capsule carries a long hollow or solid stylet which can protrude from the mouth. Both kind of sylets are used to puncture prey and the hollow stylet may act as a tube through which the contents of the victim are pumped out.

Pharynx (Oesophagus) :

The buccal cavity leads into a tubular pharynx, referred to as oesophagus by nematologists. The pharyngeal lumen is triradiate in cross section and lined with cuticle. Some species possess valves that prevent the oesophagus empting to the outside or filling from the intestine. The opening and closing of these valves is co-ordinated with the pumping cycle. In the absence of valves, a wave of dilation passes down the oesophagus so that only half of its length is dilated at any one time (Mapes, 1965). This provides a self-sealing system.

Pumping mechanisms of oesophagus by different models :

Bennet-Cark's Model (1976) :

The oesophagus has a triradiate cuticle lined lumen which is connected to the outer wall by radial muscles. The oesophagus can be considered as two concentric cylinders (the outer wall and the lining of the lumen) which are connected by the radial muscles. Such a cylinder increase in diameter more easily than in length. When the radial muscles contract, there is an increase in pressure within the cylinder. If this pressure is less than that within the pseudocoel the excess pressure prevents the cylinder increasing in diameter and it therefore lengthens and becomes thinner, keeping the lumen closed. As the radial muscles continue to contract, the pressure within the cylinder increases until it is greater than that in the pseudocoel. The cylinder then increases in diameter and minimise stresses by becoming shorter and wider, resulting in the opening of the lumen (Fig-IV).

When the radial muscles relax, or if the pressure within the cylinder is decreased by the opening of the oesophageal - intestinal valve, the process is reversed. This, together with the elasticity of the cuticular lining, closes the lumen.

Note :

Rhythmic action potentials associated with the contractions of the oesophagus have been demonstrated by del Castillo, de Mello and Murales, 1964. The oesophageal nervous system is more or less autonomous (Albertson and Thomson, 1976). The oesophagus may act as a single, electrically excitable unit whose contractions are under myogenic control.

Digestion and Absorption :

They usually take place within the intestine. The intestine is divisible into three regions, the anterior ventricular region, the mid intestine or the intestine proper and a posterior prerectal region. None of these regions is lined with cuticle, but the outer surface is covered by a basal membrane.

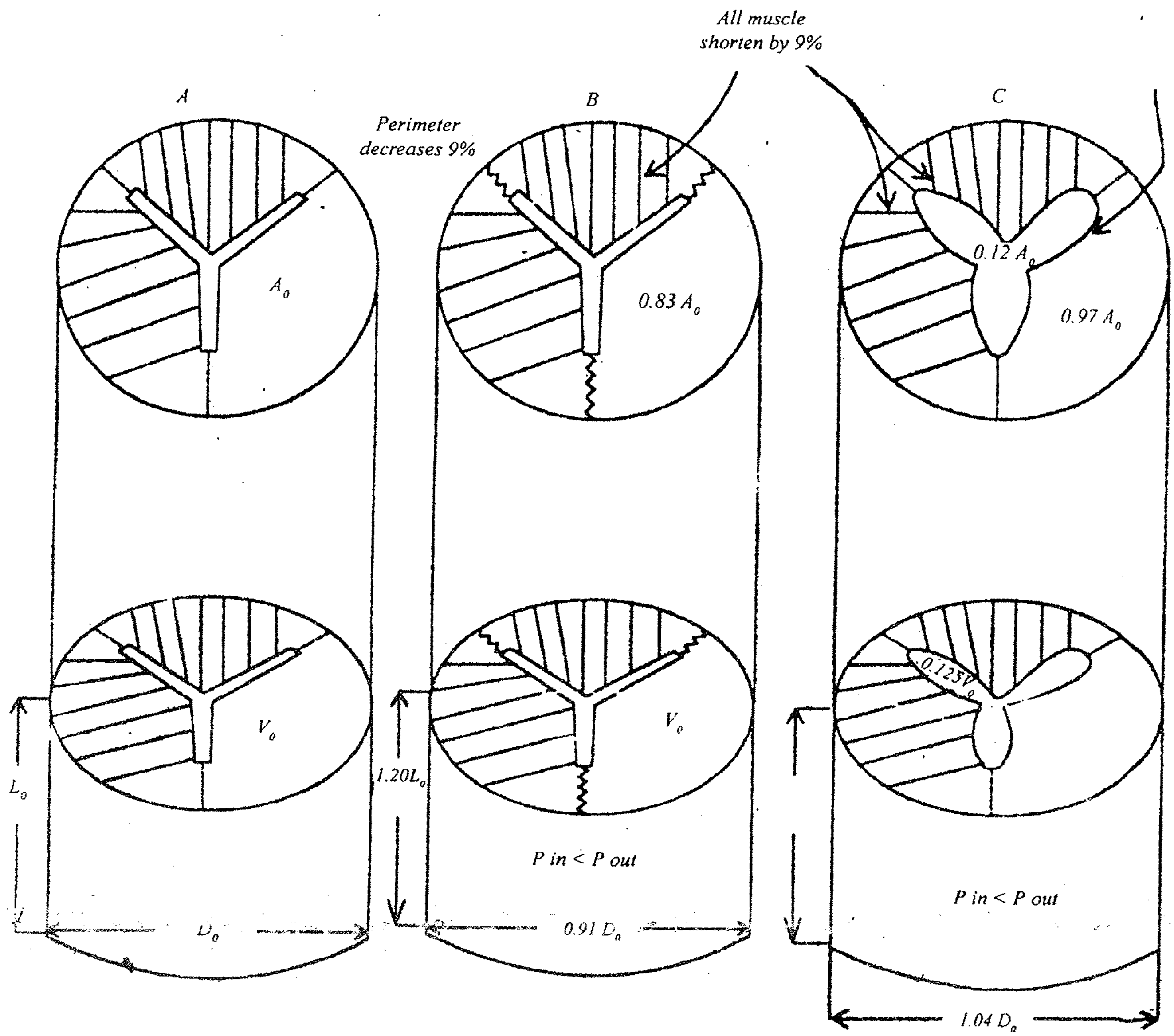
Although the intestine is generally straight and cylindrical, some nematodes have intestinal outgrowth or cecae which may be a source of digestive enzymes or a place for harbouring symbionts. The anterior ventricular region generally contains a few cells which are thought to be glandular in function. The midintestine is formed by a single layer of cells that may be uni or polynucleated or form a syncytium.

The intestinal lumen is lined by the cells with microvillae, which vary considerably in size and shape from species to species. In addition to absorbing and metabolizing nutrients, the intestinal cels serve as food storage areas. Food is stored as glycogen, lipid and protein (Bird, 1971). A number of digestive enzymes, including proteases, lipases and amylases have been found in intestine (Barrett, 1981).

Defecation :

A high internal turgor pressure provides the force for defecation. Indeed, liquid faeces may be ejected for some considerable distance upon the opening of the annus. An intestinal - rectal valve controls the entry of the materials into the rectum (Seymour and Shepherd, 1974).

Fig. IV: **Different cyclical phases of contraction and relaxation of oesophagus.**



A	- Muscles relaxes	L_0	- resting length.
B	- Mucles contracted, the pressure within the pseudocoel exceeds that within the oesophagus! it lengthens and does not dilate; keeping the lumen closed.	A_0	- resting area of cross sections
C	- The pressure within the oesphagus exceeds that within the pseudocoel. It shortens and widens opening the lumen.	D_0	- resting diameter
		V_0	- resting volume of musculature

Reproduction, Development & Life Cycle :

The reproductive potential of the nematodes is usually very prolific. There is a great variation in fecundity and generation time between different species, reflecting the life cycle and reproductive strategies employed.

Significance of different reproductive strategies :

The majority of nematodes reproduce sexually. The zygote is formed by the fusion of male and female gametes. If sperm and eggs come from separate individuals, it is called amphimictic reproduction. A member of free living species and rather fewer parasitic species reproduce hermaphroditically or parthenogenetically. All eggs produced by a parthenogenetic female can develop into egg-laying females. A parthenogen can thus colonise a habitat much more rapidly than an amphimictic species. The amphimictic species have to spend energy on mate location, copulation and fertilization reducing the relative returns from the reproductive process (Calow, 1978).

Sexual reproduction can bring about genotypic and phenotypic variation whereas mutation is the only source of variability in parthenogenetic species. In an unpredictable physical and biological environment, a sexually reproducing species is more likely to produce some phenotypes which survive these changes and reproduce. Whereas, a parthenogenetic species is very much prone to extinction as it possesses only one phenotype. Therefore sexual reproduction is only important strategy in biologically complex and temporarily and spatially variable environment and parthenogenesis to be favoured in a relatively stable environment.

The Structure of the Reproductive System

Male Reproductive System (Fig. V) :

The male may have one (monorchic) or two testes (diorchic) which lead into a common seminal vesicle and vasdeference before entering the cloacal chamber. In some species there is a vasdeference between the testes and the seminal vesicle. Males of most nematodes possess one or more secondary structures which are used during copulation. These are modifications of the cuticle.

Female Reproductive System (Fig. VI) :

A normal female contains one (monodelphic) or two (didelphic) gonads, which open to the exterior on the ventral side of the body. This opening is called the vulve and is connected to a muscular tube, the vagina. The vagina leads to the uterus, which extends into the oviduet and ovary. There is sometimes, a sperm storage are (spermatheca) between the uterus and oviduct. The uterus possess a layer of muscle cells which move the eggs against the turgor pressure of the pseudocoel. The cuticle and musculature of the vagina may enable it to act as an ovijector, expelling the eggs with some force when they are layed (Dick and Wright, 1974).

Fig. - V

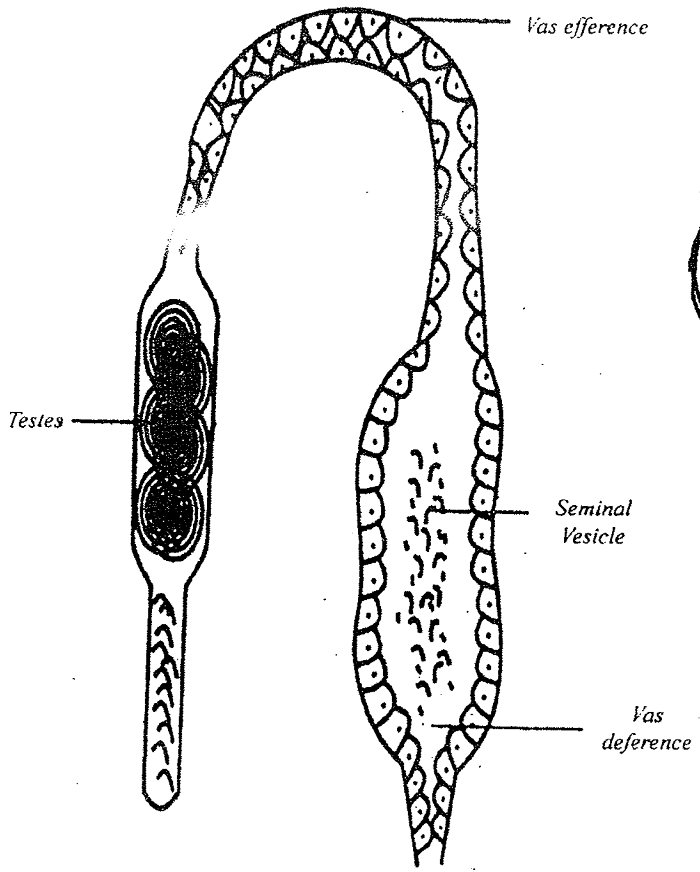
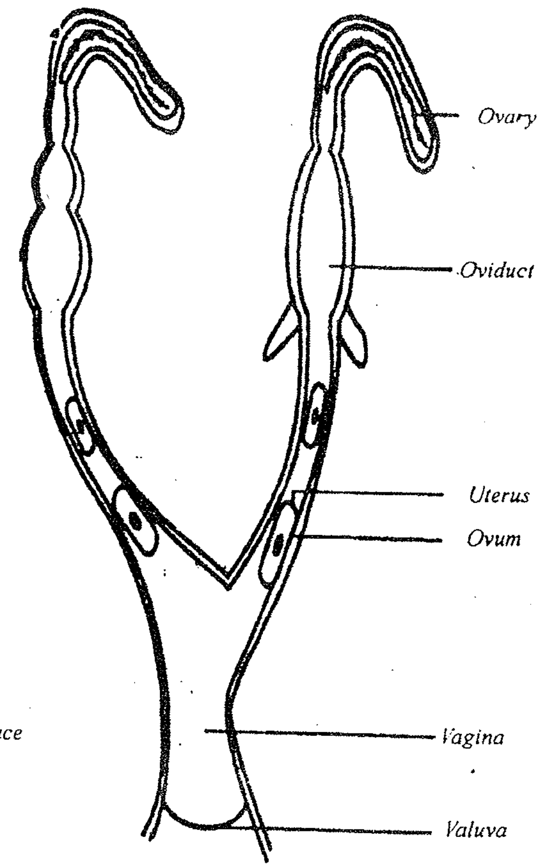


Fig. - VI



O. reproductive system

Mating Behaviour :

Nematodes possess adaptations which aid mate locations and the efficiency of sperm utilisation once mating has occurred. Mate location is aided by the production of pheromones which are attractive to the opposite sex (Green, 1980). The chemical nature of this attraction is diverse that low molecular weight materials as well as proteins and lipids have been found to serve as attractants.

Copulation :

After making physical contact, the nematode usually interwine and the posterior region of the male searches for the vulva of the female. Bursa or spicules of the male nematode help in this process.

Fertilization :

The introduced sperms migrate to the distal portion of the Uterus where oocytes are present. After penetration of the oocyte by a sperm, the oocytes continues muturation. When development is completed the male and female pronuclei fuse.

Egg-shell Formation :

Fertilization initiates egg-shell formation. The fertilized egg secretes a thick fertilization membrane, which hardens to form the inner part of the shell. To this inner shell is added on outer layer, which is secreted by the uterine wall. The nematode egg shell has a very restricted permeability and only allows gasceous exchange with the environment. Refringent (refraction) shell granules and glycogen are involved in egg-shell formation and lipid droplets, protein bodies, hyaline granule and glycogen provides food reserves for the developing embryo.

Embryonic Development :

These include the observation of zygote information by the fusion of egg and sperm pronuclei, the halving of chromosome numbers during meiosis and their subsequent restoration upon fertilization, the cleavage divisions of the egg and the seperation of somatic and germ cell lines (Ehrenstein and Schierenberg, 1980).

Nematodes are either ovipoarous or ovoviviparous. They possess predeterminat eleavate. Cell fates are highly determined. The timing of cell divisions and cell lineages is constant from one individual to another Nematodes possess cufelic development which implies that all somatic cells found in the adult stage were already present in the fully formed embryos. Nematodes experience gradual metamorphosis where the immature stages are termed as juveniles.

Life-cycle :

The life-cycle of nematodes consist of six stages or instars - the egg (or embryo), four juvenile stages (J1, J2, J3, J4) and the adult. The immature stages of nematodes are superficially similar to the adult while at an ultra structural level marked changes may be seen between one stage and the next (Bird, 1971). Like insects, thee phases are recognised in the moulting cycle of nematodes;

i) Apolysis (the seperation of the cuticle from the underlying hypodermis).

ii) Cuticle formation and

iii) Ecdysis - shedding of the remains of the old cuticle.

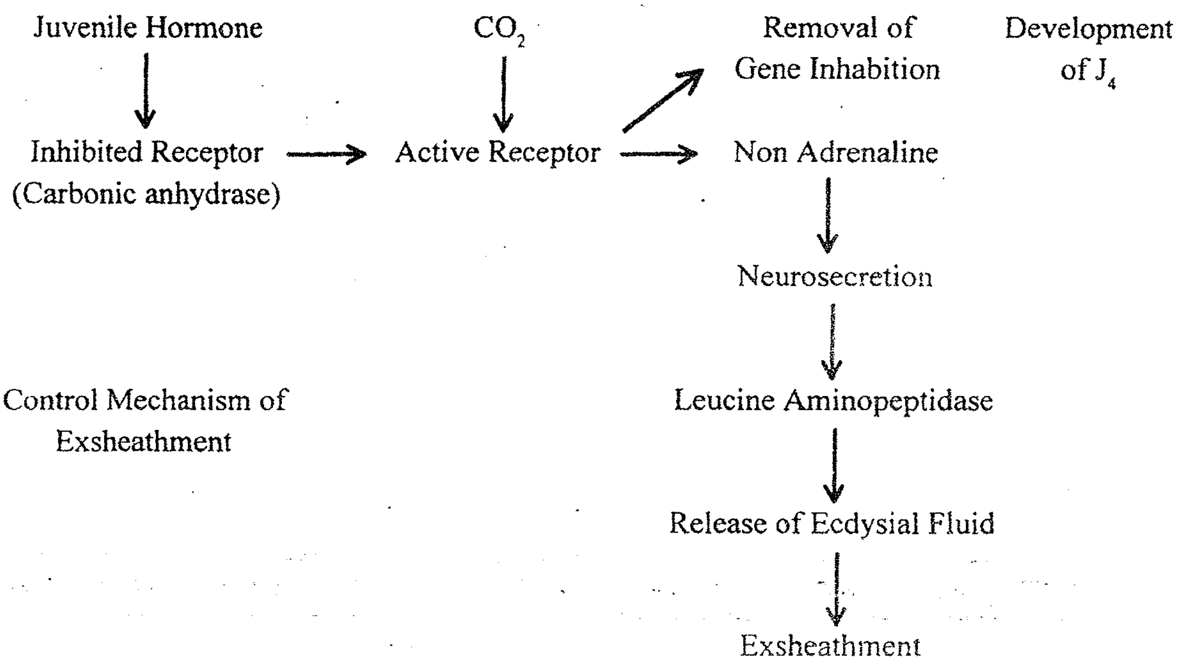
Thus, the life-cycle of nematodes is punctuated by moulting events, growth and differentiation occurring during the intermoult period.

Relationship between Growth and the Function of Moulting :

Byerley et al (1976) measured size distributiion at various times after hatching in synchronous cultures of a nematode, *Caenorhabditis elagans*. There were no discontinuties in the growth curve, suggesting that moulting had little effect on growth. Plotting the member of worms in each size class against length produces a population growth profile with discontinuites that correct with moulting. The overall growth curve of the species consists of the sum of the growth curves of the individual instars. Significant growth occurs in the intermoult period. Moulting in required in different stages of growth period of nematodes to acclimatise themselves in different changing environment as well as to accommodate different newly developed organ systems of the body. Rogers and Petronijevio (1982) suggesed that each instar possesses its own gene set, producing the structural and physiological; adaptation of the instar concerned.

Mechanism and Control of Moulting :

Moulting involves apolysis, cuticle formation and ecdysis. Hypodermal cells are instrumental in cuticle synthesis (Sommeerville, 1982; Singh and Sulston, 1978). The new cuticle may be highly folded, allowing a considerable amount of growth during the intermoult period (Howells & Blaincy, 1983). The moulting of nematodes is under endocrine control (Davey, 1982). Neurosceretary cells, ecdyson and juvenile hormone mimics have been identified from nematodes. The tissues responsible for hormone production have yet to be identified. The involvement of a carbonic anhydrase mediated receptor is indicated by the stimulatory effect of carbon dioxide and the inhibition of exsheathment by carbonic anhydrase inhibitors.



Control Mechanism of Exsheathment

Hatching :

In most species, hatching occurs as soon as development of the 1st stage juvenile is completed, providing the water is present. Perry and Clarke (1981) have suggested that an increase in the permeability of the egg-shell plays a central role in the hatching process of nematodes. The hatching stimulus may alter egg shell permeability by acting directly on the lipid layer or indirectly by stimulating the juvenile to release hatching enzymes.

Life Cycle Patterns :

The calculation from the reproductive parameters enables to understand the way in which the life cycle of free living nematodes are organised.

Rate of Natural Increase :

A measure of the reproductive potential of a population can be obtained by calculating the average number of (female) offsprings produced per female entering the population (R_0-the net reproductive rate) and the instantaneous growth rate of the population (R_0-the reproductive rate), assuming a stable age distribution and underconditions, where space and resources are not limiting (r-the intrinsic rate of increase). R_0 is calculated from life table (Poole, 1974) as the sum to the maximum age class reached in the population (t) of the number of female offspring produced per female during each time interval (m_x) times the robability of surviving from birth to that age (1_x).

$$R_0 = \sum_0^t 1_x m_x \text{ .... (1)}$$

'r' is most accurately calculated as the instrinsic rate of natural increase (r_m) by the Lotka equation.

$$\sum_0^t 1_x m_x = (-r_m X) = 1 \text{ .... (2)}$$

This also requires the measurement of age-specific survival (1_x) and age-specific fecundity (m_x) summarised in 'life table'. 'r' is sometimes eastimated as the capacity for increase (r_C), calculated from R_0 (equation-1) and the cohort generation time (T_C).

$$T_C = \left(\frac{1}{R_0}\right)\sum_0^t 1_x m_x \text{ .... (3)}$$

$$r_C = \frac{(1_x R_0)}{T_C} \text{ .... (4)}$$

'r_C' may then be used to give an initial estimate of 'r_m' (Vranken & Heip, 1983).

Equation '2' includes the measurement of the life cycle parameters of free living nematodes.

These figures are very dependant upon environmental factors, such as temperature, salinity and food availability.

Reproductive Strategies in Nematodes :

Most nematodes are Iteroparous (breed more than once) as opposed to semelparity (animals breed once and then die) and produce gamets continuously after maturation until shortly before death. The capacity for increase of population is dependant upon the fecundity of females, the generation time and survivality of adult and juveniles (Equation 1 and 4).

Animal parasitic nematodes tend to have high fecundities and relatively long generation time, whereas free-living nematodes tend to have low fecundities and short generation times (Equation-3). The intrinsic capacity for increase (r_C) is directly related to the logarithm of the fecundity but inversely related to the generation time (equation 2 and 4). Depending on the initial magnitude of the fecundaty, decreasing generation time results in a greater increase in r_C than would increasing the fecundity (Lewontin 1965; Meats 1971;

Snell 1978). The reproductive potencial of a free living species may therefore be much greater than that of a parasitic species in spite of a much lower fecundity.

If resources are assumed to be unlimited, the intrinsic rate of increase of the population (r) is also defined by the rate of change in the size of the population (N) with time (t) :

$$\frac{dN}{dt} = rN \text{ .... } (5)$$

As resources become depleted, the capacity for increase is decreased and the population size is dependant upon the carrying capacity of the habitat (K).

$$\frac{dN}{dt} = rN\frac{(1-N)}{K} \text{ .... } (6)$$

Species have sometimes been differentiated by whether they maximise fitness by maximising there instrinsic rate of increase (r-selected; maximise r in equation 5) or whether they maximise their share of the carrying capacity of the habitat (k-selected; maximise k in equation (6). Conditions of r-selection favour reproduction at the expense of adult survival-semelparity, reproduction of a small body size, rapid development, short life span and high fecundity. This is usually found in colonising species (e.g. *Caenorhabditis elegans*) and species that regularly experience a high mortality due to environmental extremes.

Where predation and competition are the dominent features of the environment, the survival of the parent rather than a high repreoductive capacity will be favoured - that is K - selection occurs e.g. *Plectus palustris.* Large experienced parents can compete for limited resources more efficiently than their small, inexperienced offspring. These conditions therefore favour ineroparity - large adult size, delayed breeding, the long - adult longivity and the production of relatively few but well protected and provisioned offsprings.

Not all species fit strictly into the r-selected or K-selected categories and may show a mixture of r and K influences in the environment (Calow 1978).

Ecology of Nematodes :

Free living nematodes are cosmopolitan in distribution. They harbour mostly as meiobenthic fauna in bottoms of marine environment. The density of such meiofauna ranges from 0.1 and 10 million individuals, per square meter. On the basis of their stomal structure, Weiser (1962) placed marine nematodes into the following feeding groups.

1. **Selective deposit feeders :**
   These are nematodes with a very reduced stoma. Only small, soft particles are ingested primarily by contraction of the pharynx.
2. **Nonselective deposit feeders :**
   These forms possess a well developed but unarmed stoma which is capable of ingesting soft and hard particles.

3. **Epigrowth feeders :**
   This category includes forms possessing a stoma armed with teeth, rods or plates for scraping microorganisms from surface or possibly piercing plant cells.
4. **Predators and Omnivores :**
   These forms possess well-developed teeth or plates for ingesting prey whole or piercing the latter and sucking out the contents.

All the above mentioned feeding groups of nematodes occur on all types of the sea-bottoms, ranrging from sandy beaches to silt loaded ocean trenches. Some form are euytopic while the others are stenotopic. Most forms occur in the upper 10 cm on sediment; however, under strong wave action intertidal forms can migrate to 20 to 30 cm below the surface. Many marine nematodes exhibit seasonal fluetuation in their population structure. Mucus, secreted by the pharyngeal and caudal glands produce slimy traces, over the substrate which entrap the microorganisms and other detritus particles to be used up as food.

Freshwater Nematodes :

In the transition from salt water to fresh water, a number of diverse nematode species are found. Many that occur in brackish water can tolerate rapid changes in salinity. The benthic nematode community are often used up as good indicator of pollution.

Terrestrial Nematodes :

Most of the terrestrial nematodes belong to the order Rhabdita. On the basis of morphology and behaviour, they are considered to be the most primitive groups among the nematodes. They lack a stylet and those which ingest microorganisms possess a valve in the median or basal bulb. In thos forms that have adapted to a semifluid nourishment in animal host the valve usually degenerate and may be entirely absent.

Role of Nematodes in Ecosystem :

Nematodes are important faunal components that are instrumental in recycling dead organic matter. By feeding on soil bacteria, the primary decomposers form part of the food chain usually enjoining second trophic level and occupy the key position in the ecosystem. They themselves preyed upon by other invertebrates (Mites, Collembola, Annelida, Crustaceans etc. and by small fishes.

During dry spells, when the physical conditions are severe, developmental stage perish. Nematodes are unable to form resistant cyst or spores, but rhabditids do have the ability to form a special third stage, a resistant non-feeding juvenile called a daur survival juvenile. This ability is probably the main reason why rhabditids have been so successful in exploiting new niches. When foods exhausted or moisture deficient, the daur stage has other advantages. Many daur juveniles can attach themselves to the exoskeleton of arthopods, thus expanding their distribution and reaching new nutritional niches in the environment.

The dauer, the third stage juvenile differ morphologically and physiologically from other normal developmental stage. The stimulus for dauer fermation is the lack of food during second stage juveniles, which begins to narrow, its gut collapses, it mouth closes and it changes into a dauer.

VIDYASAGAR UNIVERSITY

DIRECTORATE OF DISTANCE EDUCATION
MIDNAPORE - 721 102

M.Sc. in ZOOLOGY

Part – I : Paper - I : Group – A : Unit – I

Module – 3

Topic - 4 : **Bryozoa – anatomical peculiarities, feeding mechanisms and phylogenetic relationships.**

The Lophophorates : The lophophorates are a group of three phyla, sometimes given taxonomic status collectively as the lophophorata or tentaculata and having in common the presence of a special kind of feeding organs, made up of a ring of ciliated tentacles surrounding the mouth, termed as lophophore.

The lophophore – is a feeding organ designed to filter small particles from water. It is a horshoeshaped or circular, endowed with a array of tentacles. The classic features required of a true lophophore are that each tentacle is hollow and coelomate and the tentacles are arranged to surround the mouth but not the anus which is located outside the ring of tentacles.

Phylum Bryozoa (Ectoprocta)

The phylum Bryozoa or Ectoprocta is the greatest and the most common of the true lophophorate phylla. The other two lophophorate phylla are Brachiopoda and Phoronida.

Derivation of Names :

The name Ectoprocta (Gr. Ektos – without; proktos – anus) refers to the position of anus outside the tentacular crown (lophophore) surrounding the mouth. The name bryozoa (Gr. Bryon – moss; zoon – animals) means moss animals.

Classification :

The phylum is divided into three classes :

(1) Phylactolaemata – although it is fresh water and widely distributed but contains only about 50 species.
(2) Gymmolaemata – exclusively marine, includes mostly living bryozoans and many fossil groups.
(3) Stenolaemata – contains living marine species and over 500 fossil genera.

Characteristic features of Phylum Bryozoa :

Bryozoans are microscopic and fascinating aquatic, colonial coelomates. Presence of cilia on tentacles distinguish it from hydroids. Phylum Bryozoa contains 4000 species and each bryozoan is a compound animal made up of about 100 of zooids. In some, a calcified skeleton hides the whole structure.

Habit and Habitat :

They are sessile, a few inhabit fresh water but most are marine. Being filter feeder, they do not need light to live but they require food-bearing water.

Morphology and Anatomy :

A. EXTERNAL FEATURES :

1. **Zooids :**

The colony of basic bryozoa consists of a loose tangle of stolons from which zooids arise at intervals. Each zooid attains a height of 1 mm from the point of its origin. Zooids are essentially cylindrical in shape, broader distally than proximally.

i) **Tentacles :**

a) At the tip of the zooids, a series of slender, filiform tentacles are found. The number of tentacles ranges upto 34 (Hyman, 1959).

b) The outer surface of each tentacle is unciliated but each side bears tracts of long lateral cilia.

c) Each tentacle is roughly rectangular or triangular in section.

d) The expanded tentacles fan outward from their origin on the lophophore to form a funnel with a mouth at its vertex.

e) The cilia induce water current and so direct particles to mouth.

ii) **Lophophore :**

The lophophore, a flap of muscles, encircles the central mouth and consisting of a basal ridge continuous with a single row of tentacles.

iii) **Collar :**

Just beneath the lophophore, lies a muscular sheath – the collar.

iv) **Body-wall :**

Just beneath the cuticle, the epidermis is composed of a single layer of large flattened cells, which rests on two layers of muscles – the outer circular, inner longitudinal and an irregular cellular tissue or parenchyma.

v) **Coelom :**

The extensive coelom is lined by parietal layer of parenchyma, forming the innermost layer of the body wall and internally by a visceral layer of the same tissue ensheathing the alimentary canal.

B. INTERNAL FEATURES :

1. **Alimentary system :**

i) The digestive tract ('U' – shaped) starts from the mouth and ends to anus, which are placed outside the circle of tentacle.

ii) The mouth is a simple round opening encircled by the lophophoral base.

iii) The mouth is closable with circular fibres and may also be provided with radial fibres.

iv) The mouth leads into a wide chamber – the pharynx which is lined with columner ciliated epithelium continuous with the inner epidermis of the tentacles provided with a layer of circular muscle fibres.

v) The pharynx passes into the oesophagus recognized by its lack of ciliation, and the epithelium is with vacuolated cells with circular and delicate longitudinal muscle fibres.

vi) The foregut terminates with a constriction at which posterior end may project into the lumen as a valve.

vii) The stomach is differentiated into 3 regions as mentioned below.

A) CARDIA :

The first section or cardia is shortly tubular in species with cylindrical zooids but is longer in those with short broad zooids in order to allow the retracted tentacles to the alongside rather than above the alimentary canal.

B) CAECUM :

The middle sac like part of the stomach is caecum that occupies the turn of 'U'.

C) PYLORUS :

The ascending part of the stomach is pylorus. The pyloric epithelium is ciliated (e.g. phylactolaemata) and is provided with circular fibres.

viii) Beyond the pyloric constrictions, the intestine (usually called rectum)leads into the anal opening through the side of tentacle sheath.

Note : In some ctenostomes, the cardia is altered into the gizzard, the internal space of which is provided with teeth secreted by the periphery of the epithelial cells. This is dependant on the nature of food particles.

II. Respiratory System :

Gaseous exchange occurs at the body surface mainly through the lophophore.

III. Circulatory System :

The coelomic fluid is inadequate for internal transport. The peritoneum is partially ciliated and constant, definite circulation of coelomic fluid is maintained.

IV. Nervous System :

The nervous system consists of a plexus throughout the body wall and main ganglionic mass situated between the mouth and anus encircling the pharynx. From the center, nerves ascend into he tentacles and descend along the digestive tract and other parts of the trunk.

V. Sense Organs :

There are no special sense organs but sensory cells are there for the reception of tactile, chemical and water current stimuli. The funiculus is an important means of communication between zooids and there is clear histochemical evidence for a movement of lipid along the funiculus among the zooids.

VI. Reproductive System :

Most ectoprocts are hermaphrodites with gonads borne on the peritonium.Ova may be released through a supraneural pore or an intertantacular organ and in some cases sperms escape though open tips of the 2-dorsomedial tentacles. Development takes place in sea-water or in special broad chambers of the colony and includes a free swimming ciliated larvae, the actinotroch a modified form of trochophore.

Feeding Mechanisms of Bryozoa :

Bryozoans are sessile, aquatic, colonial coelomates. They are ciliary feeders, apparently without the assistance of mucus. A current of water, made by the lateral ciliary tracts of tentacles, containing nutritive particles (micro organisms, namely diatoms) moves down the center of the tentacular funnel towards the mouth and out between the tentacles. The ciliary beats can be stopped or reversed or its speed altered, perhaps as a means of preventing the escape of food particles in the outgoing current.

Food Capturing Devices :

Associated Structures :

A. LOPHOPHORE :

The lophophore is a circular fold of body wall that encircles the mouth and consists of a basal ridge continuous with a row of ciliated tentacles.

B. TENTACLES WITH CILIA :

1) The number of tentacles varies in different species from 8 to 34.
2) The tentacles are hollow, containing a coelomic lumen continuous with a ring coelom in the lophophoral base.
3) Each tentacle is roughly rectactangular or triangular in section.
4) The outer surface and tentcular tips are devoid of cilia and provided with the projecting tactile hairs of neurosecretary cells.
5) The cilia occur as a pair of lateral longitudinal tracts.
6) The median cilia lack the power of motility according to some authors.
7) The tentacles are independently movable by way of longitudinal muscle fibres, situated along the inner and outer side, just beneath the peritoneum.
8) Shorter frontal cilia are present within the inner side of tentacles.

Function :

The expanded tentacles fan outward from their origin on the lophophore to form a funnel with the mouth at its vertex. The cilia beat obliquely downwards and outward in relation to the long axis of the tentacle and exhibit motachronal waves which pass up the left side of the tentacles (viewed from inside of the cone) and down the right side. The combined action of these cilia is to generate a water current which enters the top of the bell and passes outwards between the tentacles. Some of the particles in suspension must get carried away by the outflowing water but an adequate portion will be directed by the action of frontal cilia straight to the mouth. The main function of the frontal cilia is to augment the main water current and to direct it towards the mouth.

Mechanism of feeding :

A. Protrusion of lophophore :

1) During feeding, the lophophore expands into a funnel shaped structure.
2) In the proximal part contraction of 2 bands of transverse parietal muscles pull the ventral and dorsal walls of the flexible zoecium close together.
3) This contraction reduces the coelomic volume and raises the internal hydrostatic pressure.
4) The contraction of transverse muscles is followed by the relaxation of longitudinal, parietal and retractor muscles.
5) The contraction of transverse parietal muscle raises the pressure still further.
6) Further relaxation of the retractor muscles permits the tentacles to raise through the collar.
7) Then the tentacles are spread by the action of their intrinsic musculature.

B. Production of feeding current :

When the lophophore is protruded, the lateral ciliated tracts on the tentacles create a current that sweeps downward into a funnel and passes outward between the tentacles. Regardless of the tentacle's length and numbers, the distance between adjacent tentacle tips is generally about 110μ Small phytoplanktonic organisms which are probably the principal food of bryozoans, are driven into the funnel with the water current and on touching the lateral cilia, effect a local reversal beat, which bounces the particles back into the upstream side of the tentacles and down towards the mouth. This is thus a ciliary upstream collecting system.

C. Hypothesis with regard to the feeding current in Bryozoa

a) Impingement feeding hypothesis :

Outward and downward beating of lateral cilia exhibit metachronal waves which pass up the left side of tentacles and down the right side. Combined action of these cilia generates the water current which enters the anterior part and passes outward between the tentacles. Some of the suspended particles get carried away by outflowing water but an adequate proportion is directed straight to the mouth (Bullivant, 1968).

b) Ciliary reversal hypothesis :

According to this hypothesis, the ciliary beating produces a current on inner side. Particles may either be swept past or retained by local reversal of the lateral cilia which balance them towards the mouth. Since, the component of the current towards the base of the lophophore is greater near the center of the lophophore, the inward flicking of the tentacles often may serve to throw the particles into the central current where they can be carried towards the more proximal part of lophophore (Strathmann, 1971 & 1973).

c) **Rejection of Unwanted particles :**

Unwanted particles may be prevented from reaching the mouth of individual by concerted movement of the tentacles and closure of the mouth, which results in particles being carried away by the outflowing current, or ciliary reversal which ejects particles from the pharynx (Bullivant, 1968).

d) **Ingestion :**

The frontal cilia augment the main water current and direct it towards the mouth. This effects is enhanced by the beating of cilia inside the pharynx, so that smaller particles are drawn through the mouth. Larger particles are ingested by the sudden dilation of the lower portion of the pharynx which thus acts like a suction pump. Once inside the pharynx, the cilia in the buccal region prevent particles from escaping.

Remark :

There is no evidence that mucus play any role in feeding (Bullivant, 1967). No secretary cells have been identified in the tentacles. However, Smith (1973) reported that the tentacles were coated with a layer that is mucosal.

D. Withdrawal of lophophore :

Withdrawal is achieved by the extremely rapid contraction of the retractor muscles while the transverse parietal muscles relaxed. In the latter stages, retraction is accompanied by the sequential contraction of the two sets of longitudinal parietal muscles. Finally, with the withdrawal of tentacles, the circular muscles of the sphincter close off the zooid from the exterior.

G. Passage of food through the Alimentary Tract :

1) The food enters the stomach through the valves. Just after it, the stomach shows an almost endless variety of movements and changes of shape (Silen, 1944b).
2) Concomitant contraction of the cardia and expansion of the stomach coecum draws food into the latter and the reverse actions can particles to the cardia.
3) No grinding action of the stomach was seen, but the caecal contents rotate continuously as a result of the action of the phyloric cilia. The food is thereby formed into a rotating cord extending from the caecem into the pylorus and this cord rotates at a rate of 70 to 150 turns per minute.
4) After remaining for some time in the stomach, the food passes into the intestine but may be sucked back for further digestion by the sudden depression of the stomach roof.
5) To pass the food remnants into the intestine, the pylorus depresses into the stomach, and thereby its exit into the intestine usually closed, is opened.
6) Absorption of digested food particles and faecal pallets formation do not take place in the rectum, the terminal portion of alimentary tract but in the intestine.

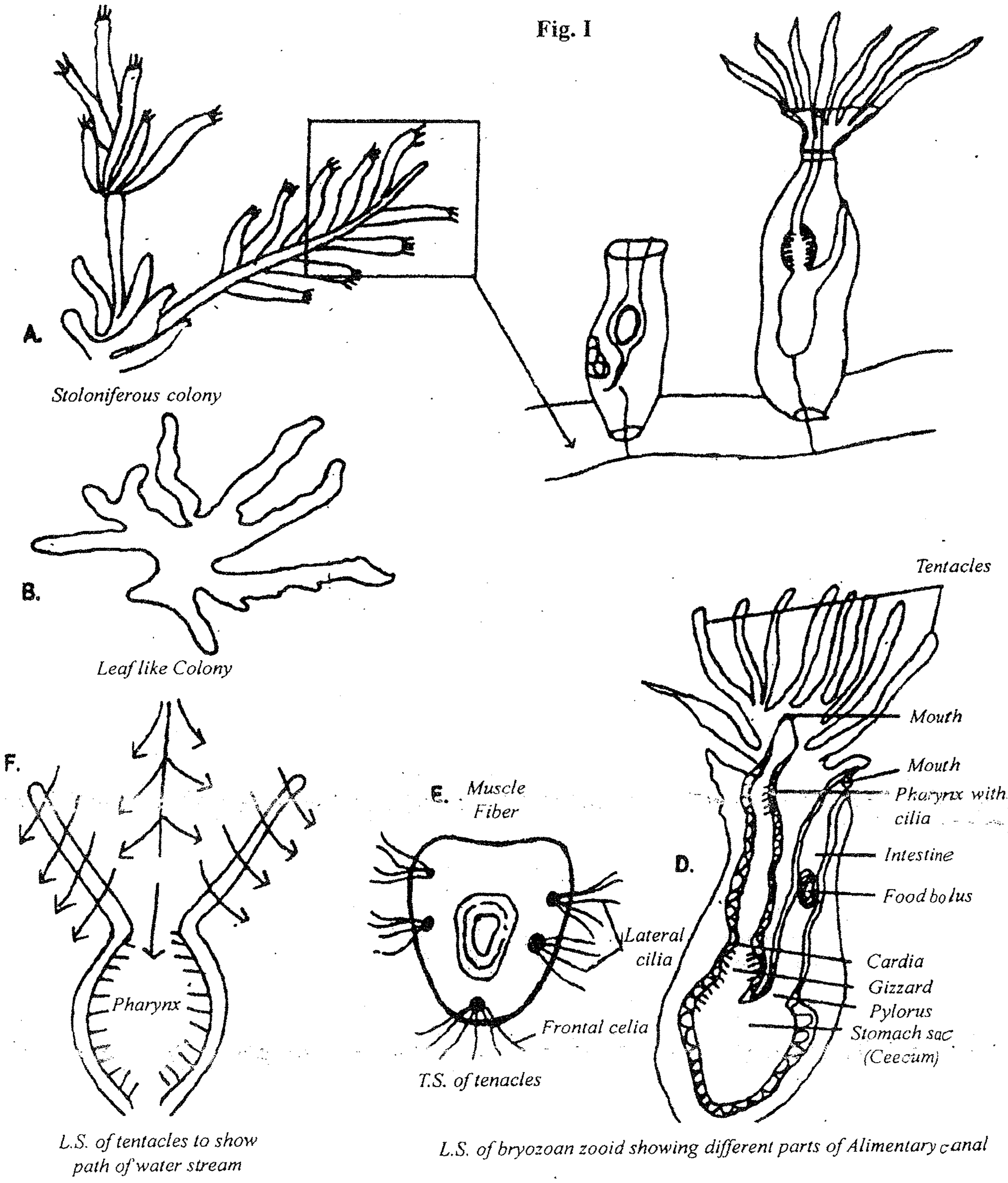


Fig. I
A.
Stoloniferous colony
B.
Leaf like Colony
Tentacles
Mouth
Mouth
Pharynx with cilia
Intestine
Food bolus
Cardia
Gizzard
Pylorus
Stomach sac (Ceecum)
D.
E.
Muscle Fiber
Lateral cilia
Frontal celia
T.S. of tenacles
F.
Pharynx
L.S. of tentacles to show path of water stream
L.S. of bryozoan zooid showing different parts of Alimentary canal

Phylogenetic relationship of Bryozoa :

Intraphyletic relationship : Of the there classes of living bryozoans, the freshwater Phylactolaemates are considered the most primitive and specialised as they posses cylindrical zooids, the anterior orifice, an epistome and the non-polymorphic colonies. These freshwater bryozoans are widely distributed in lakes and streams but avoid turbid water. It is difficult to draw any relationships of this fresh water group with their marine counterpart due to the non-availability of fossil forms.

The class Stenolaemates dominate the entire palaeozoic era while the dominant Gymnolaemate made their appearance in the late Jurassic era. Of the varios trends relating to their intraphyletic relationship in course of the evolution of marine bryozoans, adaptations associated with protection of the vulnerable frontal surface are especially striking. In primitive bryozoans, the frontal surface behind the orifice is covered only by the frontal membrane which must be thin and flexible in order to bow inward in the process of elevating the coelomic fluid pressure and protruding the lophophore. In some from viz. *Cellaria, Micropora* etc., the protection of the zooid assured by the development of a wall beneath the frontal membrane, resulting in a double chambered zooid. The wall is perforated to permit passage of the parietal muscle bands responsible for in bowing of the frontal membrane. In some forms, the frontal wall has become calcified and a sac (ascus) develops as an invagination of the body wall near the orifice, projecting backward into the coelom. The parietal muscles are attached to the underside of the sac; when they retract, the sac dilates, water enters, coelomic fluid pressure rises, and the lopohophore is protruded.

Marine bryozoans are highly successful animals, exploiting all types of hard surfaces – rock, shell, coral and woods (mangrove stems, roots etc.) and capable of leading an epiphytic life. The mineralized skeletons form no part of their anatomical ground plans. This group does require rigid skeletons in order to occupy all of the habitats and to perform the array of ecological functions they have achieved.

Interphylletic relationship :

Relationship with Phoronida : Caldwell (1988) emhasised the relationship between Bryozoa and Phoronida. The idea was based on the basis of the presence of the following similar features.

i) Same body and coelomic regionation, with a definite system between mesocoel and metacoel.
ii) Both are provided with horse-shoe shaped lophophore.
iii) Presence of a U-shaped alimentary canal.
iv) Main nerve center found in mesocoel. A sub-epidermal nerve plexus present.

But the other details of anatomy and embryology are different in the two groups – (1) the line between mouth and anus is dorsal in phoronida and ventral in ectoprocta. (2) the lack of nephridea and circulatory system in ectoprocta.

Because of these differences the relationship between ectoprocta and phoronida can be established, of the three lophophorate coelomates, the phoronida is nearer to the lophophorate ancester and the ectoprocta occupies a subsequent stage.

Relationship with Brachyopoda :

Similar features :

1) Similar body construction.

2) Bivalved shell of cyphonaute larvae of Ectoprocta is compareble to the shell of Brachipoda.
3) Presence of a coelomic septum between mesocoel and metacoel.
4) U-shaped alimentary canal.

Different features :

1) Presence of vascular system, paired nephridia and chitinous setae in brachyopoda.
2) Disposition and nature of brachiopod shell in different form of ectoprocta.

Relationship with Entoprocta :

Formerly, ectoprocta and entoprocta were linked together as classes under the old phylum Polyzoa or Bryozoa because of the following similarities.

1) Presence of a crown of ciliated tentacles ; 2) Presence of a looped digestive tract, 3) the cyphonaute larve of ectoprocta bears a marked superficial resemblance to the larva of entoprocta.

But the two groups differ from each other by the following features.

1) Entoprocta is pseudocoelomate. 2) In entoprocta, the mouth and anus are included within the crown of tentacles, 3) Nephridia and gonoducts present in entoprocta, 4) the entoprocta larva has no adhesive and pyriform organs as in ectoprocta larva.

Topic – 5

Rotifera : General organisation, Mastax, Reproduction & Cyclomorphosis.

The rotifers are very common and abundant freshwater animals, commonly designated as the "Wheel animalcules". The name of the phylum Rotifera came from two latin wards – rota = Wheel and ferre = to bear.

They are microscopic and perhaps are the smallest amongst the metazoa (the size varies from 0.4mm – 3mm in length.) They form an important part of food chains leading to man. Sometime, this small sized and highly reproducing animals pose problems to water filtration.

Definition :

Usually microscopic, unsegmented, bilaterally symmetrical, psedocoelomate, dorsoventrally compressed sac like body, free living aquatic animals, typically having a ciliary apparatus called corona at the anterior end for locomotion and food collection, with a muscular pharynx containing movable jaws; with typical flame-bulb nephridia opening into the cloaca; sexually dimorphic and without specialised circulatory and respiratory systems.

Ecology :

The rotifers are cosmopolitan as their eggs are easily distributed by the wind, water and animals. The same species may occur in similar environment all over the globe. They are the most common inhabitants of freshwater and a few are marine but very few are parasites. They have adapted veriety of habitats and ways of life. Thus they may be free or fixed, solitary or colonial (e.g. Conochilus sp), creeping or swimming or pelagic, epizoic or parasitic or carnivorous. They feed on microscopic organisms brought by the ciliary action.. They are ecologically divided into three groups.

(a) Alkaline Fauna

Found in hard water. Eggs of amictic females can tolerate alkaline conditions.

(b) Acid Fauna :

Found in soft water. Eggs produced by mictic females can withstand acidic conditions.

(c) Transcursion fauna :

Some forms produce dormant eggs which can tolerate both alkaline and acidic conditions.

Tolerance against desiccation.

Rotifers can withstand drying even for years. They undergo desiccation becoming shriveled, wrinkled, and reduced much in volume. Generally, there is no secretion of a protective cyst. The creature survives in such a dormant state for 3 to 4 years. Upon the advent of water, dried creatures swell, unfold, resume normal activities and start reproduction. Sometimes, the animal itself dies, though the contained eggs may survive until moisture returns.

General Morphology :

External features :

The elongated or saccular body of a typical rotifer is divisible into three regions - an anterior head, a middle trunk and a posterior foot.

(a) Head :

The blunt anterior end of the body is not distinctly delimited as head. It may be narrow or lobbed but it is typically broad and truncate. The head consists chiefly of a characteristic retractile ciliary crown or disc called the corona or trochal disc, with a central unciliated apical field. The distribution of crown cilia varies in different rotifers. In some cases (*e.g. Epiphanes*), the corona is surrounded by a double ciliated ring, the velum, made of an outer ciliary band or cingulum and an inner ciliary band or trochus. The cilia beat in a circular manner-one clockwise and the other anticlockwise and look like two wheels spinning, hence the name 'Rotifera'. The beating of cilia helps in locomotion, in drawing water currents containing exygen and food towards mouth and in carrying off wastes.

(b) Trunk :

The trunk is the middle, elongated region containing the chief visceral organs. It may be cylindrical or variously flattened and broadened. It is generally surrounded by the shell-like transparent, flexible cuticular covering, the lorica, which is often ornamented or spiny.

(c) Foot :

The post anal or terminal, gradually tapering region ofthe body forms the tail or foot. The tail terminates either in an adhesive disc or in one to four pointed, movable, finger-like projections, the toes. The foot contains cement or pedal glands, the ducts of which open at the tips of the toes. In sessile rotifers, the secretion of this gland serves to anchor the animal temporarily.

Body Wall :

It consists of cuticle, hypodermis or epidermis and sub-epidermal muscles. The protective noncellular and thin cuticles, secreted by the hypodermis, consists of scleroproteins. In some species it forms a rigid shell or lorica around the trunk. The hypodermis is a thin syncytium containing a constant number of scattered nuclei.

Epidermal glands are rare. The ducts of a retrocerebral organ, lying near the brain, open on the apical field; while those of pedal glands, located in the foot, open on the tips of the toes. There are several bands of unstriped muscles passing from lorica to trochal disc and tail.

Pseudocoel:

The spacious cavity, between the body wall and the gut, is a pseudocoel derived from the embryonic blastocoel. It is filled with fluid containing a loose syncytial mass of amoeboid cells, presumably phagocytic and excretory in nature.

Digestive system :

The food, consisting of protozoa, other minute organisms and organic debris, are swept by ciliary action into the mouth, situated in the center or near the ventral edge of corona.

The mouth leads, by a short baccal cavity, into a rounded, elliptical or elongated and highly muscular pharynx or mastax, which is an efficient chewing apparatus characteristic of rotifers alone. It is composed of masticatory parts e.g. trophi and musculature. The mastax is usually oval or elongated and highly muscular. The inner epithelium bears seven large interconnected, protecting pieces or trophi, composed of an acid mucopolysacharid materials.

Typically the trophi comprises of two chief components (A) Incus and (B) Maleus (**Fig. 1 & 2**).

The Incus is again made up of a single basal piece called fulcrum and two lateral triangular pieces called rami. On either side of incus, lies a hammer-shaped malleus, consisting of a handle like manubrium, embedded in the muscles and a toothed claw or uncus.

Operated by muscles, the trophi are in constant movement which distinguishes a living rotifer from other organisms. They are variously used to grasp, cut and grind the food. They vary in shape and size, according to feeding habits in different rotifers and are with classificatory value.

The mastax leads through a short, narrow and dorsal oesophagus into a large, thick walled and sac like stomach, attached anteriorly to which a pair of digestive or gastric glands are associated. The stomach passes through a short, almost straight intestine to an oval cloaca, which opens to outside through the anus or cloacal opening situated mid-dorsally at the junction of the trunk and foot. Except pharynx, the digestive tract is lined by cilia.(**Fig 3**).

Fig. 1

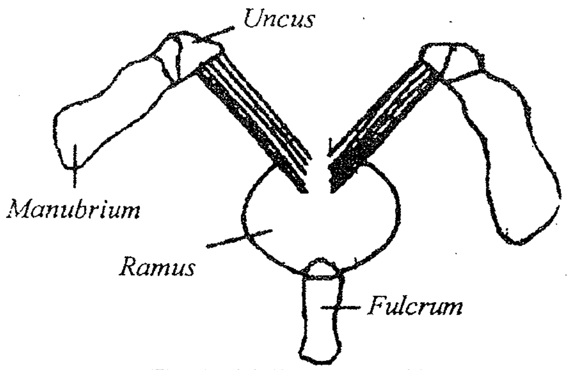


Fig. 1 : Malleate type of Mastax

This type represents the primitive condition found in Brachionus, Epiphanes are all the components are relatively short & strongly fault

Fig. 2

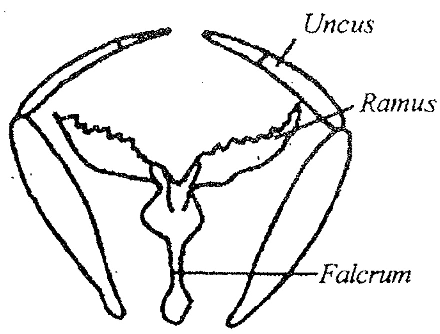


Fig. 2 Forcipate type of Mastex

This type represents modern condition all the pieces are elongated and slender. The rami are toothed found in Dicronophorus.

Digestion takes place in the stomach and absorption in the both stomach and intestine. The digested food through the pseudocoelomic fluid reaches all the parts of the tiny body.

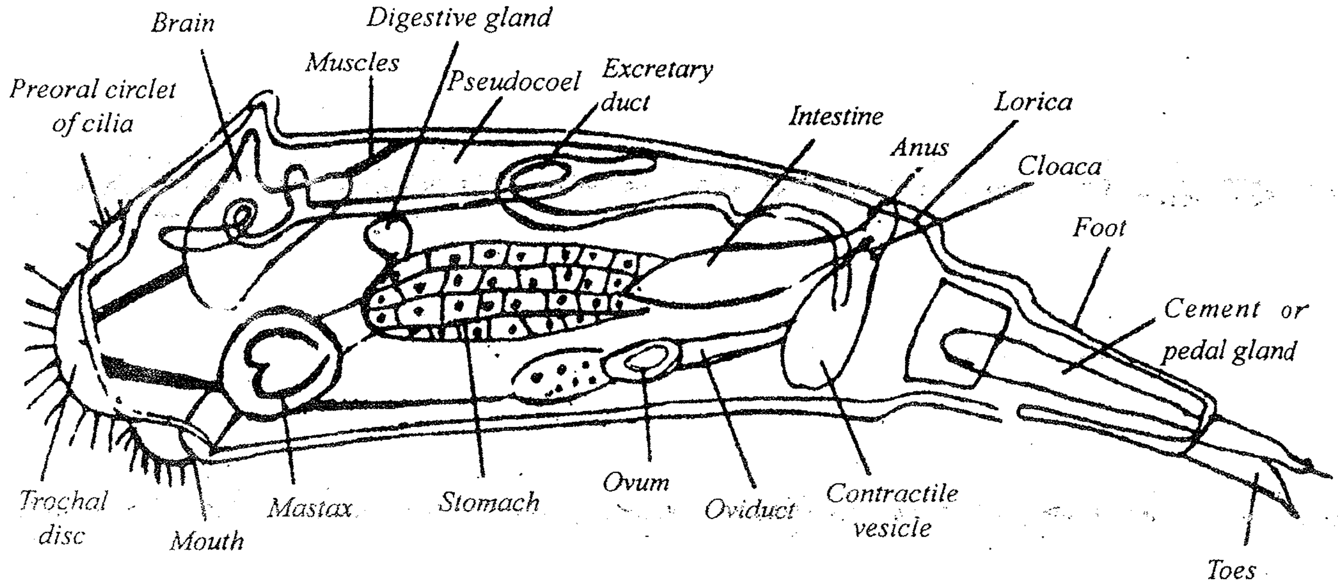


Fig. – 3 : Section of the generalized rotifer in lateral view showing internal structures.

Detailed account on Mastax :

Mastax is a peculiar structure characteristic to Rotifers. It has created lot of interest among different workers, all over the globe. Some researchers suggest it to be a digestive component while others used it for the classification of rotifers.

Historical Resume :

...died its structure, function and homologies. Hudson and Gosse (1956) in their monograph tried to draw closer relationship between mastax and arthropodan appendages. However, this view was criticised by others (Hyman 1951, Mellanby and Heuen 1963, Grasse 1965, Strathmann *et al* 1972, Barnes 1980) who put forward more comprehensive description of mastax.

Structural excellence :

Mastax or pharynx is muscular chamber with cuticular lining and appendages. Shape of the structure is rounded, trilobed or elongated. Inner wall bears the masticatory apparatus, the inner epithelium of which bears seven interconnected, projecting hard cuticle made pieces or trophi, composed of an acid mucopolyssacharide materials (Fulcrum-unpaired, rami, unci and manubrium – paired). On the basis of structure of trophi, mastax may be of different types like – Malleate, Virgate, Caudate, Forcipate, Incaudate, Ramate and Uncinate.

Mascular supports to mastax :

Mascles extending between the pieces of trophi are as follows :-

1. Abductor muscles open at the rami.
2. Adductor muscles close to the abductor muscles.
3. Fulcro – manubricus between the fulcrum to manubrium.
4. Ramo-manubricus – from rami to manubricum.
5. Flex or mol – allows unci to move against rami.
6. Uncus muscles – connect unci to both end of manubrium.
7. Adductor muscle – continuous band in pharynx wall between caudae and manubrium. This is the principal muscle producing the chewing movement.
8. Lateralis Manubri – Similar to adductor muscle.
9. Abductors and adductors of caudi.

Muscles connecting the trophi to mastax :

1. Fulcro-oralis – From fulcrum to buccal field and adjacent part of the head.
2. Fulcro-mucosus – From fulcrum to pharynx between the rami and act as piston muscle in virgate mastax.
3. Fulcro-oesophagus – Fulcrum to oesophagus.
4. Scapules – From falcrum to pharynx wall by muscle band.

Histology :

The lumen of the mastax is lined by cuticle and is ciliated only in case of current feeding forms with ramate mastax i.e. the forms belonging to the class Digonota, Rotaria and Philodina. The wall has an epithelium (syncitial or cellular). This epithelium secretes the trophi and numerous muscles of the mastax appear to be fibrilar extension of its cytoplasm.

Types :

On the basis of the structures of the trophi, mastax may be of the following types :

1. **Malleate :**
   This is most primitive type. All the pieces are relatively stout. Rami are untoothed. Unci are with curved plates (teeth) on their dorso-median side which help grasping, grinding and chewing. This type is the feature of the family branchonidae, trochospeeridae and testudenenidae.
2. **Sub-malleate :**
   Rami slender, manubri twice as long as unci, other structures similar to that of malleate. This type occurs in some members of Brachionidae.
3. **Virgate :**
   Fulcrum and manubri are elongated and rod like. Rami are broad triangular plate and provides mechanical strength to the piston. Unci bear teeth which help grasping the prey. The prey is sucked by the action of piston (hypopharynx). The anterior dorsal wall is stiffened bythe cuticular plates i.e. the epipharynx occur in Trichoceridae, Gastropodidae, Synchetidae, Notomatidae.
4. **Caudate :**
   Epipharynx present Manubrium is forked. Pistone is lacking. Sucking is done by the movement of Unci. Occurs in *Lindia* sp.
5. **Forcipate :**
   All pieces are slender and elongated. Curved rami with fulcrum form forcep like structure. Sharp teeth are closely approximated to the pointed unci. This occurs in the members of the family-microcodonidae.
6. **Incaudate :**
   It is similar to that of forcipate type and appears to have forcep like shape. Manubria are rudimentary but stout. These occur in the members of the family – Asplancknide.
7. **Ramate :**
   Fulcrum and manubrium are very much reduced. Unci large and plate like. Surface is provided with several parallel ridge forming a masticatory apparatus. It occurs in the members of the order Bdelloida (e.g. Rotaria).
8. **Malleoramate :**
   Manubrium looped, incus wide, provided with a number of slender, elongated parallel teeth. It occurs in the members of the family Trochosphaeridae.
9. **Uncinate :**
   Fulcrum and manubrium are reduced. Unci with a few teeth. Rami stout and large Subunci present. It occurs in the members belonging to the order Collothecaces.

10. Fulcrate :

A median elongated piece – presumably the fulcrum is present. The anterior end of it is attached to a pair of limb like manubria, and several other small pieces. It occurs in the members of order Seisonacea.

Function of Mastax :

1) Mastication – by rubbing and grinding.
2) Grasping prey like the jaws in case of predaceous forms.
3) Attachment to host as in parasitic forms.

Reproduction in Rotifera :

Sexually dimorphic Rotifers usually display pronounced reproductive cycles more or less related to seasonal condition. In planktonic and other monogonotic rotifers, sexual and asexual phases may alternate. In the species, belonging to Bdelloida and monogonontida where males are unknown, reproduction is assumed to be entirely asexual. In the genus belonging to Seisonoida, the reproduction is exclusively sexual.

Reproduction in Monogontida :

The reproductive life history of typical planktonic rotifers (maximum members of Monogontida) is characterised by a large number of generations and the reproduction is parthenogenetic by females. These females are amictic females which produce large, thin walled and developed eggs referred to as amictic / parthenogenic /summer eggs, during most of the years. They are incapable of being fertilized and develop into females. Whereas, mictic females lay small sized, haploid, thin walled mictic eggs which are capable of being fertilised especially during later phase of the year when sexual season approaches. If not fertilised they develop parthenogenetically into males. If fertilised, they become thick walled, diploid and can overcome unfavorable conditions. **(Fig. 4).**

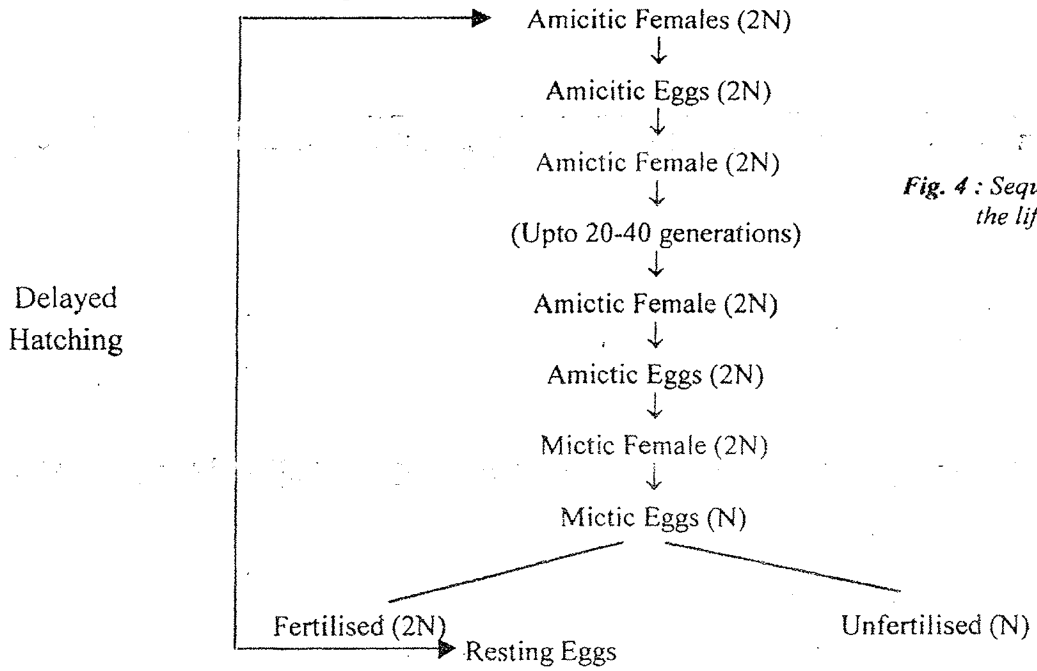


Fig. 4 : Sequence of different phases in the life history of Rotifers

Occurrence of upto 20-40 amictic generations have been noted with an egg development time of about one day under warm optimal conditions and without the need to encounter the males for fertilization. The population of amictic females can develop rapidly in 2-5 days under good growing conditions.

The non-reductional division occasionally is interrupted once or twice in the year by the development of a morphologically indistinguisible mictic females. The eggs of mictic females undergo normal double meiotic divisions. If these mictic females are fertilised by males, the eggs developed into thick walled resting eggs that undergo a prolonged diapause and are highly resistant to adverse environmental conditions. If the mictic females are not fertilised, the much smaller eggs rapidly develop into males. The males are small sized, extremely active, short lived and sperm producing organisms with least complex body organisation. They are capable of copulation with an hour of hatching. Hatching of resting eggs are induced by bio-chemical factors, the nature of which are poorly understood. The resting mictic eggs always result in parthenogenetic amictic females. The diapause extend over a period of several weeks or months and hatching is related to changes in temperature, osmotic pressure, water nutrients and dissolved oxygen (Hatchinson 1967, Rutter-Kolisko 1972).

Cyclomorphosis in Rotifers :

Many pelagic species undergo seasonal changes in body shape or structures, a phenomenon known as cyclomorphosis.

In this event, individuals of certain species during one season of the year have spines that are longer or shorter than those developed by their descendants during another season. In *Brachionus calyciflorus*, spines in subsequent generations can be induced by starvation, low temperature and by some substance produced by the predatory rotifers – *Asplanchna* sp. (Fig. 5) Elongated spines protect Brachionus from being eaten by their predators.

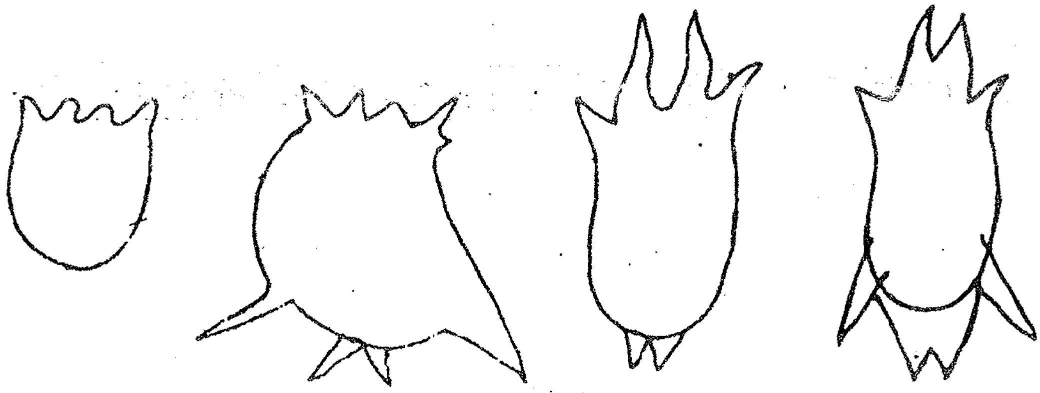


Fig. 5 : Seasonal variability in spines of the planktonic rotifer Brachionus, a favourite prey of Asplanchna.

VIDYASAGAR UNIVERSITY

DIRECTORATE OF DISTANCE EDUCATION
MIDNAPORE - 721 102

M.Sc. in ZOOLOGY

Part – I

Paper - I : Group – A : Unit – II

Module – 4

Syllabus :

1. General structure of endostyle & Iodine binding capacity.
2. Origin, evolution & distribution of Primates with special reference to India.

GENERAL STRUCTURE OF ENDOSTYLE IODINE BINDING CAPACITY

I. Endostyle in cephalochordate :

In cephalochordata greatly enlarged pharyns ix lined with cilia, which beat synchronously backward and downward, causing a stream of water to be sucked in through the mouth. Most of the water passes out through the numerous pairs of gill-slits, but the food particles are captured by a sort of flypaperlike apparatus, the endostyle. This structure consists of a glandular cilialed groove running the length of the pharynx on the ventral side. The groove is composed of four tracts of mucous glands separated by tracts of ciliated cells. The glands secrete a sticky mucus, and the cilia whip the mucus into a twisted rope and propel it forward and upward both along the gill-bars and around the peripharyngeal grooves that encircle the mouth. This traveling of food conveyor is then picked up by a dorsal groove (the hyperpharyngeal groove) the cilia of which beat backward so as to propel the mucous rope back to the intestine, where its food load is digested. The mucous and indigestivable wasts are discarded through the anus.

There are cilia on the sides and inner surface of the gill bars, the lateral ones being mainly responsible for driving the water outwards through the atrium and there by drawing the feeding current of water in at the mouth. There is a complicated plexus of nerve cells and fibres in the walls of the

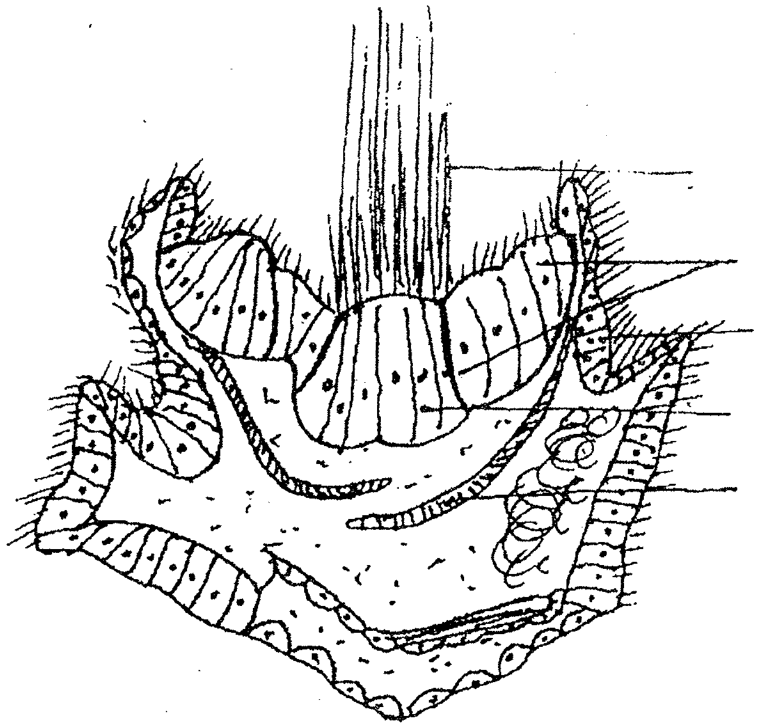


Fig. T.S. of Pharyngeal region of *Amphioxus*

pharynx and changes in the rhythm of the cilia occur, but details of the nervous connections are not known. In the floor of the pharnyx lies the endostyle, containing columns of ciliated cells, alternating with mucous - secreting cells which produce sticky threads in which food particles become entangled, various currents then draw the sticky meterial along untill it reaches the midgut. The frontal cilia of the – gill bars produce an upward current, driving the mucous from the endostyle into a mediam darsal epipharyngeal groove, in which it is conducted backwards. The cilia of the endostyle also move mucous along the peripharyngeal ciliated tracts, behind the velum, to join the epipharyngeal groove. Radioactive iodine is concentrated by the cells of one of the columsn of the endostyle and seereted with the mucous. These may be regarded as the precursors of the thyroid cells. They serve to produce iodinated mucoproteins, which are then absorbed further down the gut. Homogenates of Amphioxus show that mono and di-iodotyrosine are present, as well as tri-iodothyronine (T_3) and thyroxine (T_4).

Unlike higher vertebrates T_3 is more abundant than T_3. Metamorphosis of axolitls were produced by implants of the pharnyx of about 50 Amphioxus but not by the tails. There is no evidence that these iodine compounds have an endocrine activity in the animal itself.

II. Endostyle in Urochordata :

In urochordata, there is an endostyle, which has three rows of secretory cells on each side, separated by rows of ciliated cells and with a single median set of cells with very long cilia. The secretion of the inner layers of the endostyle is mainly of protein, which is then combined with iodined tyrosine provided by a layer of iodine uptake cells. There may also been addition of mucopolysaccharide. The main product of the endostyle is a sheet of iodinated protein which is caught up on the papillae, whose muscles move them rhythmically, spreading a curtain over the inside of the pharynx. Food particles are caught in this layer, which moves upwards and is then passed back to the oesophagus by the cilia of a dorsal lamina or of a series of hook-like 'languets'. The whole curtian is then digested,

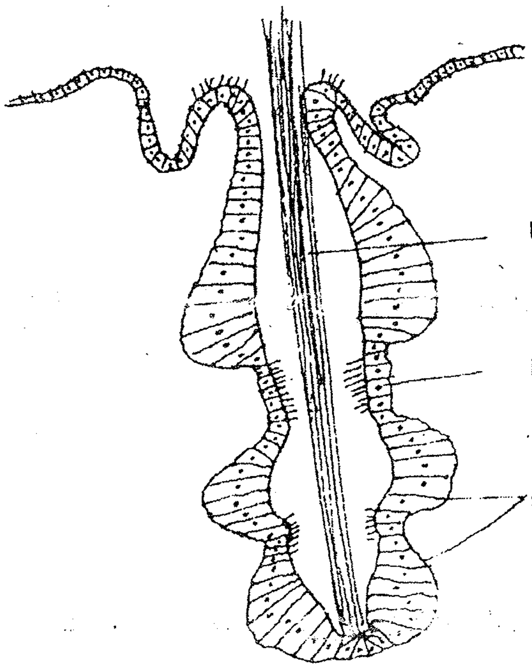


Fig. - Structure of Urochordate endostyle.

including the captured micro-organisms and iodinated protein. Autoradiographs made from tunicated that have been provided with isotops of iodine show that the campounds formed are mainly 3-mono-iodotyrosine (MIT) or 3, 5-di-iodotyrosine (DIT). There is a little or none of the tri-iodotyrosine (T_3) and thyroxine (T_4) compounds found in Amphioxus and craniates. The iodoprotein curtain evidently has some special properties as a collector of food. Iodine is even more abundant in the outer layers of the tunic but here it forms scleroproteins, as in the exoskeletal structures of molluscs and insects. The iodine-binding cells of the endostyle show some responses to mammalian thyroid stimulating hormone, but there is no evidence of any hormonal effects of the secretion within the sea-squirt itself.

III. Endostyle in Agnatha :

In agnatha the endostyle shows the survial of the primitive feeding methods of chardates, but it also undergoes at metamorphosis an astonishing change into the thiroid gland. The mucous secreting columsn shrink and the whole organ becomes reduced to a row of closed sacs, lying below the pharynx. Each of these sacs is lined by an epithelium, containing a structureless "colloid" substance and is therefore closely similar to a thyroid vesicle. Moreover, experiments have show that extracts of this organ contain iodine and exert an accelerating effect on the metamorphosis of forg tadoples. Although nothing is known of the part payed by the secretion of this gland in the life of the adult lamprey, we may sakely conclude that we have here the conversion of an externally secreting feeding organ into a gland of internal secretion. The actual mucous-secreting cells are not transformed into those of the thyroid follicles, these latter are derived from epithelial cells in the wall of larval organ. One cannot avoid speculating on this extraordinary change of function. It may perhaps be significant that the endocrine gland that regulates basal metabolism (the thyroid) is derived from the part of the feeding system that in the earliest chordates was responsible for providing the raw materials of metabolism. Experiments with radioactive iodine show that this element is concentrated in certain cells of the larval endostyle. Moreover, after addition of the anti-thyroid substance thiourea to the water there is hyper secretion by the endostyle. Thyroxine has been extracted from the gland and it probably has endocrine function as well as secreting mucus, though no one has ever produced any changes in larval lampreys by adminstering thyroid hormones. Iodinated secretion can be detected by autoradiography in the intestine and digested. Iodine is thus bound and synthesized into thyroid hormones by a part of the gut in the larva, showing a stage between digestion and endocrine secretion, which is achieved in the adult. It is doubtful whether the pituitary produces a thyroid-stimulation hormone at either stage. Lampreys thus show, as larvae, a stage in which the accumulation of iodoproteins, previously widespared, becomes concentrated in the pharynx perhaps at this site there were already cells specialized for halide transport (the ionocytes of teleosts, used for osmoregulation). In adult lampreys and all higher chordates the iodoprotein is secreted into the blood under the control of blood-borne signals. The change may well be related to developments in the regulation of metabolism which, in the animals with a fully endocrine thyroid becomes more nearly independent of variations in the external supply of iodine.

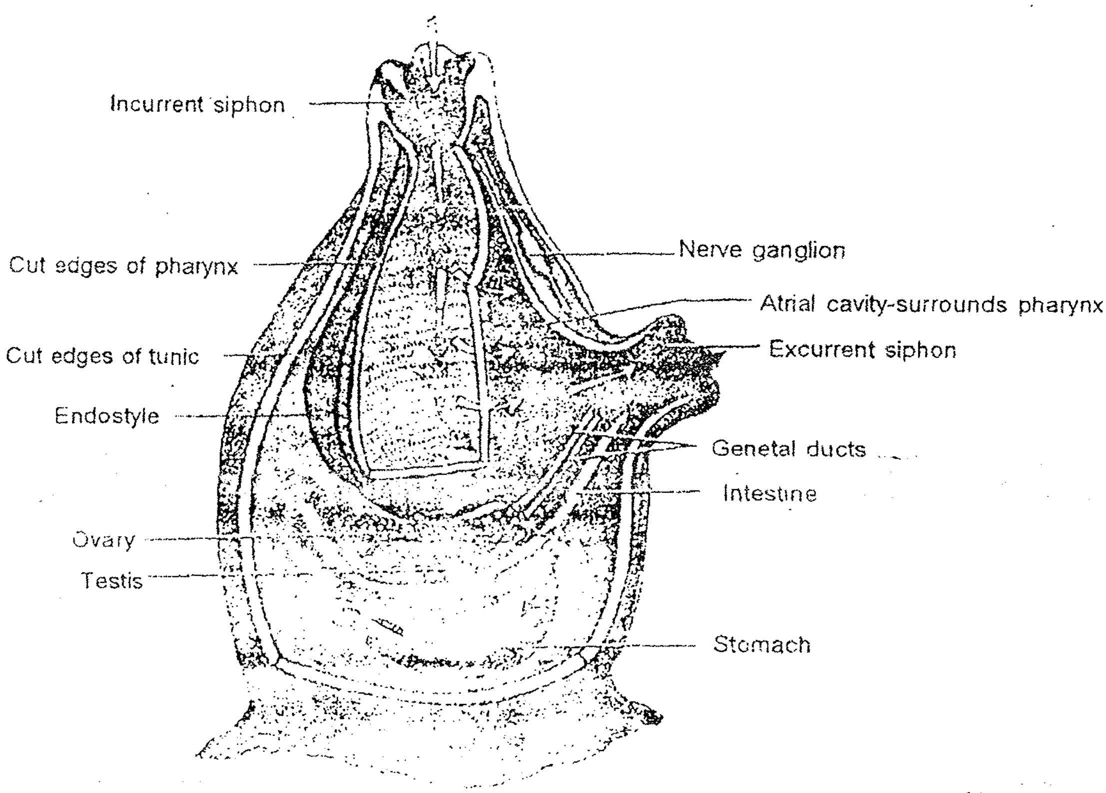


Fig. - Location of endostyle in Urochordata

The great change in the endostyle is only part of the complete metamorphosis by which the ammocoete larvae changes into an adult lamprey. It is not known what triggers the change. The mough becomes rounded and its teeth, tongue, and complex musculature develop. The paired eyes (previously buried) appear, the olfactory organ becomes internally folded, and the olfactory nerve and tracts much enlarged. The nasohypophysial sac grows backwards to the gills. In the pharynx the gills develop into sacs opening to the barnchial chamber, changes also take place in the intestine. The yellow brown colour of the larva gives place to the back with silver iunderside of the adult. The animal more and more frequently leaves the mud and finally migrates to the sea to begin its parasitic life.

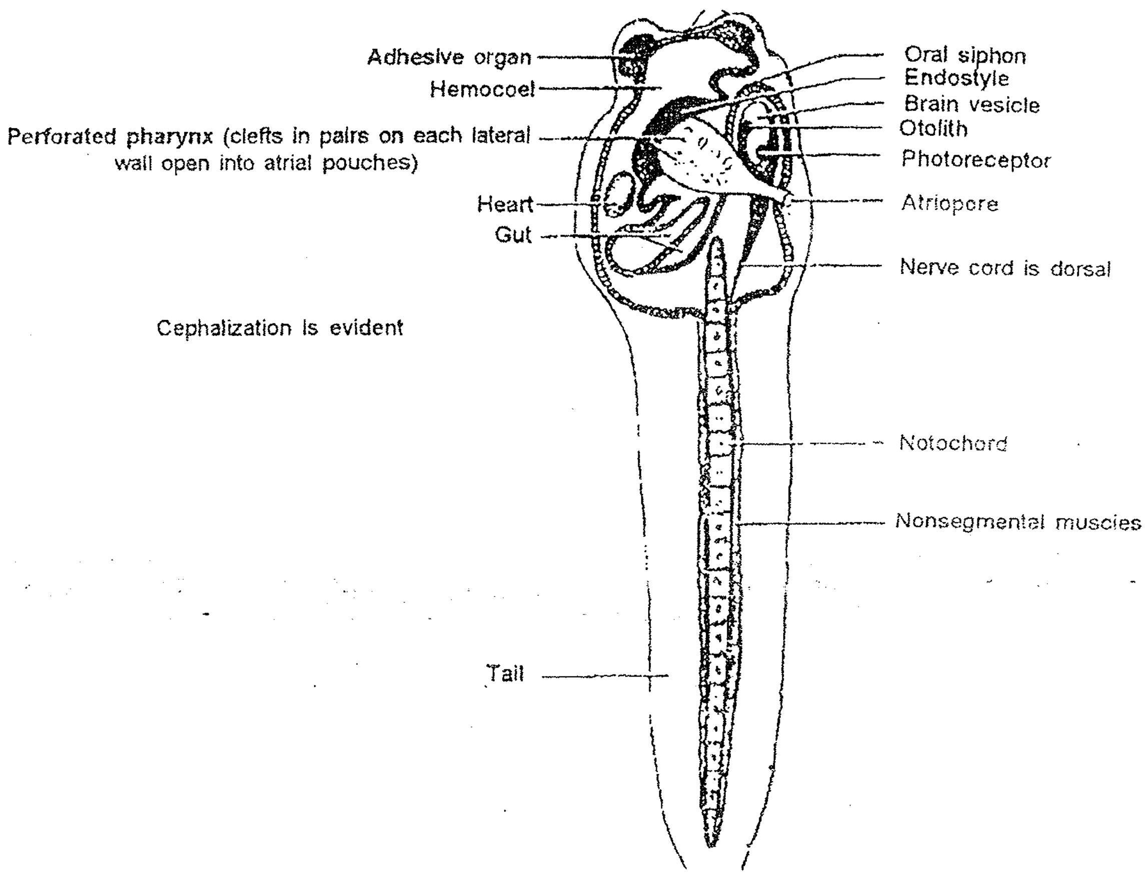


Fig. - Location of endostyle in a Urochordate Larva.

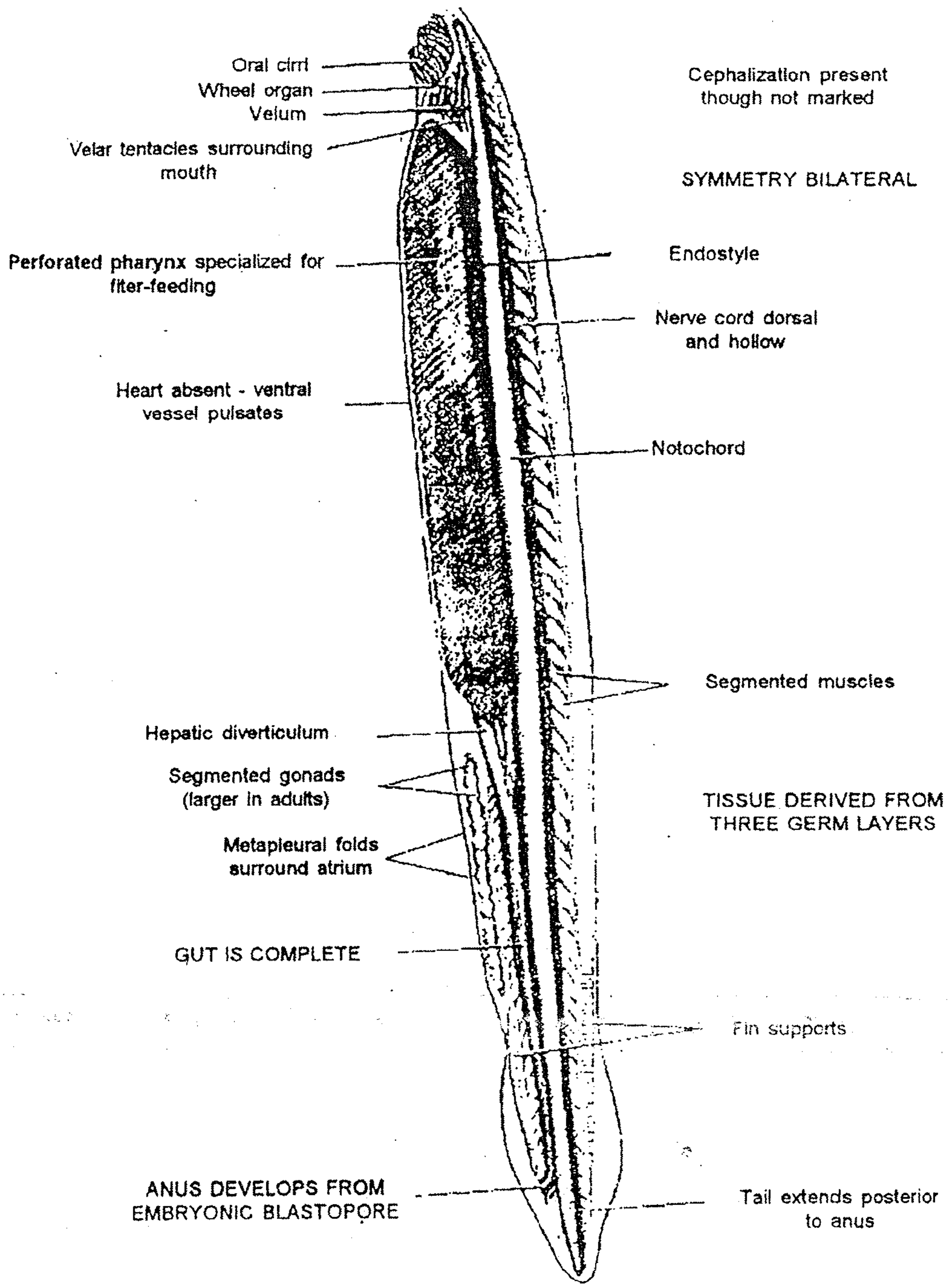
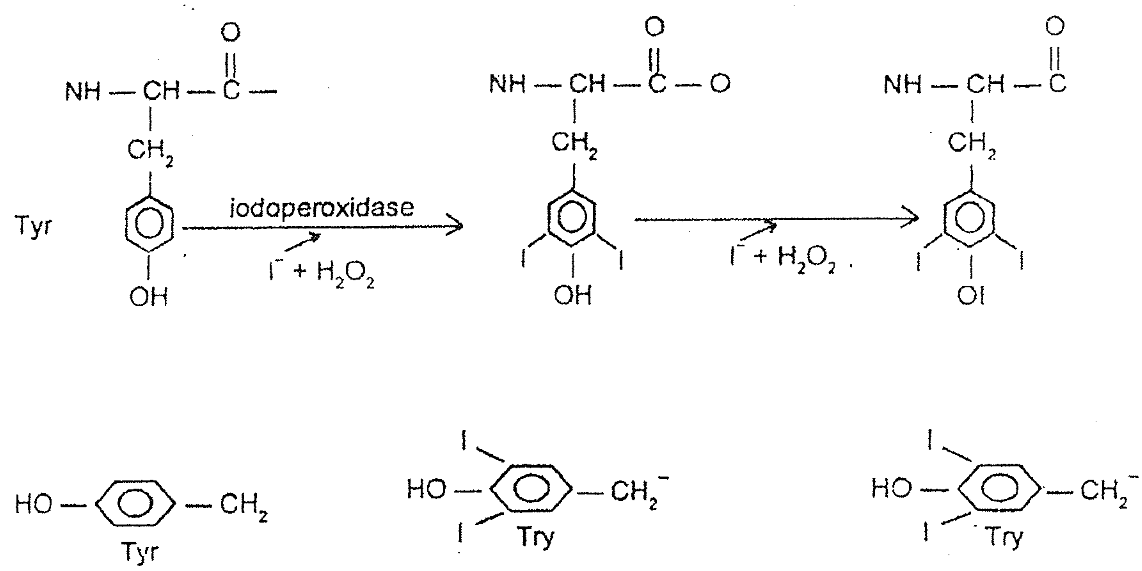
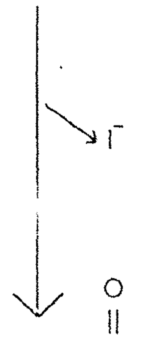


Fig. - Location of endostyle in Cephalochordata

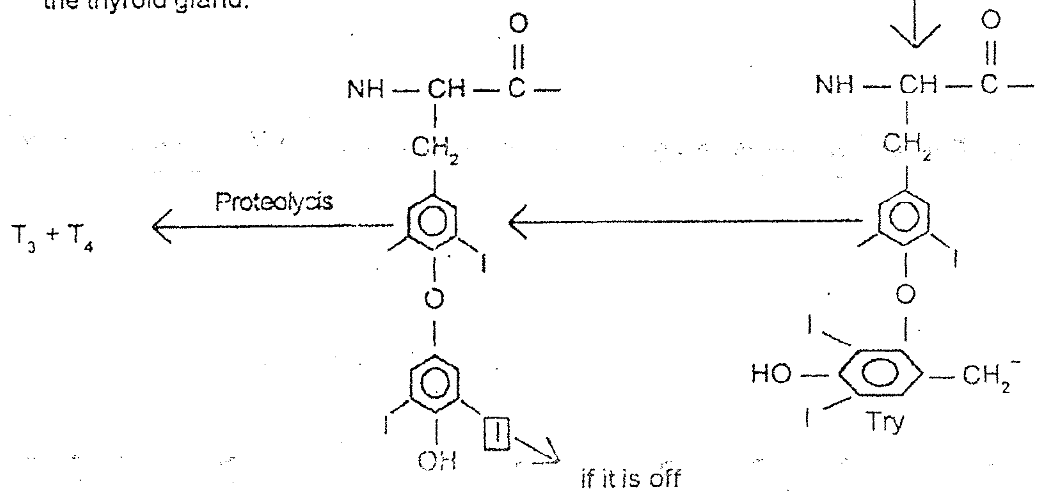
Iodine binding





Biosynthesis of T_3 and T_4 in the thyroid gland through the iodination. Rearrengement and hydrolysis of thyroglobin. Tyr residue.

The relatively scaree I^- is actively sequentrated by the thyroid gland.



if it is off
then it is T_3 (Tri iodothyroxine)

T_4 (Thyroxine)

I. Chemistry :

Thyroid hormones, thyroxine (T_4) & tri-iodothyronine (T_3) are stored within the thyroid follicle as monoiodo-tyrosine (MIT) and di-iodotyrosine (DIT), these are then bind with a highly specialised storage protein called thyroglobulin. Thyroglobulin is an iodinated glycoprotein of about 680,000 MW. MIT & DIT are biologically inactive. Thyroxine is 3, 5, 3', 5'-tetraiodothyronine where as tri-iodothyronine is 3, 5, 3'-tri-iodothyronine. Secretory process of thyroid hormones consist of several complecated steps, such as –

i) Synthesis of large molcular protein – thyroglobulin.

ii) Yodonation of tyrosine molecules of the thyroglobulin.

iii) Kelease of thyroglobulin into the follicular lumen.

iv) Keabsorption of thyroglobulin from the follicular lumen into the follicle epithelial cell.

v) Hydrolysis of thyroglobulin to release thyroxine and tri-iodothyronine.

vi) Release of thyroxine and tri-iodothyronine in the blood capillaries.

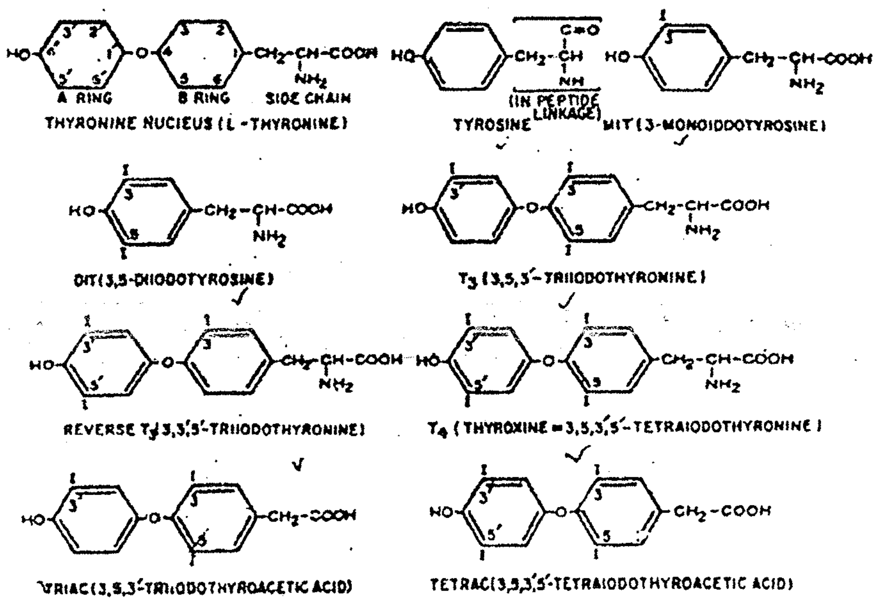


Fig. : Structural formulas of tyrosine, MIT, DIT, T_3, T_4 and some analogues of thyroxine having varying hormonal action

II. Synthesis :

Synthesis of thyroid hormones involves through several complecated process, which are as follows:-

a) Synthesis of Thyroglobulin :

i) It is an iodinated glycopeptide of molecular weight about 680,000. The polypeptide part of this glycoprotein is synthesized by the rough endoplasmic reticulum of the thyroid cell. The carbohydrate part is added possibly mainly in the Golgi apparatus.

ii) The protein is then iodinated. Then the thyroid cells pass iodine rapidly through itself into the colloid. In normal circumstances iodination mainly takes place in the colloid at the edge of the endostylar follicle.

b) Trapping of Iodide :

i) Trapping of iodide from circulation is an important phenomenon in the synthes of thyroid hormones. The cells of the thyroid follicles or endostylar follicles have the unique abilities to trap iodide from the circulating blood.

ii) The thyroid gland or endostyle concentrates the iodide by actively transporting it from blood. This transpert, mechanism is often called 'iodide-trapping mechanism'.

iii) The resting membrane potential of the acinar cell is – 50 mV with respect to interstial fluid and colloid. As a result iodide pump into the cell against the negetive potential and then diffuses down at the eletrochemal gradient into the follicular lumen.

iv) The ratio of thyroid iodide to plasma iodide is about 20: 1 to 100:1. This iodide pump is also dependent upon ATP-ase system.

c) Iodination & Condensation of Iodotyrosine molecules :

i) Within the thyroid or endostyle, the iodide is quickly oxidised to an active form of iodine by a catalytic reaction.

Oxidation of iodine to nascent form of iodine :

$2I^- \rightleftarrows I_2 or\ I^0 + 2e$

Peroxidase system :

$$H_2O_2 + 2I + 2H^+ \xrightarrow[peroxidase]{yodide} 2'oxidised\,I' + 2H_2O$$

ii) Two di-iodotyrozine molecules undergo oxidative condensation with the liberation of alanine residue and the formation of thyroxin (T_4) is in peptide linkage to thyroglobulin. It is stated that T_3 is formed by condensation of monoiodotyrosine with di-iodotyrosine. This process of codensation is known as coupling.

iii) The receptors of the activated iodine are the tyrosine residues of the thyroglobulin. The iodination of tyrosine in thyroglobulin takes place first at 3 position and the 5 position of aromatic nucleus, forming respectively the monoiodotyrosine and di-iodotyrosine.

iv) Simply, the addition of one atom of iodine per tyrosine residue results in the formation of MIT and the addition of a further atom of iodine per tyrosine residue results in the formation of DIT.

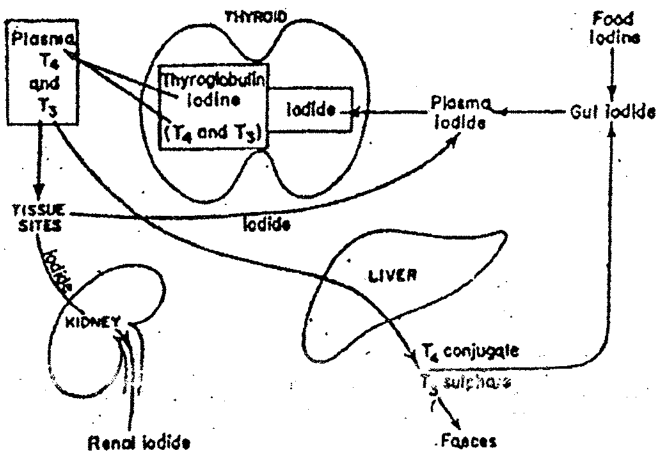


Fig. : Schematic representation of the iodine cycle.

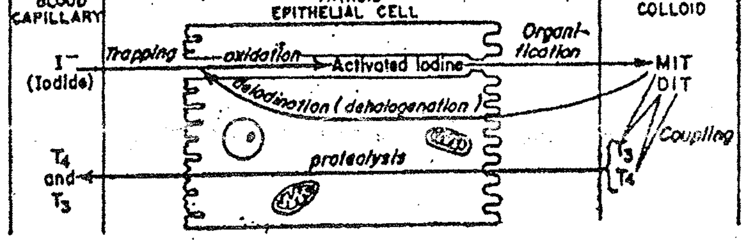


Fig. Simplified diagram of the synthesis and degradation of the thyroid hormone.

In the skulls of the Primates are arranged according to their taxonomic position, beginning with the prosimians and ending with modern man, a number of changes are seen in the forms and relative positions of the neurocranium and the spanchhocranium. The former, which is the braincase develops forwards, backwards and upwards with the evolution of the brain. The changes in the facial skeleton, e.g. shifting of the position of the eyes and orbits from a somewhat lateral to frontal position and the reduction of the olfactory organ are among the factors which bring about the change.

The facial skeleton serves not only for the housing of the above head organs but also for the insertion of the teeth. The alveolar processes of the maxilla and the premaxilla are directly concerned, alongwith the mandible. The size of the teeth, the dimensions of the body and the ramii of the lower jaw, constitute together with forms of the crowns oft he teetch, an effective masticatory organ served by more or less powerful masticatory muscles which needs space for their lodgment on the surface of the skull. If these muscles are too large and for strong, the upper surface of the of the skull. If these muscles are too large and for strong, the upper surface of the skull develops sagittal and nuchal crests. This is dependent upon the size of the animal's body. If it is relatively small, with reference to the volume of the brain, the development of the head organs bring about a reduction fo the heavy snout. The orbits may be enlarged and frontally directed, and the nasal cavity reduced while the mixllae still remains primitive. The foramen magnum moves from its backward position to the base of the skull. Thus, different groups shows different developmental trends. Throughout the entire range of primates, however one finds (i) tendency of the brain case to develop vaults, more and more spacious, ahead of the sella turcia and posterior to it and upwards above the external audiotary meatus, and (ii) another tendency for the facial skeleton to bound on the basal axis of the neurocranium. Such changes in the angulation of the component elements of the cranial base are characteristic of the order Primate as a whole.

The plane of the dental arch moves away, from the more or less continuously horizontal position, relative to the external audiotory meatus, found in primitive mammals in a downwards direction until, together with the orbits becomes subcerebral.

The shifting of the plane of the dental arch, away from the eye-ear plane, is associated with the nutcracker type of the lower jaw which developed with the decrease in the basicranial angle (which is already much more in Megaladapis than in the modern lemurs). In Primates, such as Papio and the Pingids, it is much in evidence. In Primates, with recession facial skeletons, for instance, in Saimiri, its function is less under request.

There recession of the facial skeleton, in different degree, appears to have taken place not in a continuous line in order Primative while the brain would seem to have developed in a more steady way. The divergence in growth tendencies appears very distinctly in comparison to MAN and Pongids. In the young of the anthropomorphs the frontal lobe overlies the roof of the orbits as in the human infants. But with the increasing age, the growth of the brain lags behind in the anthropomorphs, the roof of the orbit shifted forwards and the anterior pole of the frontal lobe remains considerably behind it. This is much more the case in the Gorilla than in the Orangutons. The skull of the organs in infants is very much similar to the humans, except for the extremely narrow nasalia and the ovoid shape of the orbits with advancing years, the facial skeleton grows downwards and forwards and the orbits decrease in size. In the human child, the skull growth leads to an enlargement of the skull resulting in a remarkable development of the cranial vault. The face also develops, though relatively less, but downwards in a sub-cerebral manner. A detailed study of the primate skulls brings out important changes that are taking place in the respective segments. One of these is the inner or the medial wall of the orbital cavity which is formed by a fusion of several bones. In the Poilocercus, this is formed by the orbital plate of the forntal bone uniting with the orbit process of the palatine bone. In front of them is the lacrymal bone extending beyond the orbital margin and the lacrymal formen opening in the front of it. Orbitosphenoidal bone and the alisphenoid appear posteriorly to these. On the orbitosphenoid is the optic formamen, for the optic nerve, and between the two bones i.e., the opthalmic and maxillary, comes out though the sphenoidal fissure. Foramen rotundum in the higher primates serves the maxillary nerve. At the posterior margin of the alisphenoid is the foramen ovate for the mandibular nerve.

The situation is however, different in the insectivores there in, the orbital surface of the maxilla unites with the frontal and with the lacrymal in front and alisphenoid, orbitosphenoid and the palatine posteriorly.

In large eyed animals with their Orbits rotated more or less frontally, f.i. in the carnivores and primates, the maxilla does notunite with the frontal bone. It is thrust back to the orbital floor. In Lemuriformes, including the subfamily Tupaiinae, the palatine reaches out to the lacrymal forming the inner wall of the orbit by uniting with the frontal bone. In Lorisiformes and the higher primates, it is not the palatine which unites with the lacrymal and the frontal bones in the medial wall of the orbit but in the ethmoidal bone, the ethmoid keeps away the maxilla from the frontal. The orbitosphenoid and the ethmoid keep back the palatine from the frontal bone.

The other characteristic is the bony tympanic ring on which spreads the tympanic membrane attached to the wall of the bulls by the annnular membrane. The bull a develops from the ectotympanic, an independent center of ossification which is an extension of the petrous bone. In the Tupaiinae, the brain case is more expanded due to the greater development of the ecrebral hemispheres. The orbital apertures are directed more laterally.

The lemurs are the most ancient of living primates and as such have departed least from the ordinary quadruped. They are however, exclusively arboreal, mostly nocturnal, and of comparatively low organization, which is manifest not only in their body but also in the brain, for the fore brain is relatively small and smooth and does not completely cover the hind brain as in the higher primates. The second digit of the foot bears a claw, the rest terminate in nails.

The present home of the lemurs is above all, Madagascar, of which they are so highly typical that they constitute perhaps one half of the total mammalian fanuna. Lemurs are also distributed through the tropical forests of Africa and the Oriental realm. They are found fossil in the Eocene rocks of North America and of Europe. Two interesting relic animals belonging to this group still survive chiromys, the aye aye, now living in Madagascar but having near allies among the long departed fossil forms of North America, and Tarsius, the tarsier; now confined to Sumatra, Borneo; Celebes, Java, and the Philippines but which also had relatives in the American Eocene.

The Anthropoids are the most highly organized of Primates, with 32 to 36 teeth, a completely closed orbit, two pectoral mammae, feet usually prehensile and generally the hands also; pollex sometimes vestigial; and cerebral hemispheres richly convoluted, covering the cerebellum. This suborder includes all Primates other than the lemur and this of course means man as well as the monkeys and apes. It is divided into two sharply marked series; the old and new world primates; and those, so far as our evidence goes, represent parallel evolutions which because of the long period of South American isolation, must have diverged from a common ancestry in early Eocene time.

The Platyrrhine may be distinguished by the broad nasal septum, the thumb is not opposable, and sometimes reduced the fail may be prehensile; there are no cheek-pouches nor ischial callosities. The family Hapaliae, the marmosets or squirrel-monkeys are small monkeys with a long; hairy nonprehensile tail. The pollex is elongated, but the hallux very small. The latter bears a flat nail; while all of the other digits are no larger than squirrels and are active forms living among the trees in small groups. This food consists of fruit, to which eggs and insects are added, a very common dietary. The cebidx, the common South American monkeys, differ from the marmosets in the possession of an additional molar tooth in each jaw; making thirtysix teeth all total, in having flat nails instead of claws and frequently a prehensile tail. These forms, none of which is as large as the larger Old World monkeys, are exclusively to the tropical forests, notably those of Brazil. Among the more remarkable are the slender spider-monkeys whose prehensile tail is an organ of the greatest use, the howler monkeys; whose prodigious voice arises from and especially modified vocal apparatus; and the capuchins (cebus), whose pathetic figures, garbed with human habiliments, are so ofern seen with itinerant musicians.

The group Catarrhini includes all of the Old World apes and man, excluding of course the lemurs. They are characterized by the possession of a narrow nasal septum with the approximated nostrils directed downward; thirty two teeth as in man; and a nonprehensile tail, which may, however, be vestigial or entirely absent. The hallux; except in man, is fully opposable and the pollex as well; although often less developed.

The Cercopithecdae are the monkeys and baboons; exclusive of the man-like apes, from which they differ in the fore-and-after elongation of the molar teeth, the presence of ischial callosities on the rump, occasional cheek-pouches; a narrow breast-bone; and in the absence of the vermiform appendix. The baboons are almost the only primates with the exception of man which have forsaken the arboreal for a terrestrial mode of life; but unlike man this has not resulted in an erect posture but a typically quadrupedal one. Their head is more dog-than apelike, hence the generic name, with powerful jaws bearing immense canine teeth which, added to the equally powerful hands, enable competition with terrestrial creatures to be readily met. The old male mandrills are remarkable for their ferocity. These creatures are colored most gorgeously on the cheeks and ischial callosities, but colours which in themselves are beautiful blue, scarlet, lilac — are in combinations which seem grievously misplaced. Thus while the fur is often beautiful and the colours lovely; the general effect is such that, as Cuvier says, "It serait difficile de se figure unetre plus hideux quele mandrice". The mandrills; which are typical baboons, like the rest of their race, appear to be somewhat indiscriminate eaters; feeding upon fruits, roots; reptiles, insects, secorpions etc. and inhabit open rocky ground rather than forests. Their present range includes Africa and Arabia. Ditmar says — "It is fortunate for general animal life than their tendency to develop size and massive frame stopped where it did. If they had reached the rire of the omthropoid apes; they would be among the most frightful creatures the each has ever know".

The macaques are rather stoutly built monkeys, the tail being variously developed. They are both arboreal and terrestrial in habit but their principal interest lies in the fact that, whereas almost all are Asiatic, extending as far as Japan, one species, the so called Barbary ape is North African and is the only living primate other than man which is found within the confines of Europe, as it has spread from northern Africa to Gibralatar.

Semnopithecas is another characteristic genus, containing very and typical of a subfamily, the semnopithecinae. This group is both African and Oriental in its distribution. The man like or anthropoid apes; family simiidx; lay greatest claim to our interest; since they of all creatures come nearest to mankind not only in similarity of structure; but in actual relationship for they are our next of kin in that they and humanity spring without question from the same bough of the free of life; and though the relationship is very remote according to human standards of consanguinity; from the evolutionary point of view it is very colse. This does not mean that man arose from any known ape, or that any ape could ever in the course of evolution give rise to a man, but that man and the ape had at some not very remote time, geologically spreaking; a common ancestor. It is, however, highly probable that were we to see this common progenitor on the flesh *we* would be at a loss for a descriptive term to apply to it if we excluded the word ape. The primates which we have discussed play a subordinate part, in that they serve to link man with the lower animals; the simiidae, on the other hand are all-important; for only by an understanding of them and their habits can we come to a true appreciation of our immediate prehuman progenitors.

The simiidae are thus diagnosed; Man-like apes, tailless; no cheek-pouches or ischial callosities; except in the gibbon; arms much longer than the legs, an opposable polex, a broad sternum & a vermiform appendix. Several extinct genera of simiidae are known while among the living there are four; Hylobates; the gibbon, simia, the Orang; "Anthropopithecus" or Pan, the Chimpanzee, and Grills, the Gorilla of these the first two are Oriental, the last two African in their present distribution; although all are apparently Asiatic in origin.

The gibbons are the smallest of the man-like apes, rarely exceeding 3 feet in height, but have relatively the longest arms, for the hands reach the ground when the creature stands erect. Ischia) callosities are present — true of none of their allies — and they are variously coloured. The jaws and dentition as in all Simiidae are adapted to a frugivorous diet, but the molar teeth are more primitive than in their relatives, although the upper canines are enlarged and saber-like, either for defense or more probably; as a dietary adaptation. The skull is rounded; lacking the high sagital crest for muscle attachment seen in the adult males of the other genera, and the head is posed upon the vertebral column more like that of a man, doubtless a response to the erect posture which the ape assumes both at rest and in motion. This upright pose may have originated in connection with a change in the mode of locomotion. The primitive lemurs ran and jumped on the upper side of the branches, and hence were quadrapedal, whereas the gibbons swing beneath the branches, the arms being held above the head. "This acrobatic mode of locomotions which has been appropriately called 'brachiation' by professor Keith; very probably look rise in the earliest anthropoids and has been carried to an extreme specialization in the excessively long-armed gibbon. Thus the habit of sitting upright which first set free the hands for prehensile purposes .... very probably preceded the habit of brachiation and the loss of the tail; as it has also in the genus *Indris* among the lermurs".

Huxley's description of the gibbons contains the following :

They "are true mountaineers; loving the slopes and edge of the hills; though they rarely ascend beyond the limit of the fig-trees. All day long they haunt the tops of the tall trees; and though toward evening they descend in small troops to the open ground, no sooner do they spy a man than they dart up the hill sides; and disappear in the darker valleys". The voice is prodigious; much more powerful than that of any singer; and yet the animal has hardly half the height of a man and far less proportionate bulk. They walk erect with the arms either down, touching the knuck less to the ground, or above the head. The gait is quick; waddling with no elasticity of step; and they are soon run down.

In the trees; however, their locomotive powers are quite another matter; as their method of progression is by brachiation, the hands and arms being the sole organs of locomotion; clearing spaces of 12 to 18 feet with the greatest case and uninterruptedly; for hours togather. According to Duvaucel, they can clear 40 feet which may be readily believed. They start and stop instantly with no appreciable showing down or acceleration of speed. Moreover, their leaps not only require great strength; but the nicest precision. The significance of this mode of progression cannot be ignored; because of its educative value to the creature concerned; for every time such a hand leap is undertaken it requires the instantaneous solution of a mathematical problem; since an accurate estimate of distance; trajectory, direction; and the ability of the objective branch or branches to bear the impact of the creature's weight must all be estimated; and upon the correct solution of this problem depends the amount of muscular force to be used in order that the creature may neither under nor over shoot the mark, and the penalty placed upon the incorrect solution of the problem and its practical application may be death. Nature has abundant opportunity; therefore; for the weeding out of the unfit and she places a high premium upon mental preparedness; more perhaps in the gibbon and other branchiating primates than in any other group of animals, and this undoubtedly was also true of the arboreal ancestors of man.

Osborn thus summarizes : "The gibbon is the most primitives of living apes in its skull and dentition; but the most specialised in the length of its arms and its other extreme adaptations to arboreal life. As in the other Anthropoids; the face is abbreviated, the narial region is narrow; if catarrhine, and the brain-case is widened; but the top of the skull is smooth, and the forehead lacks the prominent ridges above the orbits; thus the profile of the skull of the gibbon is more human than of the other anthropoid apes, when on the ground the gibbon walks erect and is thus afforded the free use of its arms and independent movements of its fingers. In the brain there is a striking development of the centers of sight; touch, and hearing. It is these characteristics of the modern gibbon which preserve with relatively slight changes the types of the original ancestor of man".

The orang, *Simia* satyrus; the second of the Oriental apes, is confined to the swampy; coastal. forests of Sumatra and Borneo. It is reddist in color and rarely exceeds four feet in height, but, unlike the gibbon; it is very bulky; measuring two thirds of its height in circumference. The arms are immensely long the creature spreading from 7 feet 2 inches to 7 feet 6 inches. The head is short, round, and of great vertical diameter, with very closely approximated orbits. The skulls of the old males show a sagittal crest and the face is surrounded with a remarkable glaring rim of flesh which gives it a very ferocious aspect. The jaw is deep and massive, and the canines are very efficient either for the opening of fruits or for fighting. The principal weapons, however; when used against other animals are the hands.

The great size of this ape renders it less agile than the gibbon and while highly intelligent it is sluggish in disposition; reposing with the back curved and head bowed until hunger stimulates it to activity. By day the orang climb from one tree top to another and they descend to the ground only at night. They climb slowly and they are carefully, more like a man than an ape; and are nest-building of in that they break off branches and lay then in a convenient crotch of a tree, thus forming a sort of platform whereon they repose utilizing one nest until the food in the immediate vicinity is exhausted; when they move on and build another. These nests are 10 to 25 feet above ground. On the ground the orang runs laboriously and shakily on all fours and is soon overtaken by man. It never stands erect. "Dyaks tell of old orangs which have lost their teeth, but which find it so difficult to climb that they maintain themselves on windfalls and juicy herbage". Normally the food consists of figs; blossoms, and young leaves, never living animals. The intelligence is very great, the hearing acute; but the vision less so.

The Chimpenzee; Pan Pygmaeus or *Anthropopithecus troglodytes, is* the first of the African apes and may readily be distinguished from the orang by its black hair; although the skin of the face and ears is apt to be light in color. In size they never exceed 5 feet but are not so bulky relatively as the orang and as a consequence are much more expert as climbers, swiping from tree to tree with great agility as do the gibbons. They rest in the sitting posture and sometimes stand or walk on the hind limbs, but run on all fours. The head of the Chimpanzee is larger than that of the orang and the brow-ridges above and outside of the orbits are especially prominent. There is a sagittal crest for muscular attachment in the males. The brow-ridges and the prognathous or forward sloping teeth and receding chin strongly resemble those of the more ancient species of prehistoric man. In their nest-building the chimpanzee resemble the orangs; in their activity and biting propensities, the gibbons. There may also be more than one species as with the latter. They are confined today to West and Central Equatorial Africa, from Sierra Leone to the Congo, Chimpanzees are abundant.

Gorilla gorilla, by far the most formidable of the man-like apes is also restricted to tropical Africa, extending from the Cameroon in the West across the Congo basin to Uganda and Tanganyika. There are apparently two species. A specimen killed in the Cameroon and now mounted in the museum of the Academy of Natural Sciences in Philadelphia stands; 5 feet $1^1/_2$ inches in height, and weighed in the flesh 418 pounds; while the Karisimbi male, shot by Akeley; measured 5 feet $1^1/_2$ inches in height and weighted 360 pounds; the arm spread being 97 inches. The torso and upper limbs are immense;

but the legs are short compared with those of man. If the latter were of human proportions the height would probably exceed 7 feet and the weight would approach 500 pounds. Even as it is one cannot but view this creature in terms of humanity; hence he becomes to the imagination one of the most terrible creatures upon earh for more impressive than a much larger quadruped would be.

In describing the skull Gregory says :- "The Gorilla carries to the logical extreme the frugivorous and fighting specializations which are foreshadowed in the Chimpanzee. The head is lengthened by the forward growth of the muzzle and by the extreme backward growth of the skull-top. Thus the gorilla skull to a certain extent; parallels that of the Baboons. The supra-orbital protrusion is now extreme. The ...... sagittal crest and widely flaring occipital crests attain an excessive development in old males; and are conditioned by the massive size of the muscles of the jaws and neck. The canines from real tasks and hence the muzzle and lower jaw are very wide in front ...... Thus the fundamental resemblances to the human skull are largely disguised in the male gorilla, which is distinguished by the great tusks and massive cheek teeth, the divergent tooth rows; the Baboon-like muzzle and protruding orbits; in contrast with the opposite specializations in man. The young female Gorilla; on the other hand, except in the dentition; more distinctly approaches the human type than any other anthropoid."

The Gorilla is the negro of the anthropoids, with the skin a dark brown; approaching black, and coarse black hair which becomes gray with age. The limbs and body are markedly adapted to its gigantic and clumsy stature. It has departed from the primitive slender-limbed and arboreal type and exhibits a more or less transitional stage leading to ground dwelling habits. As in the ground sloths; the long arms; short legs; and widely expanded pelvis are adapted for the support of the enormous thorax and abdomen. The hands of the gorilla are more human than those of any other anthropoid; without the thumb is relatively smaller than in man and has not acquired the power of opposing itself to the other digits. So also the foot of the Gorilla distinctly approaches the human type in several ways.

Carl Akeley, who collected material for the Gorilla group in the American Museum of Natural History, gives us a picture of those huge apes which is in marked contrast with the popular conception based upon travellers' tales of their aggressive ferocity. He says :- "I saw no indication that the Gorilla is in the least aggressive or that he would fight even on just provocation ...... The first Gorilla I even saw alive was a lone old male, who might be expected to show some war-like spirit, if that had been a characteristic of his tribe. I saw his face — ugly and wrinkled; but mild and gentle — across the valley and caught a glimpse of his gray back as he went over a log and up the slope through dense vegetation ...... While I am certain that normally a gorilla is a perfectly aninable; good natural creature who would not look for trouble, yet I am willing to concede that, in regions where he is more or less in competition with the natives and where he is constantly harassed in his efforts to might be called a "bad gorilla".

The Gorilla is not a tree dwelling animal. Only they were seen off the ground and these not more than ten feet up — no higher than a civilized boy would climb — and there was no indication that any of the other trees had been climbed. They never sleep in the trees but make their nests on the ground. They are not partial to fruits or nuts; preferring to feed on grass, herbage; and bamboo leaves. If they climb for food or at the approach of danger; they must come down the trunk they ascend; as they cannot swing from one tree to another. They always progression all fours, as they are too bulky to walk on their relatively weak hind legs, and if they ever do so it must be with no more case orgrace than a heavily built trained dog would exhibit in making a similar attempt. When they rise and beat their chest, it is not a challenges but an indication of curiosity.

The family to which man belonges, the Hominidae; bears the stamp of close relationship with the simiidae, the differences being mainly the direct out come of terrestrial life; the assumption of the erect posture and the development of the brain. The erect posture has coordinated with it the alternation in the curvatures of the spine; the more complete adaption of the hind limbs to bear the weight of the body; the loss of the power of opposition of the great toe and its more complete development in the thumb; and the greater length of the hind as compared with the fore limbs.

"The omthropoids are chiefly frugivorcus and typically arboreal when upon the ground they ran poorly and use the fore limbs in progressing. Thus they are confined to forested regions. Man, on the other hand, is omnivorous; entirely terrestial; erect, bipedal and cursorial; an inhabitant primarily of open country. The anthropoids use their powerful canine tusks and more or less procumbent incisors for tearing open the tough rinds of large fruits and for fighting. Primitive man on the contrary uses his small canines and more erect incisors partly for tearing off the flesh of animals, which he has killed in the chase with weapons made and thrown or wielded by human necessary, for man to use his teeth in fighting and functionally they compensate for the reduced and more or less defective development of his dentition".

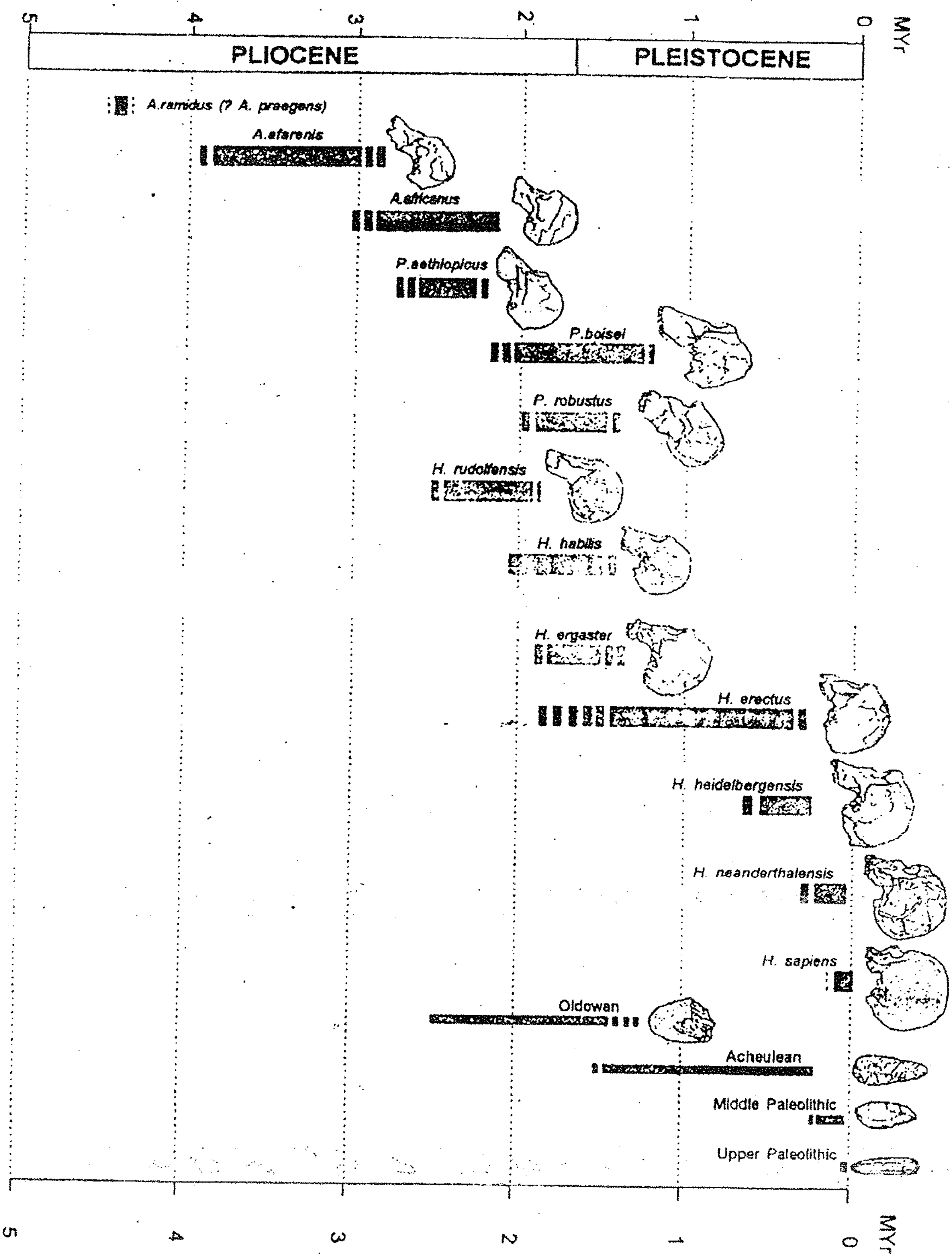
There is but one living genus; Homo; included within the family Hominidae, and all existing men of whatever race or colour are given but a single specific name, sapiens. The divisions of this species into its various races of which not fewer than 26 subspecies are recognized by Gregory; are, perhaps, unnecessary to our purpose, other than to enumerate the following :-

Australian race :- Skull long; extremely prominent eyebrows; large teeth, especially the canines; tall limbed; skin chocolate-brown; hair black; long and woolly. Habitat; Australia, Dekkan Hindustan.

Negroid race :- Dilichocephalic; forehead round and childish nasal bones flattened; teeth sloping; skin and eyes brown or black; hair the same color; short; woolly; not abundant. Habitat :- Madagascar and Africa from the Sahara to the cape of Good Hope.

Monogolian race:- Brachycephalic; flat nose, small and obique eyes; short and thick-set; golden-brown skin; sleek, coarse black hair; scanty beard; Dwell east of line drawn from lapland to Siam; Chinese, Tartars; Japanese, Malays, Eskimos, North and South Americans.

Caucasian race:- [A] Mediterranean; short, slender; long-headed, hair and eyes dark brown to black; [B] Alipine, of medium height; stocky, round-headed; hair and eyes dark brown to black, eyes often hazel or grey in western Europe; [C] Nordie, tall, long headed; hair flaxen; red; light brown to chestnut; eyes blue; gray or green. Habitat; Mainly Europe and North America; includes also Moors; Berbers; Egyptians; Kurds; Persians, Afghans, Hindus, Turks Armenians; Africanders; and Australlians.


MYr
PLIOCENE
PLEISTOCENE
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P. robustus
H. rudolfensis
H. habilis
H. ergaster
H. erectus
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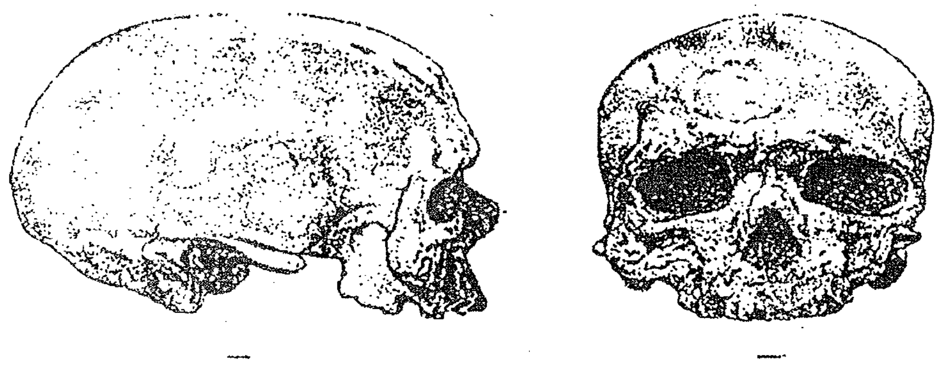
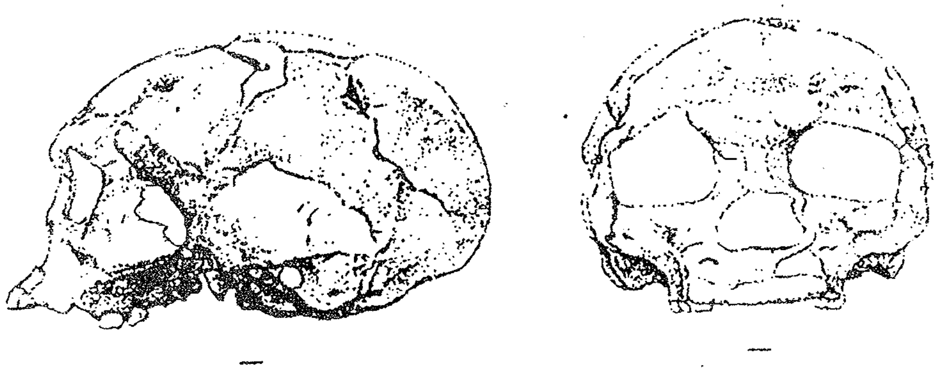


Side and front views of the "Old Man" cranium found in 1868 in the rockshelter of Cro - Magnon, southwestern France, Scales are 1 cm. DM.

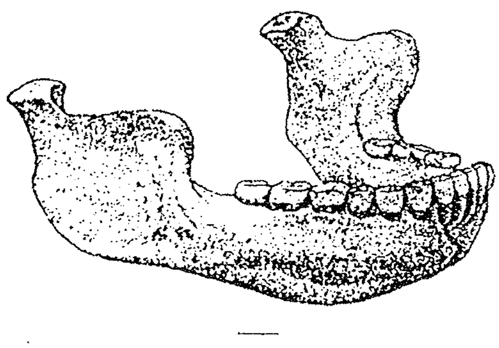


Side and front views of the fossil modern human skull found at Wadjak, Java, Scales are 1 cm DM.

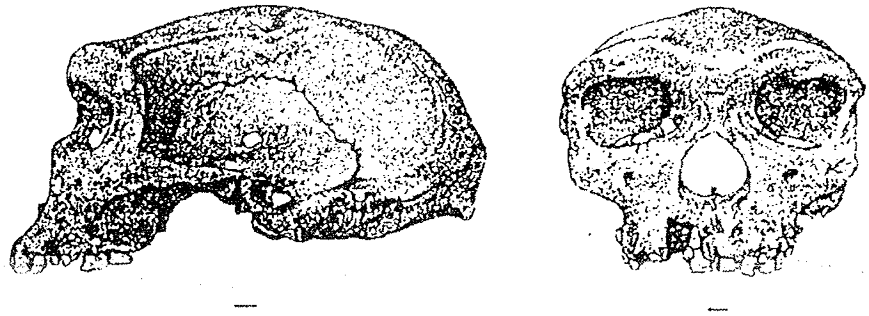
Side and front views of the origianl Trinil Pithecanthropus *skullcap discovered by Eugene Dubois in 1891. Type specimen of* Homo erectus. Scales are 1 cm.

DM.

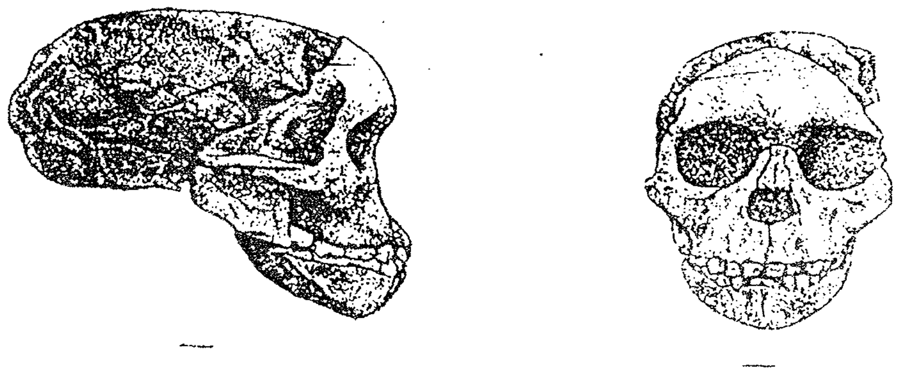
Front and side view of the cranium of the "Old Man" of La Chapelle-aux-Saints, Correze, France. Scales are 1 cm DM.



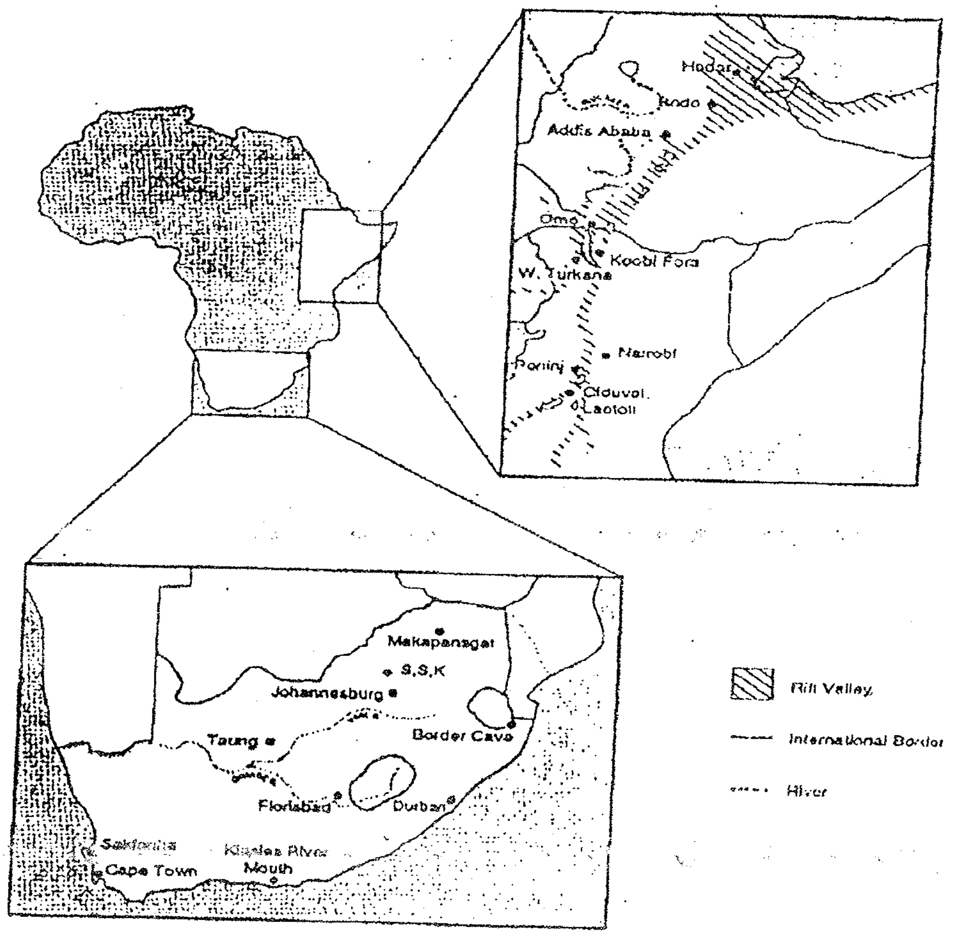
View of the mandible found at Mauer, Germany, in 1908. Type specimen of Homo heidelbergensis. Scale is *1 cm.* DM.



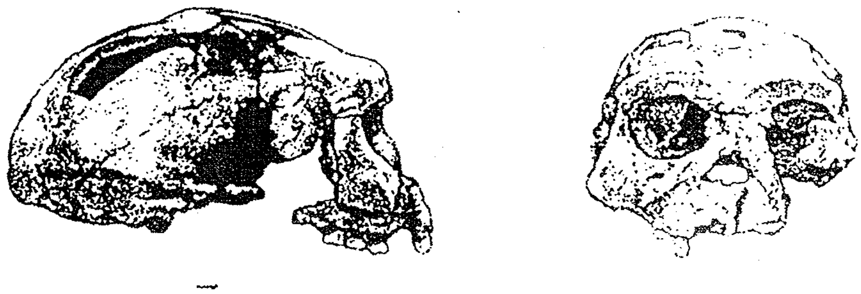
Front and side views of the "Rihodesian Man" cranium discovered in 1921 at Broken Hill (now Kabwe), Zambia. Scales are 1 cm. DM.



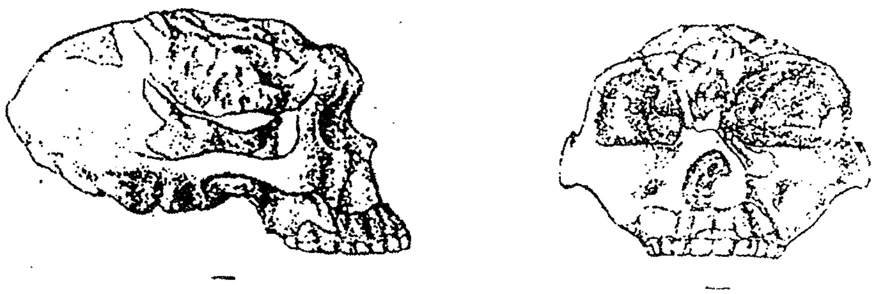
Front and side views of the face and brain cast of the "Taung Child," found at South Afica's Buston limeworks in 1924.Scales are 1 cm. DM.



Map showing the locations of hominid-bearing sites in southern and eastern Africa, S.S.K. indicates the location of Sterkfontein, Swartkrans, and Kromdraai. DS.



Side and front views of the Sangiran 17 skull from the Kabuh Beds, Sangiran, Java. Scales are 1 cm
DM.



Side and front views of the reconstructed cranium from Lantian, China. Scales are 1 cm.
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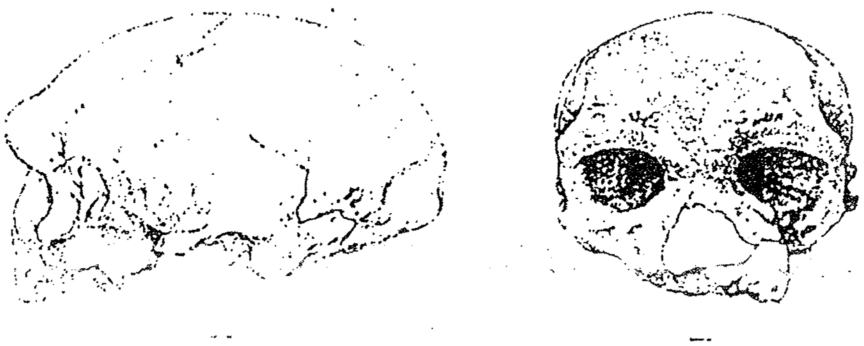

Side and front views of the damaged and distorted cranium from Dali, China. Scales are 1 cm
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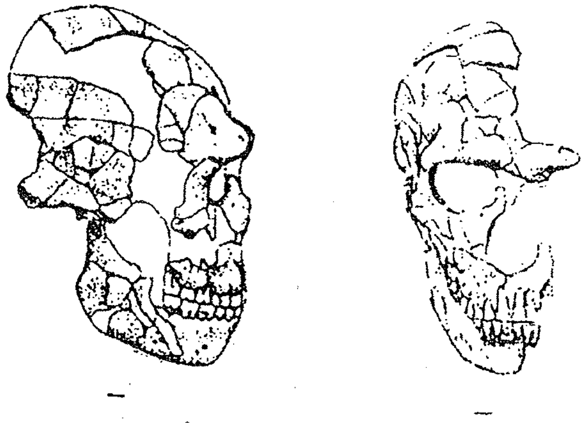

Side and front views of the partial Neanderthal skull from St.Cesaire, western France. Scales are 1 cm
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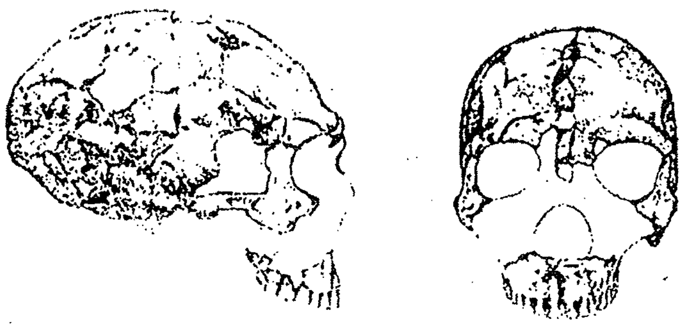

Side and front views of the cranium from the cave of Amud, Israel. Scales are 1 cm
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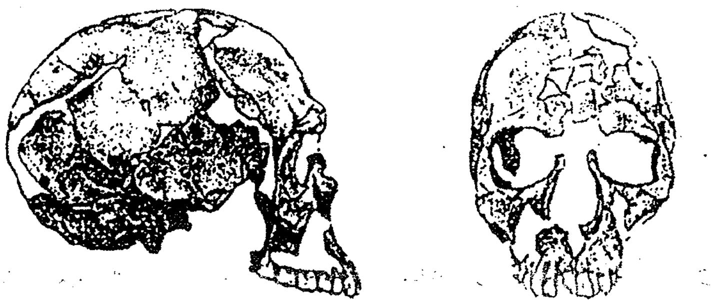

Side and front views of the anciant modern human cranium Qafzeh 9. from Jebel Qafzch, Isreal. Scales are 1 cm
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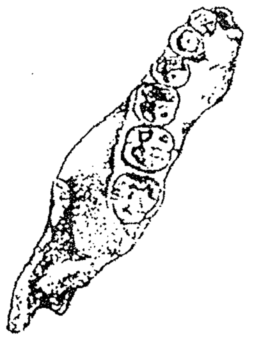

The MLD 40 half-mandible from Makapansgat Member 3, South Africa. Scale is 1 cm.
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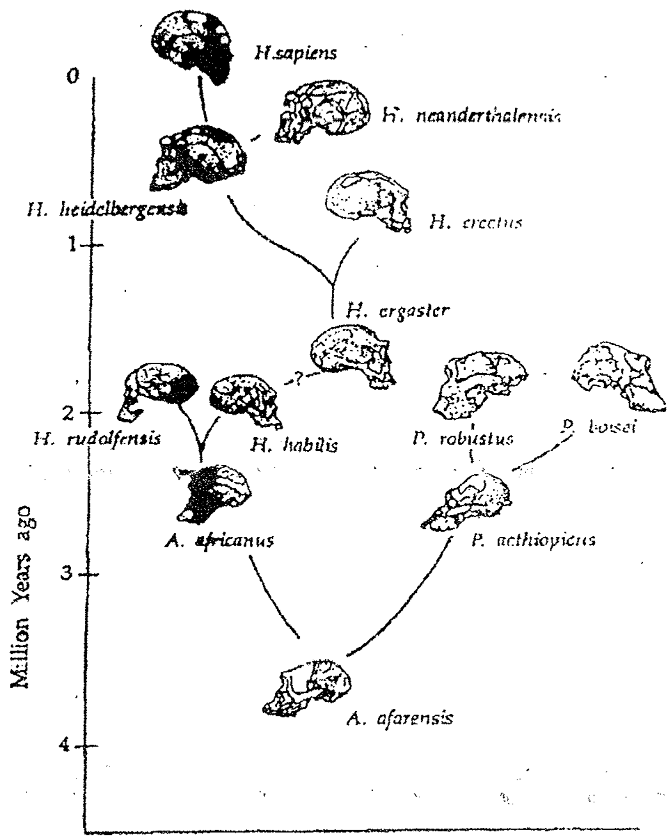

Evolution tree showing possible lines of ancestry and descent among the species belonging to the human family. From I. Tattersall, the Human Odyssey, Prentice HAll, 1993. DS.

Annexure of Module No. – 4

Syllabus :

Topic : 3

Migration of fish & bird

Migratory behaviour of Birds :

What is Migration?

In a borad sense, "migration" as defined by Cahn, "is a periodic passing of animals from one place to another, (L; migrate, to travel)". It may be applied to other animals also, which means their dispersal or immigration, implying no backward journey. On the other hand bird migration is the to and for movement of a population of some birds between their summer and winter homes, or from a breeding and nesting plae to a feeding and resting place.

Majority of birds have the quality of migration and are called migratory birds. But there are also some birds like Bob white & ruffled sand grouse, which do not migrate at all, these are called as resident birds or non-migratory birds.

Kinds of Avian migration :

1. **Latitudinal migration :**

The latitudinal migration usually means the movement from north to south & vice sersa. Most birds of the northern template and subarctic zones migrate to the south during winter. This migration ranges from few kilometers to few thousands kilometers. An opposite but lesser movement also occur in the southern hemisphere when seasons are changed.

Longitudinal migration : This type of migration includes migration in East-West direction & vice versa. The birds migrate in this manner from a breeding area in East Europe or Asia to the Atlantic coat to avoid the continental winter e.g. sea-birds.

Attitudinal Migration : Migration from high mountains in the summer to low valleys in the winter. This type occur in many Indian and foreign mountaineer birds. Altitudinal or vertical migration occurs in the grebes and coots of Andes in Argentina, violet green swallow of great Britain, and the willow ptart migan of Siberia.

Partial Migration – Many species of temperate regions are performing only partial migrations. An addition is made in constant residents which do not migrate at all, by an influx of new individuals of the same species for a short period Songthrush, redbreast, titmouse, finch etc. although are seen throughout the year, actually repreent partial migrants, as birds seen in winter are not the same as seen in summer.

Irregular or vagrant migration ; In some birds such as hereons after breeding, the adults and the young may start from their home to disperse in all directions over many or a few hundred miles in search of food & safety from enemies. In an unnatural situations sea birds are exhausted or died as they are taken by hurricans to as far as 2000 miles away from home seas.

Seasonal migration : Field observers in temperate countries have grouped migrating birds according to seasons. As, in Britain, swifts, swallows, nightangles &cuckoos are summer visitors, for they are arriving in spring from the south, seems to be breed and leave for the south in autumn.

Erratic migration : When the migration does not follow the different laws of migration and thereby migration occurs in a haphazard manner, it is known as Erratic migration, as found in case of Muke susan, Plover, etc.

Special types of migration :

Besides these following type, some special types of migration are also found.

(i) Flemental migration : Migration occurs due to scarcity of food materials found in inseetivorus birds.

(ii) Climatic migration : Occur as a result of daily or seasonal changes in the climate of the environment as found in case of summer visitors of Britain like swallows, cuckoos.

(iii) Gametic migration : It results from a need to occupy some special region or environment for some part of the reproductive processs.

Times of Migration :

According to the time of migration the migratory birds are of two types –

1. **Diurnal migrants** : Most of the large birds fly mainly by day, such as the crows, swallows, robins, blackbirds, hawks, bluebirds, Jays, cranes, loons, pelicans, geese and other shore birds. These diurnal migrants have a greater tendency to travel in flocks, which may be well orgaized (ducks, geese & swans) or loose (swallows).

2. **Nocturnal migrants** : These birds prefer to fly at night time under the protective cover of darkness, to escape their enemies. These include mostly small passerine birds such as warblers, thrushes, sparrows etc.

Ranges of migration :

The ranges of migration commonly varies from one or two miles to thousands of miles in different groups of migratory birds but it is almost constant for a particular group. As the Himalayan snow partridges cover a distance of about one or two miles.

Altitude of flight : Some birds fly quite close to the earth, while most routine migration occurs within 3000 ft. of the earth.

Velocity during migration : The speed or velocity of flight varies from individual to individual, velocity depends on the size of birds & is affected by the speed of air and its direction. During migration thus Cranes, carrians & finches flight with the speed of 30 miles/hour. The maximum speed is about 110 miles/hr by Indian swifts.

Routes of migration :

The migratory birds usually follow definite routs of flight. The route followed by them nay be the same while going a coming back or may be differnet.

Different migratory birds may follow the following routes during their migration :

(a) **Sea routes :** Most of the marine birds follow sea –routes.

(b) **Coast routes** : The coast routes afford migration highways for a large number of migrants.

(c) **River valley routes :** While migrating from planes to hills and from hills to planes the migratory birds cross rivers & river valleys falling in the way.

(d) **Mountain ranges :** Very rarely the birds cross mountain ranges.

The river velleys, mountain ranges & coastal routes, provide good landmarks for the migrating birds, which enable the birds to recognize & remember the routes.

Segregation during migration : Certain birds such as king fishers, swifts and night hawks travel in separate companies but swallows, turkeys etc. travel in mixed companies of several species, due to similarity in their size & method of search of food.

Order of migration :

During migration the birds follow a definite order & this order is strictly followed.

Normally the adult migrates first & they are followed by youngs. I has actually been found that mainly migration occurs due to the maturity of gonads which insist them to migrate towards their breeding grounds. Hence the adult with mature gonads start for migration. Among them the adult male take leading part, adult female are the next in order, then the young birds, which are immediately followed by injured birds & lastly the old birds. During the backward journey the young birds take the lead & follow the same path.

Regularity of Migration :

Several species of migratory birds show a striking regularity, year after year, in their timings of arrival & departure.

Navigation :

It is still unknown that what guides the young ones of a migratory bird to migrate and follow the same course of their parents. Various explanations have been given for determining the direction & course of migration.

(i) The migratory birds utilize various natural structures or such as great river, river valleys, coastal lines, mountain ranges as the land mark during flight.

(ii) Some naturalists have suggested that the bird learn by experience. The older member become leaders guide the youngs during migration. But there are do not like to fly in flocks.

(iii) Some ornihogists suggest that birds navigate through responses to the earth magnetic field & their inner ear rea is : effected force produced by the rotation of earth ((

(A) old → inj → old ♀ old ♂ → (B)

(A) ← F ← F ← Inj ← old (B)

(iv) The east west & north south gradients of gravity & the magnetic intensity are supposed to have some function in avian migration.

(v) Matthews 91955) & Sauer (1957) have emphasized the position of the sun (during the time) or starts (during night) helps the bird to navigate along definite routes.

(vi) Homing instict & telluric currents enable the migrate birds to.

(vii) Stars as guiding agent in nocturnal migrants - e.g. Warblers.

Cause of migration :

There are many causes of bird migration varying in relative importance with different species.

(1) Aquatic species must leave northern area before their food supply is cut off by the freezing of lakes, ponds & rivers etc.

(2) Inscetivores birds must migrate before the insects go into hibernations to avoid cold.

(3) Sudden or abrupt changes in the weather condition compell the bird to migrate.

(4) Sometimes due to the early maturation of gonads birds migrate to the breeding area to complete their breeding cycle.

Stimulus of migration :

In migratory birds there must be some proximate factors which act on each individual to induce it to migrate.

(i) **Gonodal stimuli :** In a general way migration is a part of the sexual birds begin to migrate as their gonads begin to ripen which leads to an impulse of migration.

According to Rowan (1922), the migration is stimulafed by the gonodal hormones. Spring migration is stimulated by hormones secreted by developing gonads & autumn migration caused by gonad regression.

(ii) **Photoperiodism :** Photopriodism or day length induces pre migratory restlessness. Light stimulated the pituitary and this in turn stimulates the gonads which then affect the nervous system bringing about the urgen to migrate.

(iii) **Thyroid hypothesis :** Thyroid hormones also produce certain necessary changes in the fat metabolism of the migrants birds. But in what extent the hormone is involved remains undecided.

(iv) **Deposition of fat :** Fat deposition leads to high temperature of the body, which is primary requirement of migration.

(v) **Hypothalamus, pituitary and pineal gland :**

It was often suggested that pituitary gland play a key role to stimulate the bird migration Gonadotropin is synergistic with prolactin in promoting an increase in lipid reserves & cortisterone in the development.

Problems of Migratory Birds :

The following factors create great problems to the migratory birds - stroms & hurricanes, strong current of wind, fog; manmade towers & lgiht houses.

Conclusion : Migration is expensive in terms of food & energy requirements. Moreover every year so many birds never reach to their destination due to adverse weather, predators, food, forage etc. But still such behavious would never been established through ovulation, if it not had a strong survival value. Advantage to be expected from a change of living range, include beter climate, plenty of food supply, longer day light, breeding plce. It has recently been observed that migration is a habit & it has to be aquired. It is an interaction of intelligence associated with some sort of social behaviour. The habit of migration is possibly due to their special sensitivity to geomagnetism (Dr. Moore-1977).

Migration of Fish :

Usually fishes live in a constant habitat and restore their movement within a restrict zone. However many types of fishes migrate on a regular basis, on time scales ranging from daily to annual and over distances ranging from a few meters to thousands of kilometers. Fish usually migrate became of reproductive needs although in some cases the reason for migration remains unknown.

On the basis of needs fish migration may be classified as follow:

(1) Alimental migration - For the need of adquate food.

(2) Spawning or gametic migration - For the reproduction & development.

(3) Climatic migration - For sustaining a suitable climatic condition.

(4) Osmoregulatory migration - For inhabiting a better aquatic condition for aquiaring a better osmoregulation.

Fish migration can be categorized as follow. It has become cutomary to classify fishes according to their capacity to cope during stages of their life with waters of differing salinities (Mc. Dowall 1988).

(1) Diadromous - (Gr. Dix. between)

These are real migratory fishes - The life cycle of this species takes place partly in marine waters, with distance to several thousand of kilometers between reproduction zones & the feeding zones.

(2) Potamodromous : (Gr. Potamos. river dromes, a running)

Fish migrate within fresh water only. Reproduction & feeding zones may be separated by distance may vary from a few metors to hundreds of kilometers.

(3) Oceanodromous (Gr. 'Oceanos', Ocean)

Herrings and Mackerels are the common ones which are catagoriesed to this group. Fish migrate within salt water only. They travel long distances in the sea and after laying their eggs at suitable places return to their feeding ground.

(4) Anadromous (Gr. Ana, up.)

Fish live in the ocean mostly & breed in fresh water (e.g.-salmon). After egg laying they return to their feeding places in the sea.

(5) Catadromous (Gr. Cata, down)

Fish live in fresh water & breed in the ocean. Catadromy is much less common than anadromy (e.g. eel). The fresh water eel Anguilla travels several thousand miles in reaching the sea, starting from the river. They lay their eggs in the sea. The young ones come back towards fresh water.

(6) Amphidromous (Gr. Amphi, both)

Fish move between fresh & marine water during their life cycle. The migration is not for the purpose of breeding but is typically associated with the search for food & or refuge. The migration of some gobies fall into this category as reproted by Myers.

Migratory movements :

Meek (1915) introduced two terms. Denatant (Swimming with the water current) and Contranatant (Swimming againsts water current) to describe the movements of fish in relation to the water current.

1. **Drifting :** When overall water current is at one direction, 'directional movement' ocurs. By the method drifting fishes are carried indirectly along with the water current.

2. **Swimming :** The fishes swim in a specifict direction either towards or away from the source of stimulation or at some angle to an imaginary line between them & point of stimulation. Migration by swimming occurs along the direction of water current or against the current of water as already mentioned.

Some factors to regulate fish migration :

These following factors are influencing fish migration.

1. **Physical factors :** These include water temperature, photoperiod, water current etc. During hot summer when water temperature rises in fresh water rivers, triggers a stimulus for upstream movement of fishes for spawning.

2. **Chemical factors :** Chemical factors like salinity, p^H etc. affecting fish migration. Most of the fresh water fishes are stemohaline (can tolerate a very short range of salinity). Although some of the species are euryhaline (to larent to drastic salinity changes) and used to travel long distance from

ocean to freshwater river & vice versa.

3. **Biological factors :** In addition to chemical factors there are some biological factors to stmulate fish migration which include food memory, sexual maturity, physiological clock & the endocrine glands. Obviously presence or absence of predators and competitors may also be considered as biological factors. Baggerman (1962) has stated that gonadal hormones influence mignation of anadromous fishes. In addition to the above mentioned factors change of salinity and intensity of light also play key role in the migration of fish.

Migration and Homing : The periodic and directed travel mainly for feeding, breeding and overcoming the adverse climatic situations has been defined migration. Modern biologists have explained the phenomenon of migration in terms of evolution through natural selection.

Homing may be defined as "The return to a place formerly occupied by the migrants instead of going to another equally probable places". There are various instances of homing and migration by salmon, herring, cod, hilsa & some other fishes.

Several workers believe in the Olfactory Hypothesis as sensory basis for homing in Salmonids. Specific substances possibly pheromones which from odour, trail & guide the mature Salmon back to the native river, although the pheromones are not considered as the sole olfactory guide. Non-phermone attractants play the key-role in the return of migration of salmon from the sea.

Again, according to Groundwater Seepage Hypothesis (Harden Jones, 1980) the spawning area and spawing grounds of marine fishes which spawn in coastal waters could be identified with reference to certain chemicals which enter the sea by ground water seepage. This idea may be linked the anadromous species of some orders.

Effect of dams on fish communities :

The building of a dam generally has a major impact on fish populations, migration & other fish movements stopped or delayed, the quality & accessibility of their habitat, which play an impartant role in sustainability, can be altered. Increase upstream & downstream predation on migratory fish is also linked to dams, fish being delayed & concentrated to the presence of the dam & the habital becoming move favourable to certain predatory species.

Upstream migration

One of the major effects of the construction of a dam on fish populations is the decline of anadromous species. The concept of obstruction to migration is often associated with the height of the dam. Certain catadromousn species have a special ability to clear obstacles during upstream migration.

Down stream migration :

Downstream migration can be major factors affecting diadrimous fish stocks. Down stream migration particularly diadromous species & Jureniles of anadromous species, adults of catadromous 7 certain anadromous species. Certain potamodronous species can migrate over very long distances, so the need for migration to provide passage to potamodromous fish must be considred species & site specific.

Summary :

Fish populations are highly dependent upon the characteristics of their aquatic habitat which supports all the biological functions. Migratory fish require different environemnts for the main phases of their life cycle in reproduction, production of Juveniles, growth & sexual maturation. The life cycle of diadromous species take partly n fresh water & partly in sea water; the reproduction of anadromous species take place in freshwater whereas catadromous species migrate to the sea for breeding purposes & back to fresh water for trophic purpose.

The construction of a dam on a river can block or delay unpstream fish migration & thus contribute to & even the extinction of species that depend on lingitudinal movements along the stream. Although the problems associated with downstream migration can also be a major factor affecting anadromous or catadromous fish stocks.

The downstream migration problems have not been as well studied or fully ocnsidered as those associated upstream migration. The accepted downstream passage technologies to exclude fish from turbines are physical screens angled bar racks & louvers associated with surface bypass.

The fact that almost nothing is known about migrating species, particularly in developing countries.

Thee is an urgent need for better biological information (e.g. migration period, swimming capacity, migratory behaviour) & to do fish passage research (upstream & downstream) for other native species.

Suggestion for further reading :

The Birds	:	R.L. Kotpal.
Fish Migration & Fish By pass	:	Mathias Jungwirth, Schmutz, Steven weiss.
Return to River	:	Richard N. William.
Applied Fisher Science	:	S.M. Shati.
Fish Migration	:	Brian A. McKeown.
The Migration & Conservation of Salum	:	Forst Roy Moulton.
Fish & Fisheries	:	B.N. Yadav.

Self Assessment Questions :

1. How many type of avian migration generally found in course of time?
2. Explain different factors to stimulate migration of bird.
3. What is fish migration? How they are classified on the basis of different migratory activiteis.

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VIDYASAGAR UNIVERSITY

DIRECTORATE OF DISTANCE EDUCATION
MIDNAPORE - 721 102

M.Sc. in ZOOLOGY

Part – I : Paper - I : Group – A : Unit – I

Module – 5

Syllabus :

Functional anatomy of organ of Excretion and osmoregulation.
Evolution of Urinogenital System with special reference to the & Separation of the two system.

INTRODUCTION :

In vertebrates the excretory and reproductive organs are morphologically interrelated because certain excretory ducts are used for the discharging of gomets also. So it has been convenient to treat them together as Urinogenital system. In fishes, the association is restricted to the pseudocopulatory papilla through which both the excretory and generative products leave by a common vent. The association is more important in male than in female.

Although the function of kidneys is different from that of gonads, the Urinary and genetal systems of gnathostomes are so intimately related, both developmentally and structurally that neither can be discussed without referrence to the other. For this reason, Urinary and genetal organs are discuss in a single chapter. Vetebrates eleminated some metabolic waste through the gut and the skin, but most are eleminated through special excretory organs, the kidneys. Vetebrates life began in water, and the early stages of the evalution of kidneys took place in that medium.

Their function was osmoregulatory. They maintained their appropriate osmotic concentration of the blood by eleminating excess water, if any by preventing the escape of water when necessary, and by regulating the excreation of certain salts. In the later role they had the assistance of the gills. These same role are performed by the kidneys of fishes todays & additional roles including excretion of nitrogenous wastes, have been acquired by terrestrial vertebrates. Vertebrates eleminate some metabolic wastes through the gut and the skin, but mostare eleminated through special excretory organs, the kidneys. Aquatic animals have a particular problem is that their gills and oral membranes are permeable blood to water and salts in the ocean the salinity of the water is more concentrate than that of the body fluids of the fish, and water is drawn out, but salt tend to diffuse inward; hence marine fishes drink sea water.

In contrast the fresh water, fishes lose salts and take up water through the gills because their internal salts concentration is greater than that of their surroundings. Many nitrogenous wastes a fishes pass through the kidneys that also assists in water-salt balance (homeostasis) by the excreation or retention of certain minerals. The gills also take a prominent part in waste excretion, eleminating mainly ammonia.

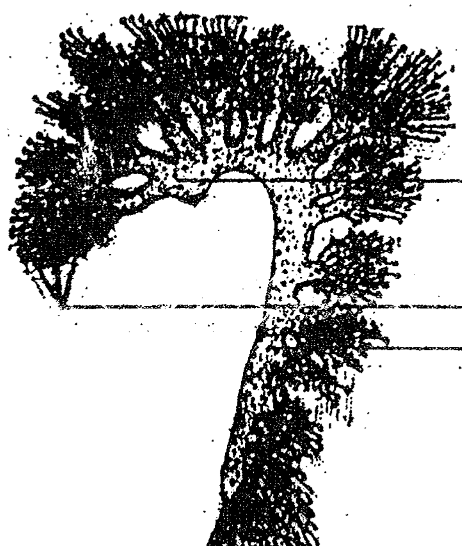
Osmoregulation in teleost fishes, whether they live in fresh water or sea water, its physiological activity is very closely related to their survival, yet inspite of the importance of osmoregulation surprisingly little is known about how fish deals with physiological problems inherent in living in hypoosmotic and hyperosmotic environments. The ability of some fishes (e.g. salmon) to regulate in both environments during migration is of great interest. The classical review of osmoregulation in aquatic animals has been done by Krogh (1939), Pyefinch (1955). In fishes the kidney play an important role in osmoregulation, but major portion of the osmoregulatory functions are carried out by other organs, such as the gills, the integuments and even the intestine.

Osmoregulation may be defined as "the ability to maintain a suitable internal environment in the face of osmotic stress". As a consequence there is always differents between the optimal intra-cellular and extra-cellular concentration of ions. In the fish body, number of mechanisms takes place to solve osmotic problems and regulate the different. Of which most common are :-

I. Between intrecellular and extracellular compartment.

II. Between extracellular compartment and the internal environment.

Types of Kidney :



One of the numerous excretory tubules of amphioxus (After Goodrich)

The excretory subules of amphioxous are of an entirely different types from those of vertebrates. A series of such tubules open into the atrium, or peribranchial space. Each lies on the outer dorsal side of a secondary gill bar. They are apparently ectodermal origin, have no connection with the coelom and are composed of numerous flame cells calles 'solenocytes' which collects westes.

It has been difficult to work out homologies among the various types if excretory organs found in vertebrates. Variations that are encountered are correlated with problems with which vertebrate have to cope in the pasts in adapting themselves to the many different environmental conditions. Whether animals remained acquatic or becomc terrestrial posed important problems in connection with excretion whether aquatic forms leaved in fresh water or salt water made a great difference in how they adapted themselves to changes in osmotic pressure, variation in salt concentrations, and the like. Comparative anatomists have long speculated concerning the evolution of the various types of vertebrates kidneys. Gradually a fairly logical sequence of events has been postulated. There has been, and still is much confusion in this field, particularly in regard to terminology. Investigators who studied kidney development in embryos of birds and mammals in the past have attempted to homologize these structures with excretory organs of lower forms. It now appears that certain of these speculations were erroneous. The student should be wary in accepting certain interpretations of homologies that appear in the older literature on the subject. Often ideas advanced were correct, but the terminology employed has confused the issues.

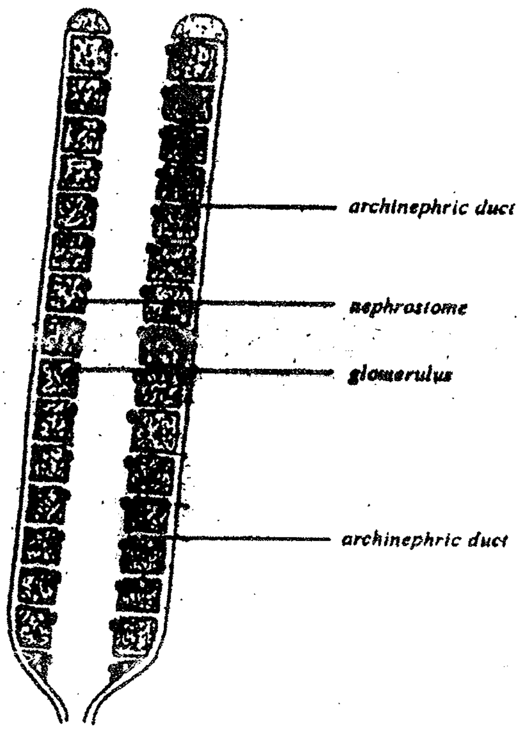


Diagram showing hypothetical structure of archinephros

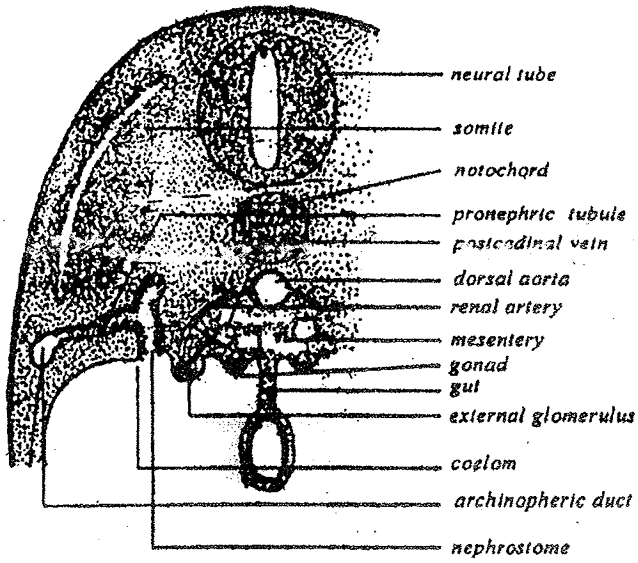
Archinephros :

It is now generally held that the primitive vertebrate ancestors possessed on excretory organ referred to as an 'Archinephros' or 'holonephros'. This was composed of a pair of archinephric ducts located on the dorsal side of the body cavity and extending the length of the coelom. Each ducts has joined by a series of segmentally arranged tubules, one tubules to each segment. At its other end the tubule opened into the coelom through a ciliated, funnel shaped aperture called the 'hephrostome'. Closely associated with each tubules was a small knot of capillories interposed within the pores of an arteriole. A thin layer of peritoneum was reflected over its surface. Tissue fluid exuded at these glomeruli passed in to the coelom and thence through nephrostomes in to the archinephric tubules and finally through the arcinephric ducts to the outside.

From this type of kidney the varius kidneys of present day forms may originally have been derived. Even today the larval forms of the hag-fish and the larvae of some caecilians possess kidney resembling this archinephric arrangement.

The Amniotic Kidney :

The anterior portion of the archinephric kidney has persisted in only a few vertebrates, and even in the adult hag-fish it is modified. It appears in the embryo of most vertebrates as a transitory structure, usually referred to as the pronephros.



Diagrammatic section through part of a vertebrate embryo, showing relation of external glomerulus to pronephric tubule and nephrostome

In the few anamniotic vertebrates in which it persists in the adult stages it is called the 'head kidney'. The remainder of the kidney posterior to the pro-nephric region is known as the opisthonephros.

There has been confusion over the correct term to be applied to the kidney duct. Both the archinephric duct and the pro-nephric duct have been used. We shall use the term archinephric duct here in referring to this primitive kidney duct as it appears in cyclostomes, fishes and amphibians.

PRONEPHROS :

The pronephors in an amniotes consists of several anteriorly located pro-hephric tubule together with a pair of archinephric ducts. The tubules and duct lie in the dorsal mesoderm that supports the gut. The duct extened posteriorly, usually opening in to the cloca. One end of each of the segmentally arranged tubules connect with the archinephric duct near its anterior end; infact, the duct is actually formed by successive tubules bending posteriorly and fusing with adjacent tubules. The other end of the tubules opens in to the coelom by means of a ciliated nephrostome. In a few forms an external glomerulous comming from segmented branches of the dorsal aorta, projects in to the coelom near the nephrostomes. A thin layer of peritoneal epithelium is reflected over the projecting subject of each external glomerulus.

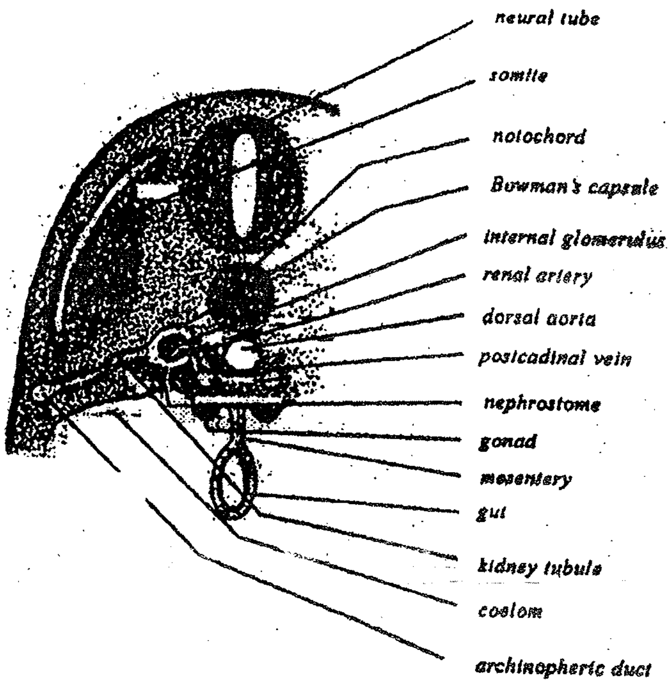
Most forms however possess in terminal glomeruli. These are small knots interarterial capillaries each surrounded by a double walled structure, called Bowmans capsule, the two together being known as a renal or Malpighian Corpuscle. Blood is brought to the glomerulous by an afferent arteriole. The later may break up in to true capillary along the course of a pronephric tubules, and the blood is ultimately returned to the heart through one of the postcardinal veins.

Pronephric tubules retians an connection with the coelom. Whether glomeruli are of the internal or external type is of no particular significance in their relation to the pronephros. A protein free filtrate of blood plasma passes from the glomerulus in to the coelom or in to the cavity of Boumans capsule and thence in to the tubule. Cells in the wall of tubules probable excreates nitrogenous wastes in to lumen, where they are added to the fluid filtered from the glomerulus.

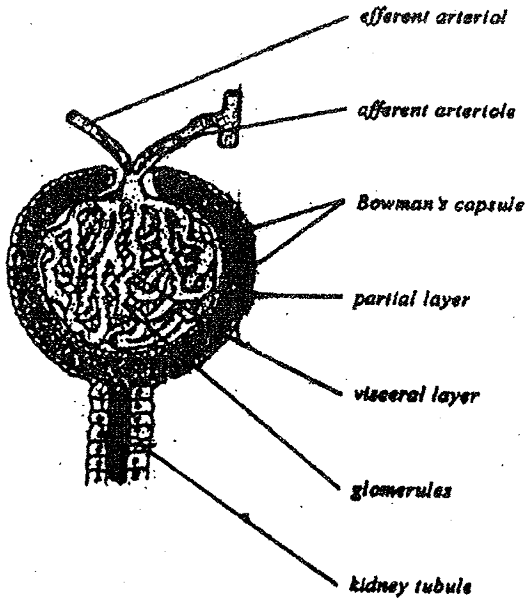
Selective reabsorption of water and certain other constituents may occur as the fluid passes down the tubule, so that a smaller volume of fluid with higher concentration of wastes in solution finally enters into the archinephric ducts. Sometime several glomeruli in units to form a large glomus. Pronephric tubule may expand to form pronepheric chembers, or several tubules may fuse to form a large chamber.

The importance of the pronephros lies chiefly in the part it plays in forming the archinephric duct, which persit even through the pronephros may disappears.

In members of the class chondrichthyes the pronephros degenerate soon after it is formed. In many fishes and in larval amphibians, however it becomes modified and functions for a time as in excretory organ. Only in the hag fish and a few teleosts does the head kidney with its peritoneal connection persists in adult life. The nephrostomes of the hag fish open into the; pericardial cavity, and the fluid which passes down the tubules enter an adjacent vein rather than the archinephric duct.



Diagrammatic section through part of a vertebrate embryo, showing relation of internal glomerulus to pronephric tubule and archinephric duct



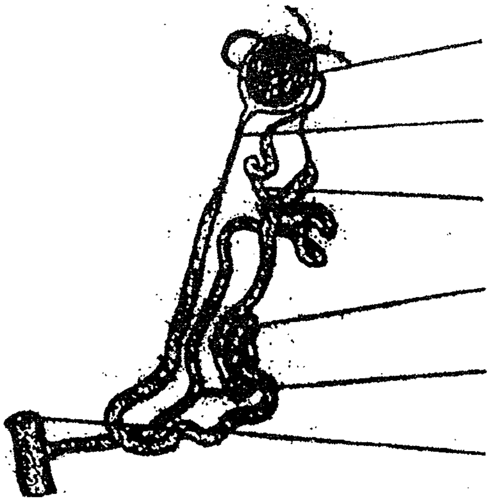
A renal corpuscle

Opisphonephros :

Since the pronephros in most cases is but a transient structure, the opisthonephros is actually the more important part. It serves as the adult kidney lampreys, most fishes amphibians.

Frequently the term mesonephros is used in describing what we have called the opisthonephros. The opisthonephros however, is not quite comparable to the mesonephros of embryonic amniotes, even though the two are structurally similar. We shall reserve the term mesonephros for the structure which appears during embryonic development in reptiles, birds and mammals.

The reason for the distinction lies in the fact that the three types of kidneys pronephros, mesonephros and metanephros, which appear in amniotes embryos represent development from different levels of the premitive archinephros which appear in succession in an anterior posterior direction. The opisthonephros of cyclostomes, fishes and amphibians actually extends over a region which is amniotes form, both mesopheric and metapheric kidneys.



An amphibian kidney tubule of the opisthonephros, showing the renal corpuscle and secretory and collecting portions.

The opisthonephros differ from the pronephros in several respects. In male the archinephric duct may be taken over almost entirely by the reproductive system, in which case accesory Urinary ducts are formed which carry away wastes materials. A main distinction between pronephros and opisthonephros in that is the opisthonephros the segmental arrangement of the tubules no longer exist, and several tubules lie with in a given segment. This is most apparent towards the posterior end of the opisthonephros. Further more, there are rarely any connections between kidney tubules and coelom. Renal corpuscles with internal glomeruli are typcially present. In some forms the anterior tubules of the opisthonephros lie in the same segments as posterior pronephric tubules, thus indicating the transitional nature of the two kinds of kidneys.

Metanephors :

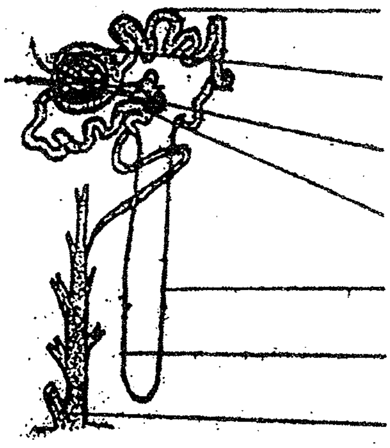
The metanephric type of kidney found only in the amniotes, arises posterior to the mesonephros on each side. It is a more compact organ than the mesonephros. It comes from a level which corresponds to the posterior portion of the opisthonephros of an amniotes. The metanephros is made up of essentially the same part as the mesonephros and contains renal corpuscle, secretary tubules and collecting tubules. No nephrostomes are present. Each kidney has a two fold origin. A diverticulum, the Ureteric bird, from the posterior end of the Wolffian duct, grows forward in to the so called metanephric blastema, which lies posterior to the mesonephros.

The blastema is continuous with the nephrogenous tissue from which the mesonephric tubules were derived. The diverticulum of the Wolffian duct is destined to form the ureter and the collecting portion of the kidney. The ureteric bird branches and re-branches a varying number of times, ultimately to form largel numbers of fine collecting tubules. Atleast in Mammals at a point where the bird under goes its primary divisions and expanded regions may be noted. This becomes the pelvics of the kidney.

Condensation in the mescnchyme of the adjacent blastema soon give rise to holoscretory tubules which become 'S' shapped. One end of each secretory tubule establishes connection with a collecting tubule, the other end expands and each soon invaded by a glomerular tuft from a small branch of the renal artery, so that a typical renal corpuscle is formed. The differentiation of a secretory tubule of the metanephros in mammals and to a lesser extent in birds, is some what more elaborate than that of a mesonephric tubules. Each tubules as it leaves Bowman's capsule consists of a proximal convoluted tubule, a long loop of Henle with its descending and ascending portions and a distal convoluted tubule.

Secretory tubule with their Bowman's capsule are very humeroys. The metanephros functions in a manner similar to that of the mesonephros. Wastes are carried from the kidney by the uterus which enter the cloaca or urinary baldder as the case may be. In reptiles and the birds resorption of water occurs in the cloaca with precipitation of the organic matter as a chalky mass of urea or uric acid.

Manner of branching of diverticulum of Wolffian duct during early development of metanephros. (After Hubs)



A mammalian metanephric tubule, showing the renal corpuscle as well as secretory and collecting portions.

External salt excretion in vertebrates :

Vertebrates that live in an environment laden with salt, or that inhabit arid environments and can not afford much body water of cary off accumulated salts, have external structure for salt excretion. Marine fishes have chloride secreting glands on the gills and elasmobarnch have ractal, glands that that performs this functions. Marine reptiles and bird that scoop fish out of salt water have nasal glands excrete salt. So do terrestrial lizards and snakes that live in arid habitats. These some lizards and snake have atrophied glomeruli which also conserve waters.

The salt secreting nasal glands of lizards are located outside the olfactory corpuscle and empty in to the nasal canals via small ducts. Whitish incustrations of nacal and potassium can be seen in the nasal canal or at the nostrils.

The nasal gland of marine birds is a large paird gland of located above the orbit. It is drained by a long duct that opens close to a nostrils. A groove extends from the opening to the top of the beak.

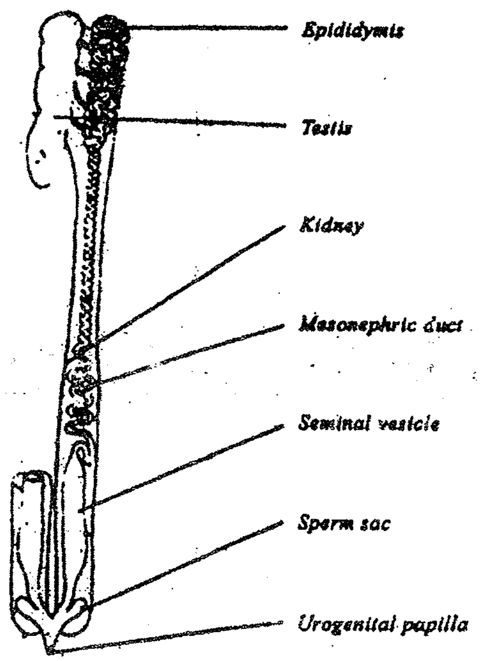
Sweat gland eliminates some salt in mammals, but salt loss by this route is incidental to secretion of water for its evaporative cooling effect, where as the excretion of electrolytes via most routes is regulated by hormones, their loss via sweat glands is unregulated. Infact, salt loss by this route usually must be replaced.

URINARY BALDDER :

Most tetrapods have a urinary bladder that serves as a storage site for urine before it is voided. Its chief survival value for terrestrial vertebrates seems to be reside in the fact that it is a reservoir of water that may be needed later, hence should not be wasted. Infrequently, in one species or another the fluid is put to another use. A.D.H. from the pituitary gland, the release of which is evoked when de-hydration thratens, causes active water resorption from the bladder, after which the water is re-cycled. Most fishes have a small unpaired swelling at the end of the urinary pathway that is called a urinary bladder; however, these appears to be inconsequential as holding site for rine. In some lower vertebrates the bladder may serve as a recovery site for certain essential ions that are scarce in the environment.

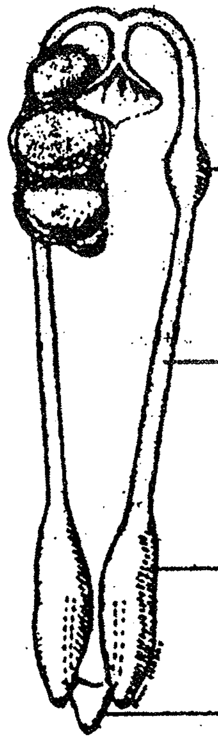
Fishes :

Urinary bladder in most fishes when present, is an insignficant terminal enlargement of the conjoined caudal ends of the urinary ducts. The urogenetal sinus of male sharks and the urinary sinus of females, both of which lie with in a urogenetal or urinary papilla, are the closest structures to a urinary bladder in sharks, but the sinuses are so small as to be useless as a reservoir for urine.



Urogenital system of male shark.

An accessory urinary duct, not shown, drains the more posterial kidney tubules. Within the urogenital papilla there is a Urogenital sinus.



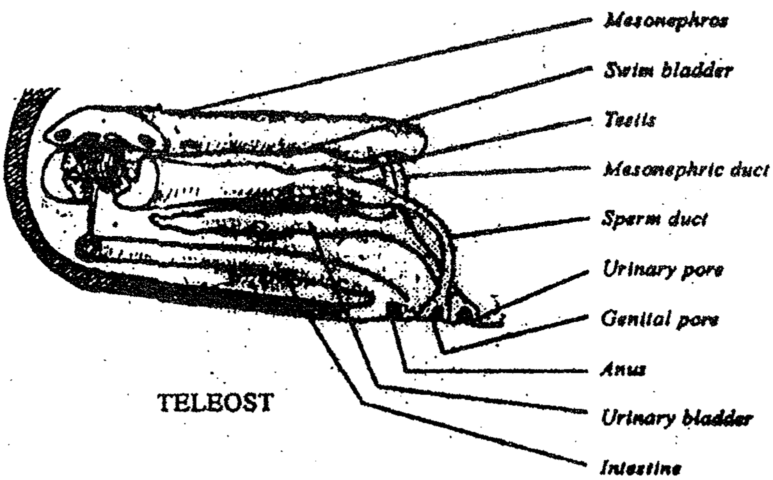
Reproductive system of female Squalus, ventral view.

The left overy has been removed. The right overy contains three mature eggs. Within the Urinary papilla there is a urinary sinus.

Homologus simses in Rejiformes, sometimes called urinary bladders, are only slightly larger and the same thing may be said of the swellings at the conjoined ends of the rinary ducts of the lower Actinopterygian. The latter have been called tubal bladders in recognition of their location. They are frequently larger in females than in males. Dipnoans have a small diverticulum of the dorsal wall of the cloaca that is called bladder.

The most conspicuous structures bearing the name urinary bladder are vesicles that arise ontogenetically as evaginations from the caudal end of the embryonic mesonephric ducts, as in pikes which are the primitive teleosts. Urine must back up in to these, as it does in to amphibians bladders.

There is no apparent survival value in the presence of a urinary bladder in most fishes for water conservation, in as much as fresh waters fishes are emerged in water and has been pointed out, many marine fishes have the capacity to extract fresh water from sea water by drinking sea water and quickly excreting the salt cyclostomes have no structure that can be called a urinary bladder.

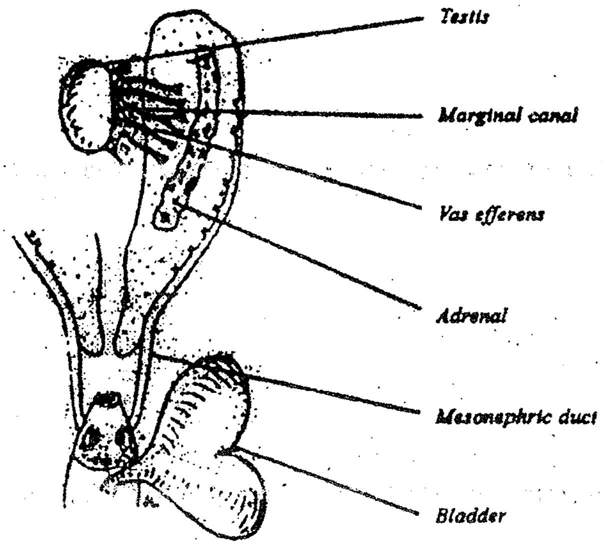


Caudal end of urogenital system of male teleost (pike), left lateral view.

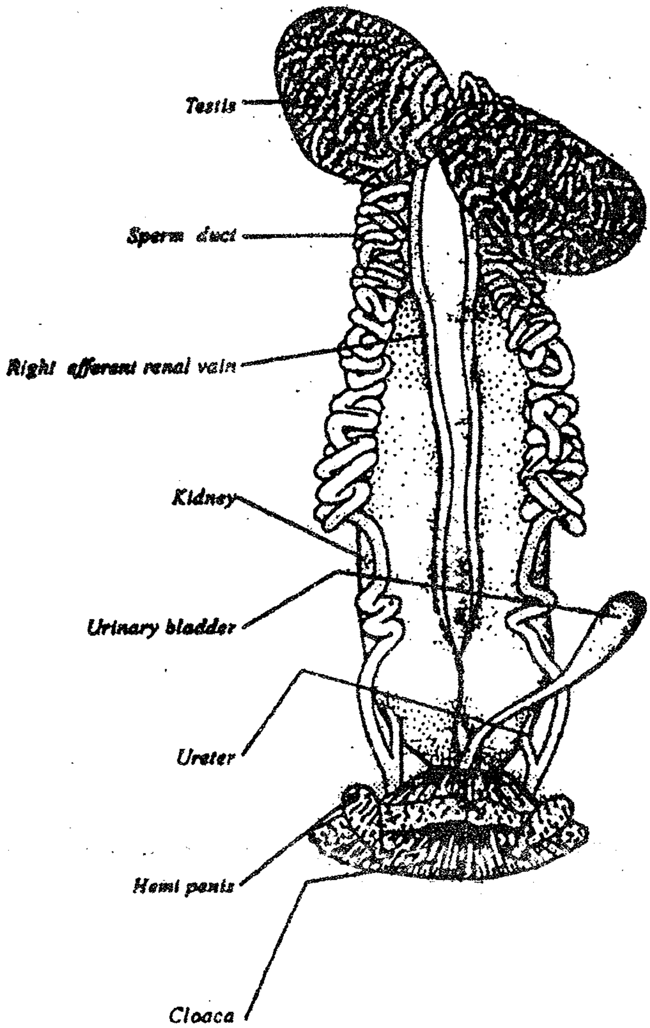
The unpaired urinary bladder arises as a bird off the conjoined caudal ends of the two meso-nephric ducts. Note abscence of cloaca (after goodrich).

Tetrapods :

The urinary bladder of amphibians through mammals arise during organogenesis as an evagination of the embryonic cloaca and they empty in to the cloaca in adults, excepts in placental mammals.

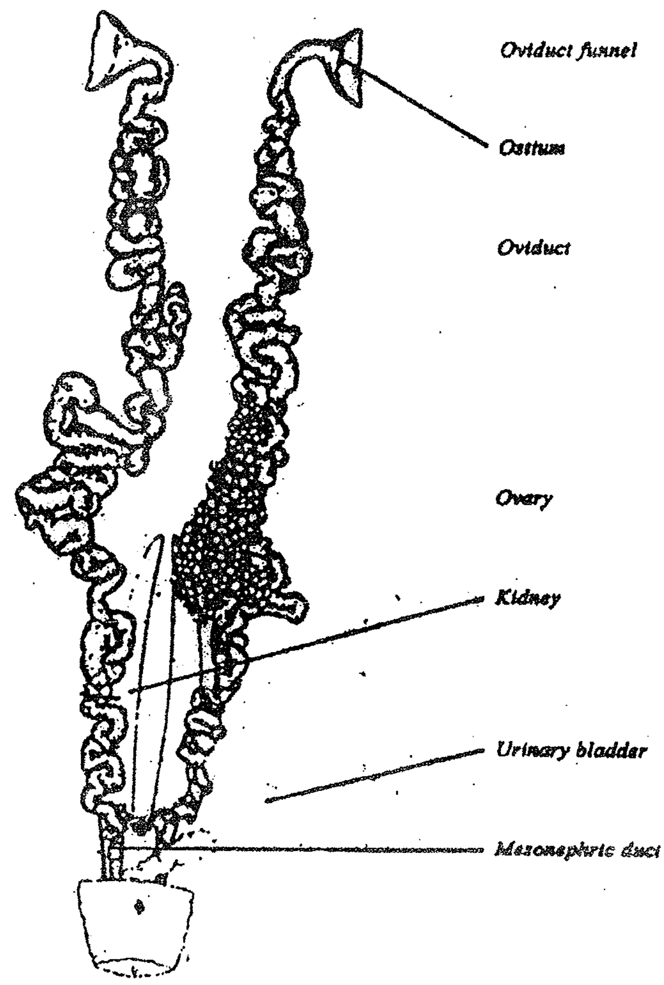


Urogenital system and adrenal of male frog, ventral view



Urogenital organs of the male lizard Anolix carolinensis ventral view

The kidneys are metanephric. The sperm duct is the persistent mesonephric duct. The hemi penes are seen in an everted (erected) position.



Urogenital system of female Uterus, ventral view

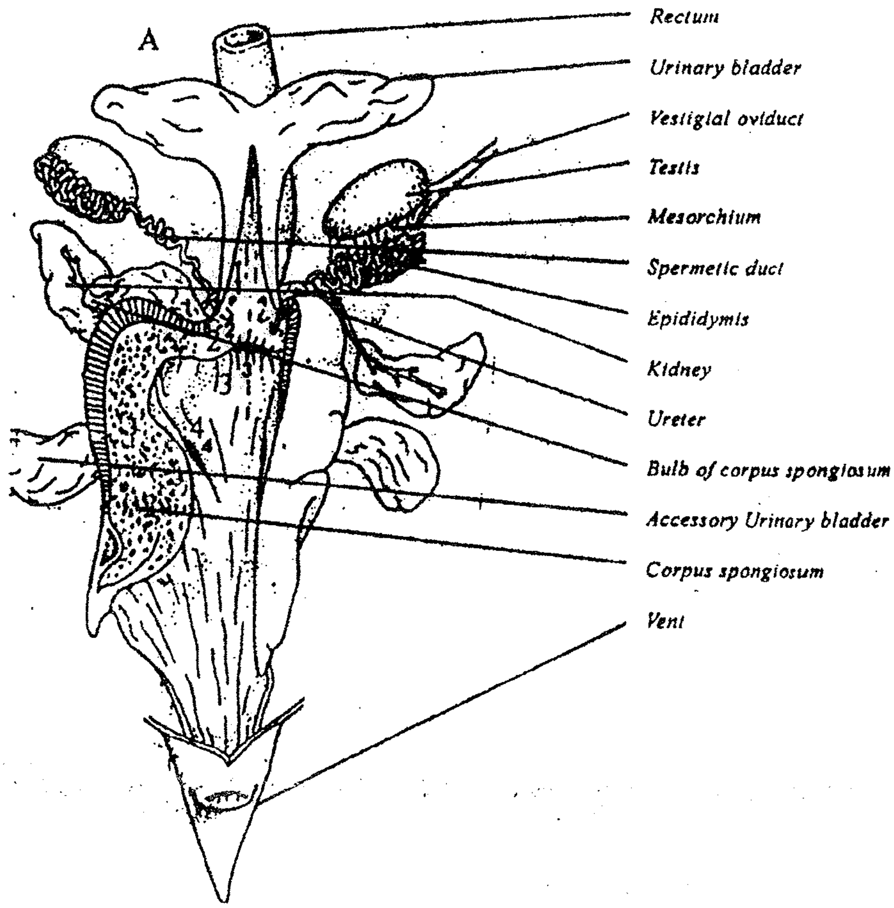
They are lacking in Crocodilians, Snakes, some lizards, and in birds other than Ostriches. Their absence in birds reduces the energy requirements for flight.

In amniotes embryos the cloacal evagination that gives rise to the bladder is prolonged beyond the ventral body wall as an extra embryonic membrane, the allantois.

Only the base of the allantois the part priximal to the cloaca-contributes to the adult bladder.

Continual after birth the part of the allantois with in the coelm and distal to the baldder remains in mammals as a urachus (middle umbilical ligment) connecting the tip of the bladder with the umbilicus. The urachus, which is more prominent in some species (Primates, for inatance) than in others (Cats, for instances) lies in the anterior border of the ventral mesentery of the bladder along with the obliterated umbilical arteries.

Annurans, turtles and some lizards have usually large bladders, and some fresh water turtles have accessory urinary bladders.



Urogenital system of a male turtle. A, ventral view

The floor of the cloaca has been sectioned longitudinally just lateral to the urethral groove and reflectected to the observer's left. The ventral wall of the urinary bladder has been opened at its junction with the cloaca. The kidneys have been displaced caudad from their normal position dorsal to the testes. 1 - opening from ureter; 2 - genital papilla; 3 - entrance of rectum; 4 - opening from accessory urinary bladder. 2 the cloacal floor viewed from above, showing the penis extruded. The rectum has been removed.

The latter are used by females to carry water for softening and moistening the soil when a nest for the eggs is being prepared; if they have an additional function it has not been demonstrated. Because the kidney ducts of amphibians, reptiles and monotremes empty in to the cloaca, urine in these tetrapods collects in the cloaca and then backs up or is forced in to the bladder while the sphincter at the vent is closed. In placental mammals the kidney ducts empty directly in to the bladder, and the bladder is drained by the urethra.

The smooth muscle in the wall of the tetrapod bladder is disposed in a reverse pattern to that of the mascular coat of the digestive tract, their being an inner longitudinal and outer circular layer. The size of the lumen at all times is only sufficient to accommodate the quantity of contained urine. As an adaptation, the muscle fibres are interspersed with a layer than usual amount of loose connective tissue which facilitates adjustment in the thickness of the bladder wall as the bladder fills or empties.

Gonads :

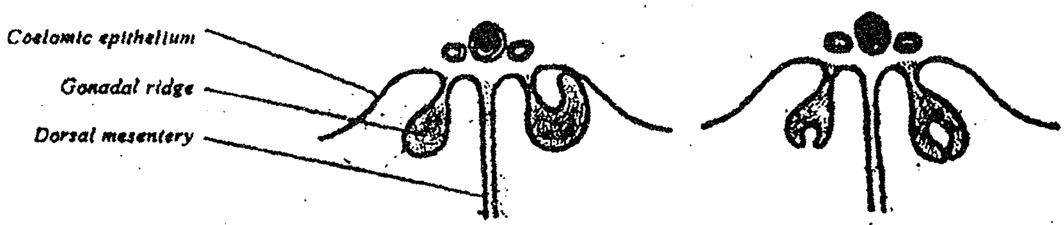
The embryonic gonads arise as a pairs of elevated gonadal (genital) ridges. These are thickness in the coelomic epithelium just medial to the mesonephroi. The ridges are longer than the resulting mature ganad, which suggests that at one time gonads may have extended the length of the pleuroperitoneal cavity as they do in living cyclostomes. Although the gonadal ridges are paired a few adult vertebrates have a single testis ovary because of fusion of the two ridges are paired a few adult vertebrates have a single testis ovary because of fusion of the two ridges across the midline (lamprey's, a few teleosts), or became one of the juvenile gonads fails to differentiates, some female crocodilians, some lizards, most female birds. A few mammals also, among which are the platipus and some bats, have only one ovary. As the gonads appraoch sexual maturity they enlarge and usually acquired a dorsal mesentary, the mesorchium in male and mesovarium in females. Gonads are the source of gamets and of gonadal hormones.

Ovary :

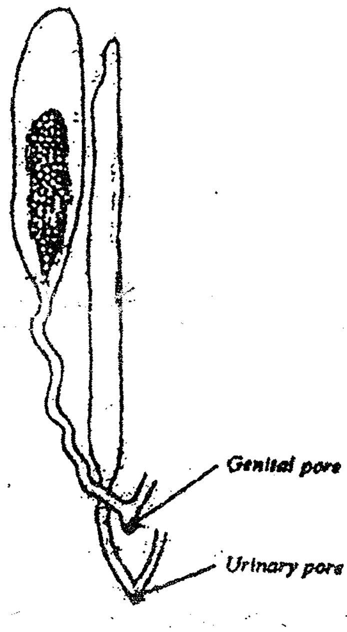
The ovary is some teleost fishes is a permamently hollow sac. The conditions results from entrapment of a small part of the coelomic cavity within the developing ovary. Consequently the ovarian cavity is lined by germinal epithelium, which is the source of eggs.

In some other teleosts the cavity within the ovary results from a secondary hollowing out of the anterior of the ovary at each ovulation. In either cases, the eggs or in viviparous teleosts the young, are discharge in to the ovarian cavity, which is continuous with the lumen of the oviduct. The ovaries of most other fishes are compact. The amphibian ovary is also a hollow sac but the germinal epithelium is on the surface and eggs are shed into the coelom. The ovaries of amniotes other than placental mammals are not compact either. They develop a large number of irregular fluid filled cavities, which evidently provide nutritive support to the developing eggs in the over lying cortex. However, the mature yolk laden eggs are shed in to the coelom. At the end of each productive season the ovaries of most vertebrates below placental mammals regress to a stage similar to that in juveniles.

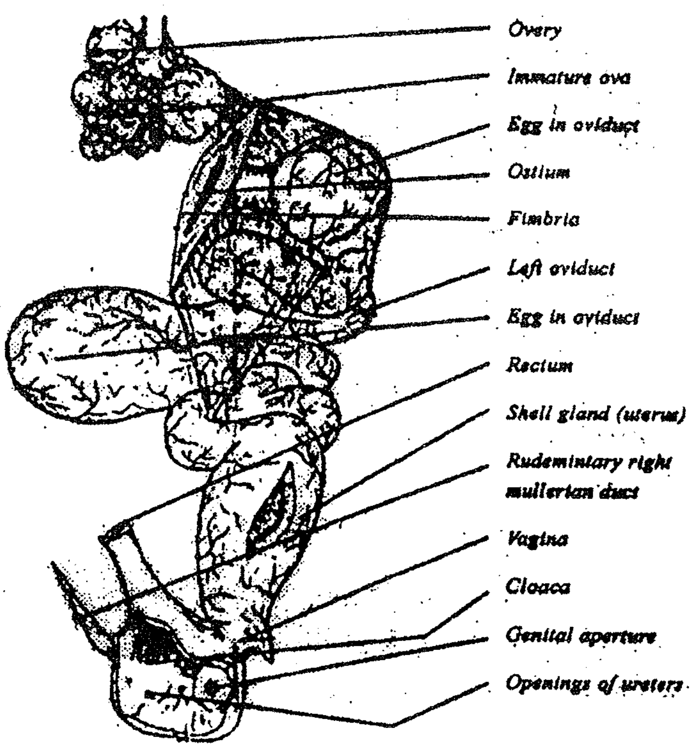
The ovary of placental mammals is compact, the only cavtiation being the antrums with in the graafian (mature ovarina) follicles. The ovary like most others, is covered on its surface by a germinal epithelium from which arise oocytes, some of which becomes mature ova during the life of the individual. Prior to ovulation, the predominent secretory product of the cells was an estrogen.



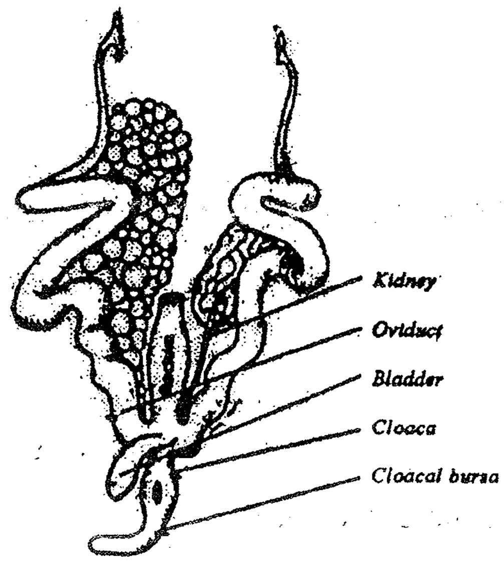
Two methods of entrapment of coelom to form a permanently hollow overy in teleosts. The gonadal ridges are shown in cross sections.



Female reproductive system of a teleost. Ova are shed into the ovarian cavity. In some teleost the ovary reaches almost to the genital pore.



Reproductive tract of a hen. The presence of two eggs in the oviduct is unusual. The larger egg is traversing the magnumm



Urogenital system of female aquatic turtle, trionyx euphraticus, ventral view. The left ovary has been removed (courtexy mohamad S. Salih, University of Baghdad)

In many mammals a membranous fold of peritoneum develops close to the ovary and to the short oviduct and grows around these two structures, entrapping them and a small portion of the coelom in a cut-sac, the ovarian bursa. The bursa may be broadly open to the main coelom by a mere slit like passage, as in most carnivores and rats or it may be closed completely, as in hamsters. Fetal rabbits are occasionally found implanted in the peritoneal [illegible] abdominal wall of pregnant rabbits.

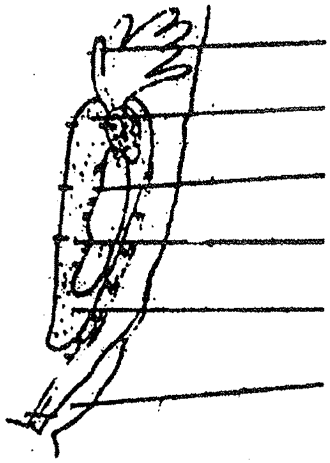
Testis :

Mature testis are usually smaller than ovaries because sperm, although more numerous by millions of times, are much smaller than eggs. The testis of placental mammals, however, are unique among vertebrates in that they are larger than ovaries because the eggs are microlecithal and only a few ripe ova are present at a time.

The basic components of vertebrates testis are essentially alike from fishes to human beings, consisting of a spermatogenic and a steroidogenic component. Spermatozoa are product by the germinal epithelium, which except in lower fishes and tailed amphibian constitute the lining of convoluted semineferous tubules. When mature the spermatozoa separate from the germinal epithelium and propelled by flagellum - like tails, transverse the tubule until they reach in the rete testis, a net work of ovary thin channels with in the testis.

In cyclostomes, most lower fishes, some teleost, and urodeles sperm mature in numerous cyst like seminiferous ampullae, in to which primordial germ cells migrate from a germinal epithelium located else where within the testis or on its surface. At the end of the spawning season after 1000 or 100 of spermatozoa have been shed from each cyst, the cyst collapse. The specific site may or may not become a site of spermatogenesis during a subsequent reproduction cycle. The seminiferous ampullae of gnathostomes discharge on to the rete testis. In cyclostomes the sperm are shed in to the coelom.

The embryonic testis of anurans is subdivided in to an anterior portion, Bidder's organ, which usually disappears before sexual maturity, and a more caudal portion, which becomes the adult testis, Bodder's organ persists in adult male toad and contains large undifferentiated cells resembling immature ova.



MALE TOAD

Bidder's organ and the rudimentary female reproductive tract in a young male Buto ventral view. Only the left organs are illustrated. The mesonephric duct and rudimentary uterus empty into the cloaca.

If the testis are removed experimentally Bidder's organ developed in to functional ovaries, and the rudementary female duct system enlarges under the influence of females hormones from the ovaries. Instances of sexreversal occures in nature in many submammalian vertebrates groups. Hence, have been known to cease laying eggs, crow, and develop other oorster like characteristics. This comes about when the left ovaries atrophies and the right ovary, which is rudementary, enlarges and produces male hormones.

During early development the gonads are indistinguishable as to sex and male and female ducts appear in every embryo. Under the influence of a combination of sex chromosomes and pituitary and gonads hormones the indifferent early gonad, develop in to either testis or ovaries and the appropriate ducts, male or female, enlarge, where as the other set remains rudementary or dis-appears.

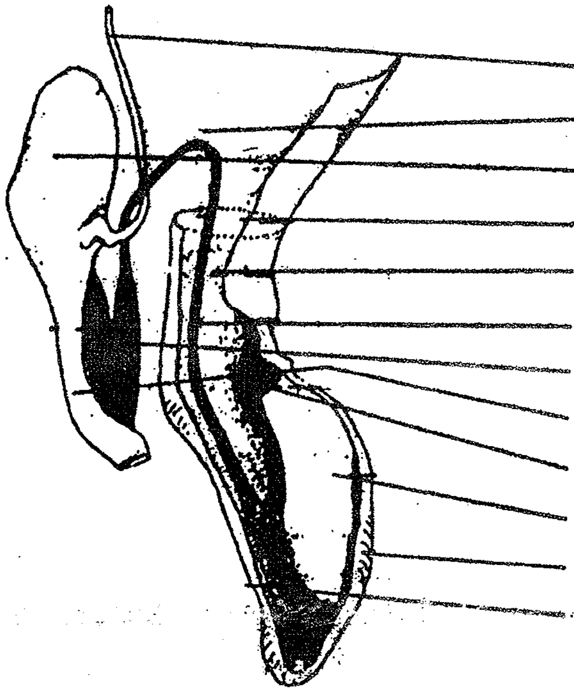
The hermophroditism is common in cyclostomes and occasional in boney fishes, but in rare among other lower vertebrates and absent among higher ones.

Translocation of Ovaries and Testis in Mammals :

The caudal pole of each embryonic ovary and testis is connected by a ligament to a shallow evagination of the coelom, which becomes the scrotal sac in males, labium, majus in females.

In female the cephalic parts of the ligament is named the ovarian ligament, and the caudal part is the round ligament of the Uterus (female). In males the ligament is the gubernaculum. Partly as the result of shortening of the ligament, partly because elongation of the ligament does not keep pace with elongation of the turnk, and partly for unknown reasons, the ovaries and testis are displaced caudad towards the labia or scrotal sac. The ovaries are not displaced as far causdad as the testis.

The testis remain retroperitoneal and descend permanently in to scrotal sacs in many mammals, including most marsupinas ungulates carnivores and higher primates. In others they are lowered in to the sacs & retracted at will. The passages between the abdominal cavity and the scrotal cavity is the inguinal canal.



Rabbit testis in scrotal cavity. The inguinal canals are broadly open to the main coelom at the inguinal ring; therefore the testis are retractable. Sperm pathway from testis to urethra is shown in red.

The opening of the canal is to the abdominal cavity is surrounded by a fibrous inguinal ring. In species that retracts the testis the canal remain broadly open. In species in which testes are permanently confined to the scrotum the inguinal canal is only wide enough to accommodate the spermatic cord.

The spermatic cord contains the spermatic duct, arteries, veins, lymphatic & nerves. These are all wrapped in a single sheath, the internal spermatic fascia, and all are dragged in to the scrotum along with the testis. Scrotal sacs do not develop in monotremes, some insectivores, elephant, whales, and certain other mammals. In these the testes remain permamently in the abdomen.

In mammals whose testis are permamently in scrotal sacs the spermatic artery and vein lie side by side in tight coils within the inguinal canal. This rete of vessels is the pampiniform plexus. The arterial blood is at temperature; the venous blood has been cooled in the scrotal sac. Heat is transferred in the plexus from arterial to venous blood so that blood reaching the testis is cool and blood returning to the internal circulation has been pre-warmed. This counter current flow of warm and coold blood protects the sperm fo these endothermic species from temparatures that would kill them, conserving body heat. No such plaxus occurs in birds, but avian sperm can withstand high temparatures.

Male genetal ducts :

Although mesonephric ducts are part of the Urinary system embryonically, they transport both sperm and urine in generalized urogenetal systems. Connection between the mesonephric and gonadal ridges are established early in embryonic life. Some of the more anterior mesonephric tubules a few to 24 or more, depending on the species grow accorss the developing masorchium to connect with the tubules of the further rete testis. These modified mesonephric tubules in the mesorchium become vasa efferentia that carry sperm from the testis.

In some fishes and the urodeles there has been a tendency to form a new sperm duct, the longitudinal marginal canal, to receive the vasa efferentia. This tendency may have been more common in plaeozoic gonoids, of which sturgeoks and polypterus are relicts. The condition has reached culmination in modern teleost in which the mesonephric ducts carries up sperm whatsoever. When a duct only sperm whether mesonephric ducts or a substitute, it is called a vasdeferens (ducts deferens).

The spermatic ducts empty in to the cloaca, in reptiles and birds and in to a derivative of the cloaca in mammals. The anatomical relationship of the spermatic ducts in mammals are the affected by –

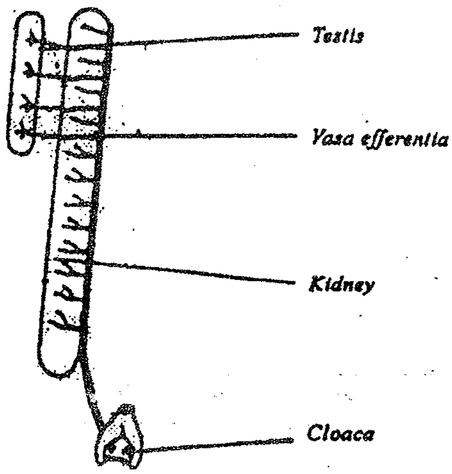
1) Complete separation of the embryonic cloaca in to a urogenital sinus and rectum and

2) Caudal migration of the testis.

As a recent of subdivision of the cloaca, the spermatic ducts of mammals finally empty in to the uroogenital sinus, which is the male urethra. As a result of caudal migration of the testis, the spermatic ducts becomes "cught" or "hung up" on the ureters, so that their after they look over the ureters en-route from the testis to the urethra.

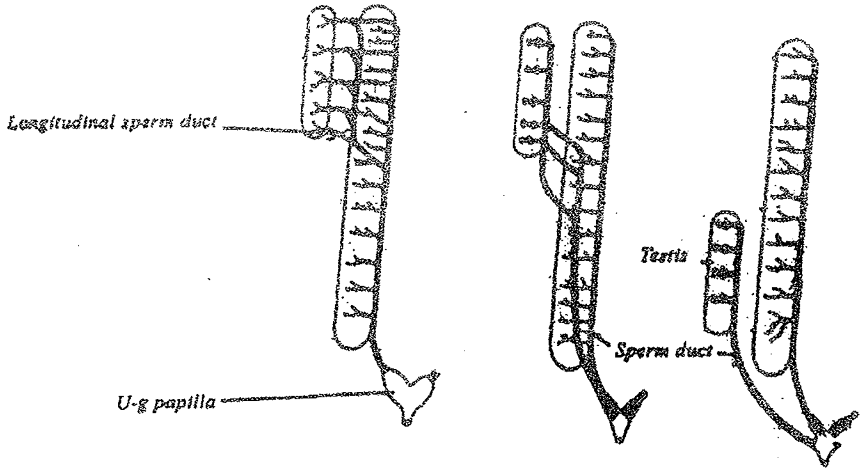
Emptying in to the urethra is the immediate vicnity of the entrance of spermatic ducts are postate glands and one or more other accessory glands that produce some of the constitutents of semen. The urethra in male mammals is frequently called prostatic urethra where prostate glands empty in to it, membranous urethra from prostate gland to the base of the penis, and spongy urethra with in the penis.

Agnathans male & female lack of genetal ducts, sperms and eggs are shed in to the ciliated coelom are propelled cauded by undulations of the body and by beating of the coelomic cilia, and exit via a pair of genetal pores. Whether this is a primitive route for shedding games in vertebrates is conjectural; living agnathans are a mosaic of primitive and specialized traits.

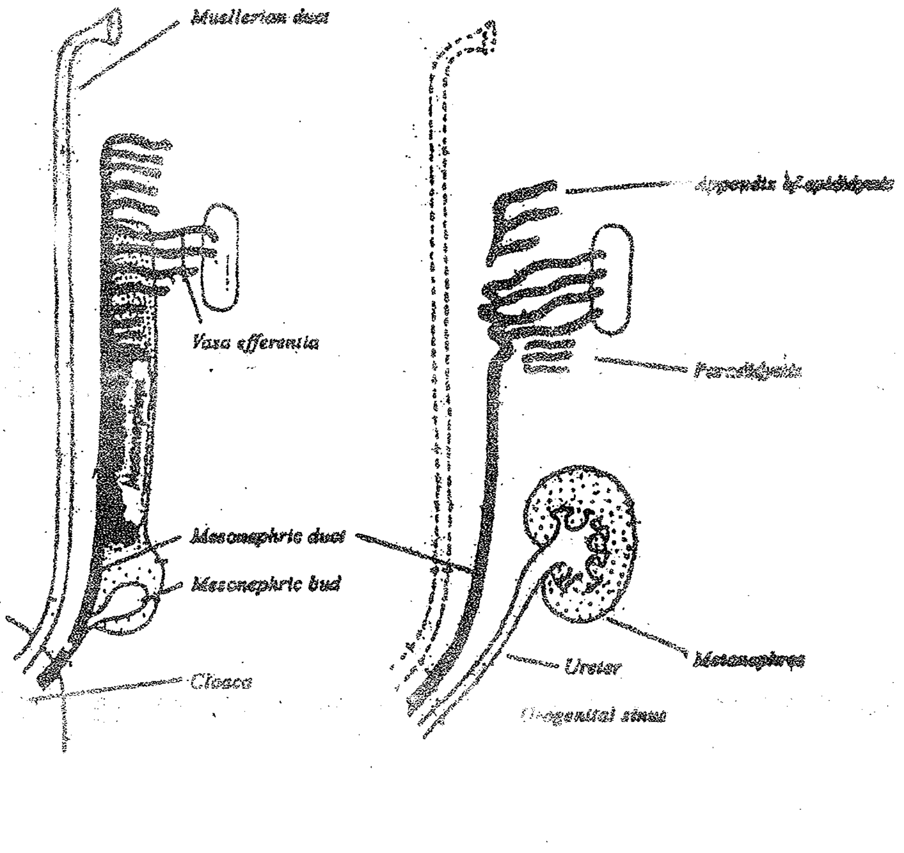


A, BASIC PLAN

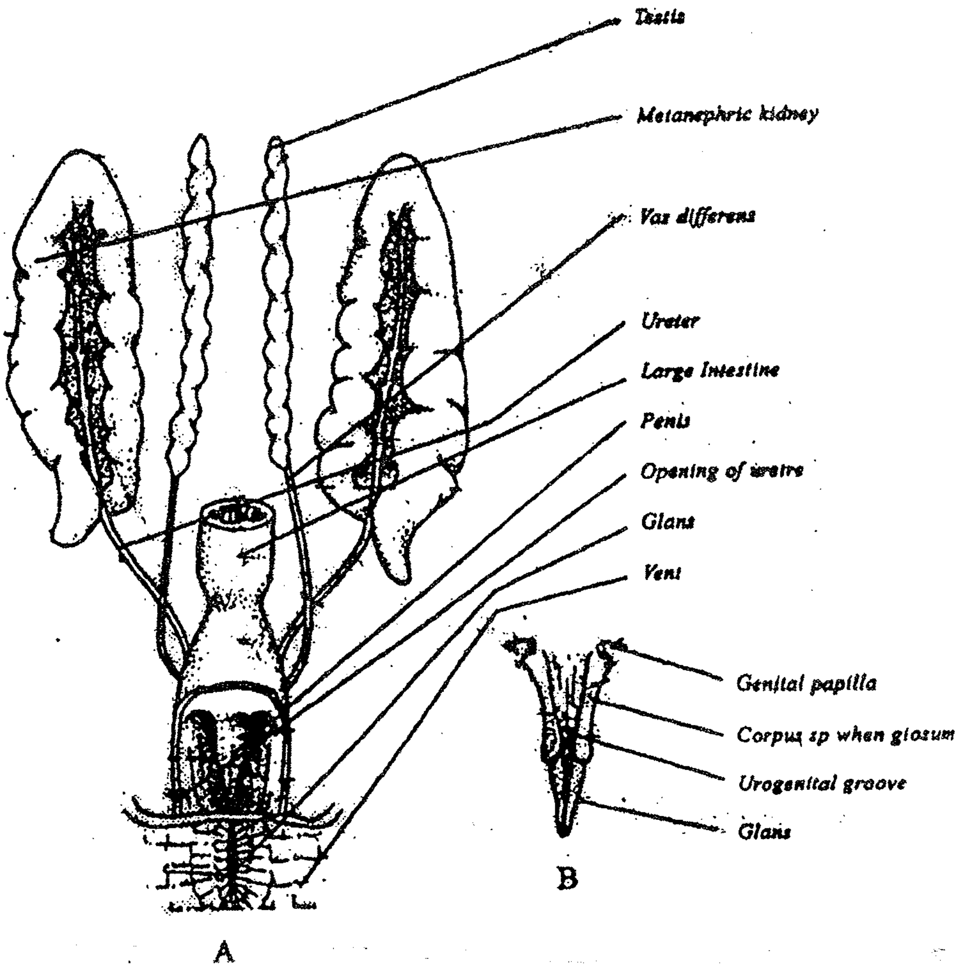
The mesonephric duct (black) as a carrier of sperm and urine. A, Basic plan, carrying both sperm and urine. B, Carrying urine from the anterior end of the kidney only chiefly a spermatic duct. C, carrying sperm only



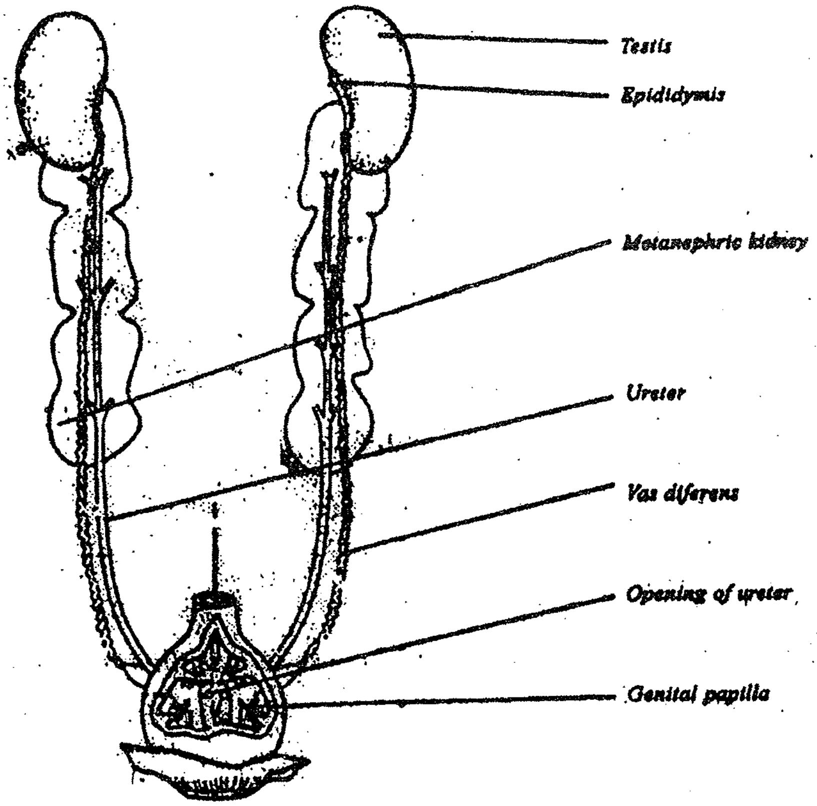
D to F, Tendency toward a separate sperm duct from in fishes, the mesonephric duct ultimately carrying [illegible] urine. Note the reverse of this condition in amniotes. U-g papilla. Urogenital papilla. For a variation of the teleost [illegible] duct see Fig. - 14.15



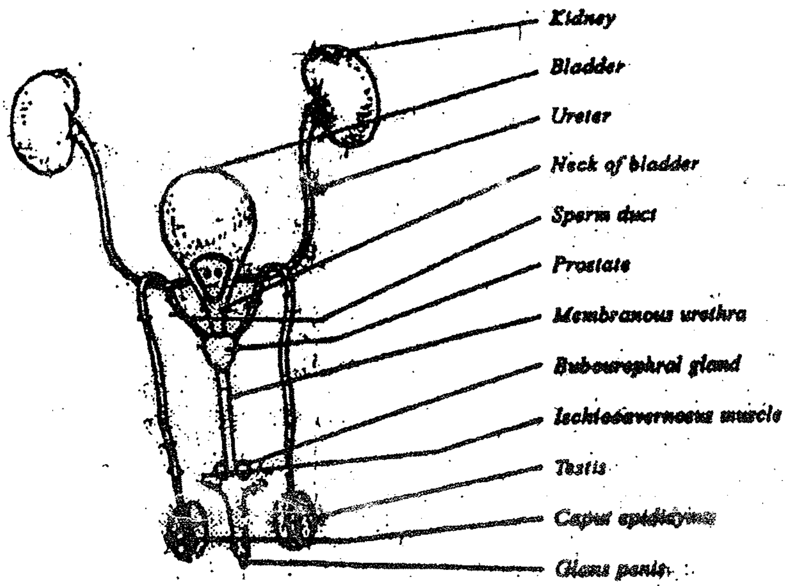
[illegible] changes in the urogenital system of a male amniote. In the earlier stage (left) some of the mesonephric tubules have invaded the testis to become vasa efferentia. In the later stage (right) the mesonephros has regressed except for remnants (appendix of epididymis, paradidymis), and the muellerian duct has regressed (broken lines at right). The mesonephric duct remains to carry sperm. Mesonephric duct and tubules are red[illegible], Epididymal portion of mesonephric duct.



Urogenital system of a male alligator. A. ventral view. Ventral cloacal wall removed. The ureters opne in an dorsal wall of the cloaca. B. dorsal view of penis. The vas-diferentia opne onto the floor of the cloaca via genital papillae



Urogenital system of a rooster, c, Coprodum; l. large intestine; u. Urodeum; v. Vent



Urogenital system of a male cat, ventral view

Female genetal ducts :

The female reproductive tracts typically consists of a pair of mascular tubes that commence at an ostium surrounded by a fimbriated oviduncal funnel and empty in to the cloaca. The tubes differentiate from a pair of mullerian ducts present in the embryos of both sexes. In mature females the ducts transport eggs, and certain segments are modified for specifics or another coating the eggs with protective substances, holding eggs or living young and maintaining them in a viable state until the eggs are shed or young are delivered, expelling eggs or young receiving the male intromittent organ, and sorting and maintaining sperm in those numerous species in which the eggs are not mature at the time of mating.

Osita appear to be phylogenetic derivatives of one or a few pronephric nephrostomes. That is how they arise in living elasmobranchs and amphibians; and in these same vertebrates mullerian ducts arise by longitudinal spliting of the pronephric ducts. In most ohter vertebrates each mullerian duct arise as a longitudinal groove in the coelomic mesothelium paralleling the pronephric duct. The groove subsequently becomes a tube, except at the anterior end, which remains open to become the ostium. At the caudal end it acquires an opening in to the cloaca.

When fertilization is internal, sperm usually penetrates the eggs in the upper reaches of the oviduct, and eggs are propelled along the tract by cilia or peristaltic action of smooth muscles. Some lizards and snakes have spermathecal that are crypts of the voiducal lining located just above the shell gland, and domestic fowl have them at the uterovaginal junction. These amniotes lay a succession of eggs during the season, and spermathecal ensures the availability of viable sperm of the time of each ovulation. Sperms are sometimes stored in spermathecae for many months.

Fishes & Amphibians :

In female elasmobranchs each mullerian duct give rise to an oviduct with a shell gland and to a uterus that opens to the cloaca. The cephalic half of the shell gland secretes albumen, and the candal half secretes the shell. Two embryonic ostia unit to form a single adult ostium suspended in the falciform ligament, a condition not typi cal of vertebrates.

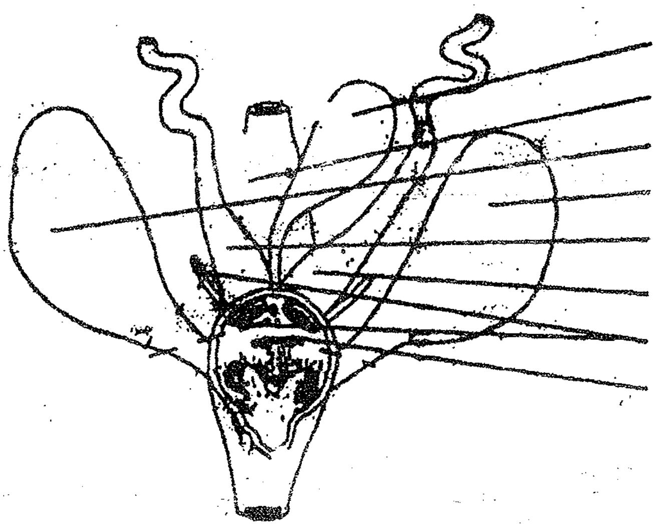
The oviducts of ray-finned fishes are pecuiliar. They are either short funnels at the caudal end of the coelom, or they are directly continuous with ovarian cavity. In either case they lead to a genital pore located between the Urinary apertures andthe more anterior anus. The genital pores is sometimes at the end of a genital papilla, and the papilla is sometimes elongaged to form a tube like ovipositor. Their development is such as to make it doubtful than they are Mullerian duct derivatives. Cyclostomes have no oviduct; eggs exist the coelom via a pair of genital pores, as explained earlier.

The female tracts of lung fishes, Urodeles, and caecilans are long and somehwat convoluted. In anurans they are much more tortuous as an accommodation to the short wide trunk. The oviducal linings in amphbians bians is richly supplied with glands that secrete several jelly envelopes around each eggs as it moves down the tube.

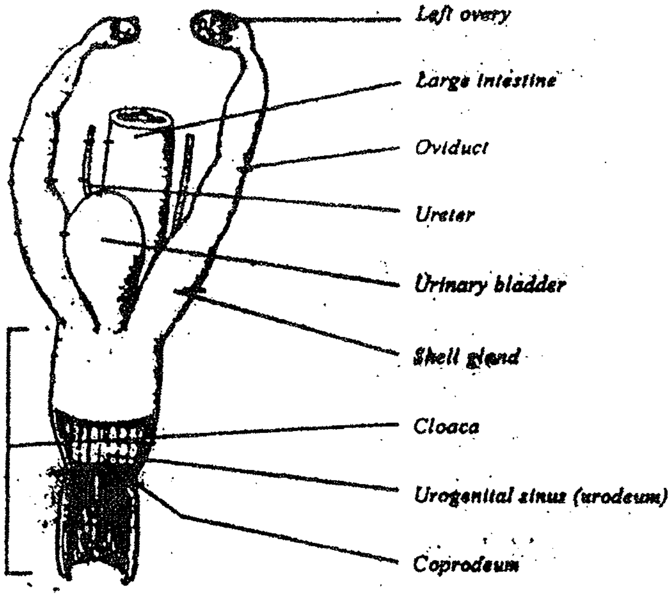
Reptiles, birds & Monotremes :

The female tracts of reptiles, birds and monotremes conform to the basic vertebrate pattern. However, only one Mullerian duct differentiate in crocodilians, some liazards, and most female birds. In oviparous amniotes other than snakes and lizards, albumen glands line in segment of the oviduct, and all have a sheell gland just anterior to the cloaca. The shell remains leathery or becomes brittle in air, depending on the constituants of the secretion.

In birds the albumen secreting region is the magnum, and the thick walled shell gland is called inappropriately, the Uterus. The short mascular terminal segment, the vagina, secretes mucous that seats the pores of the shell to water vapour but not to oxygen, thus retarding moisture loss from the egg after it has been laid. The vagina then expels the egg.



Cloaca and associated structure of a female terrestrial turtle ventral view, clitoris has been removed



Genital tract and cloaca of female monotreme, ventral view. The right ovary is usually smaller than the left and is sometimes rudementary. The cephalic half of the cloaca is divided by a partition into urogenital sinus (receiving oviducts and ureters) and coprodum.

Placental Mammals :

The Mullerian ducts of placental mammals give rise to oviducts, Uteri, and vaginae. Except in maesupials, Mullerian ducts unite at their caudal ends. As a result the adult female tract above marsupials is paired anteriorly and unpaired posteriorly, terminating as an unpaired vagina. The oviducts, or fallopian tubes, as they are called in mammals, are relatively short, small in diameters, covulated and lined with cilia.

They commence at an oviduct funnel bordered by a delicate membranous fringe the fimbria of the infundibulum.

Uteri :

In most marsupials their is not fusion of the embryonic mullerian ducts. Therefore, the entire female tract is paired. They have a duplex Uterus and paired vaginae.

In other placental mammal there are varying degrees of fusion of the caudal ends of the Mullerian ducts, which results most often is two uterine horns, a uterine body and a single vagina. When there are two complete lumens with the body of the Uterus, it is said to be bipartite. When there is a single lumen with in the body and there are two horns, the uterus is said to be bicornuate. When there are Uterine horns, the blastocysts implant in the horns. In some mammals one horn is much larger and the blastocyst implant in that horn. The right in impalas – even though both ovaries produces eggs.

Apes, monkeys, human, some bats and armadillos have no uterine horns, and the oviduct opened directly in to the body of the simplex uteres. Except in ectopic pregnancies – in which blastocyst implant in abdominal locations, such as the oviduct or coelom – the usually single fetus or the twins, triplets, quadruplets or quintuplets of these specific mammals all implant in the body of the uterus.

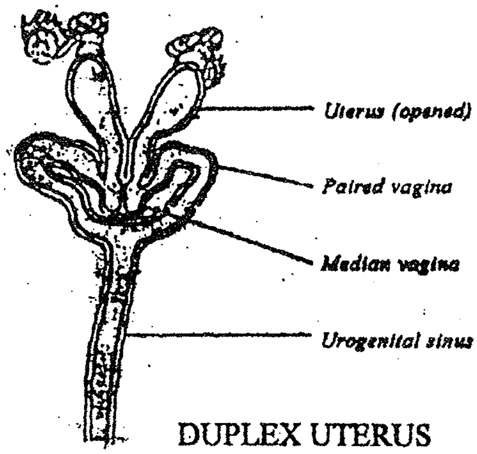
The body of all uteri narrows to form a cervix (neck) the lower end of which projects in to the vagina as the lips of the cervix. The lips surrounded the opening leading from uterus in to the vagina. The cervix must dilate under the influences of hormones for the young to be delivered.

Some deposited in the vagina pass through the uteri on route to the upper part of the oviducts, where only ones sperm penetrates an eggs. The uterine lining becomes highly vascular under the stimulates of hormones before implantation of a blastocyst. The thick mascular layer of the uterine wall assists in ejection of the young of the birth; provided it too has been hormonally prepared for this action.

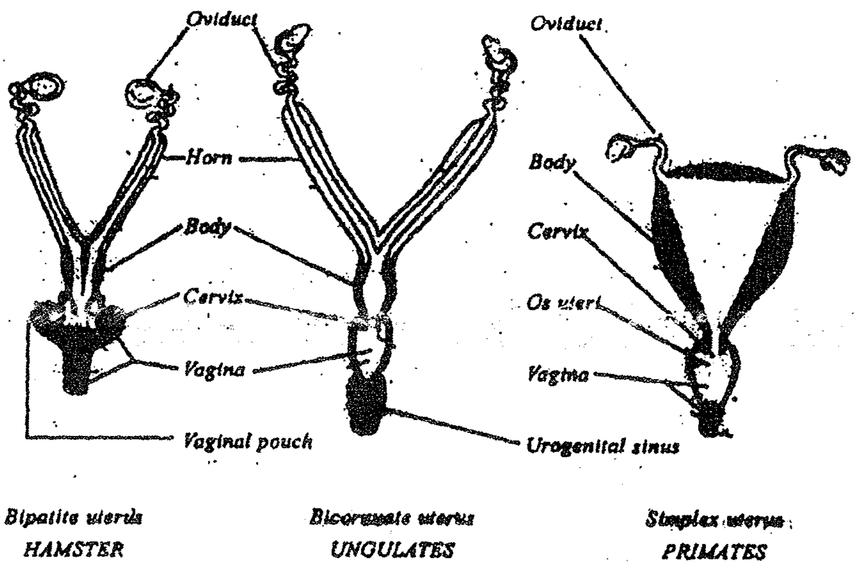
Vaginae :

Above marsupials the vagina is the fused terminal portion of the muellerian ducts and it usually in to the urogenital sinus. In higher primates however, the vagina extend at most to the exterior, opening in to a shallow vestibule between the labia and caudal to the opening of the urethra in many rodents the vagina opens directly to the dxterior immediately caudal to the urinary papilla. The vaginal lining of mammals is cornified for reception of the penis.

The vagina of marsupials are unusual just beyond the uteri the two muellerian ducts need to form a median vagina, which may or may not be paired internally. Beyond the median vagina the two ducts continue as paired vaginal. The pouch like median vagina projects caudad and lies against the urogenital sinus, separated by a septum. At birth the fetus is usually forced through the septum directly in to the urogenital sinus. The new passage way thus established may remain through out life, which results in a psendovagina, although it closses in opossums. As an adaptation to dual vagina, the penis of male marsupials are forked at the tip.



Internal passageways of the reproductive tract of a female opossum. Compare with the external view in Fig. 14-39, marsupial



Uterine types among mammals. Blackened regions represent fused caudal ends of the muellerian ducts ; red represents the cloaca or a derivative thereof. Note the two lumens in the body of the biparitive uterus.

Muellerian Duct Remmants in Adult Males :

Although Muellerian ducts do-not fully mature in males, they often develop in to prominent structures. In male elasmobranches a pair of redementary oviducts encircle the anterior end of the liver and end in a rudimentary ostium in the falciform ligament. The sperm sac of shark is a caudal remnant of the muellerian duct. A complete, although rudimentary female tract is common in male amphibians and reptiles. In male anurans after removal of testicular hormones by orchidectomy the rudimentary muellerian ducts develops in to functional oviducts and uteri. Remnants in male mammals include a appendix testis a small cyst like body on cephalic enf of the mammalian testis, and prostatic sinus, an unpaired sac near the prostate gland homologous with the female vagina.

Entrance of Ova in to Oviduct :

After seeing the very large size of a shark egg, laboratory students often enquire how such a large egg can get in to the ostium and down the relatively small oviduct. Under the influence of hormones at the time of ovulation, the fringe of the oviducal funnel waves gently in an undulating movements. When it comes in contact with an egg whether still in the ovary or separated from it, the fimbria clasps the egg delicately at fast and then more farmly, until the egg is engulfed by the funnel. At this time the egg is shapeless mass of following yolk contained in a nonrigid membrane. Muscular contraction of the funnel squirts the shapeless mass in to the oviduct. Their upon peristalsis of the wall of the oviduct moves the egg cauded.

In mammals the ovary is partially surrounded by the fimbria at all times and this increases the probability that the egg will enter the oviduct. In mammals with an ovarian bursa the egg can go no where else.

The cloaca :

The cloaca is the terminal segment of the hindgut that receives the large intestine and the urinary and genital ducts. It has become shallow or non existent in adult lampreys, chimaeras and ray-finned fishes; and in placental mammals the embryonic cloaca is partitioned in to several separate passages ways and no longer exist as an adult structures. With these exceptions a cloaca is present in all vertebrates. If acquires an opening in to the exterior when the cloacal membrane, which separate hindgut from proctoderm, reptures. The contribution of protoderm to adult cloaca is minor, except in amphibians.

The cloaca of fishes and amphibians receives the large intestine and the mesonephric ducts, and in females oviduct. In amphibians a urinary bladder opens from the ventral wall. The cloaca of reptiles, birds, and monotrems receives the same structures; large intestine, mesonephric ducts, oviducts in females, and urinary baldder unless absent.

In addition the ureters of reptiles, birds and monotrems open in to the coloca, except in those few male reptiles in which the uterers retain their embryonic connections with the mesonephric ducts. The penis of clitoris, when present, is embadded in cloacal floor, and a lymphoid pouch, the bursa of fabricious opens in to the roof of the cloaca of young birds.

In reptiles, birds and monotrems a horizontal portion, the uro-rectal fold, separates the cephalic portion of the cloaca in to two chambers, a coproderm that receives the large intestine and a urodem that receives the oviducts and ureters. The terminal portion of the cloaca in birds is called the proteoderm, but it is not entirely homologous with the ecotodermal structure of the same name in vertebrates embryos.

Fate of the Cloaca in Placental Mammals :

We have seen how in monotremes a urorectal fold divides the cephalic end of the cloaca in to a uroderm. In placental mammals the urorectal fold grows cauded until it reaches the cloacal membrane separating the cloaca from the exterior. By this process the cloaca becomes completely divided in to rectum dorsally and a urogenital sinus ventrally. Ruptures of the cloacal membrane at two points provides an anus and a urogenital aperture. The early embryonic urogenital sinus receives the mesonephric ducts, muellerian ducts, and the future urinary bladder, like the uroderm of monotremes.

As development progress in males, the muellerian ducts regress and the urogenital sinus becomes continous with the spongy urethra that has developed independently in the penis. The urogenital sinus now consists of the prostatic and membranous urethra. The ureters becomes reoriented to open in to the bladder, where as the mesonephric ducts continue to empty in to the urogenital sinus.

As development progress in females, the mesonephric ducts regress and the muellerian ducts unite at their caudal ends to form the body of the uterus and the vagina.

The part of the urogenital sinus between bladder and entrance of the vagina is the urethra. As a result of these changes most adult female mammals have tow caudal openings to the exterior, a urogenital paerature and an anus.

In most female primates and in some rodents an additional portion forms in the cloaca-this one in the urogenital sinus. It separates the urogenital sinus in to a urethra and a vagina. As a result, the embryonic cloaca in these species becomes subdivided in to 3 passages : Urethta, Vagina and Rectum. Each passages way leads to the exterior via its own apertures. In this regards the females of these species have evolved further than the males. The vagina in these females has a dual origin. The cephalic part is derived from the fused muellerian ducts and the terminal part is cloaca.

Following that Table summerizes the fate in adult males and females of the chief sexually indifferent urogenital structures found in all mammalian embryos.

SOME HOMOLOGOUS UROGENITAL STRUCTURES IN MALE & FEMALE MAMMALS –

Indifferent Structure	**Mature Male**	**Mature Female**
Mesonephric duct	Ductus deferens (vas-deferens) Epididymes	Ductus deferens feminius (Gartuner's duct)
Mesonephric tubules	Vasa efferentia Appendix of epididymes Paradidymes	Vasa efferentia ovarii* Epoophroh* Paroophoroh 1
Muellerian duct	Appendix testis* Vagina Musculina*	Oviduct, Uterus, vagina cephalic to urogenital sinus
Gonadal ridge	Testis Rate testis	Ovary Rate ovarii
Gubernaculum	Gubernaculum	Ovarian ligament Round ligament of Uterus

Genital Swelling	Scrotal sacs	Labia Majora
Genital tubercle	Penis	Clitoris
Genital folds	Contribute to Penis	Labia Minora
Urogential Sinus	Urethra, Prostatic and membranous portions	Urethra Urogenital Sinus Lower vagina in rodents and primates

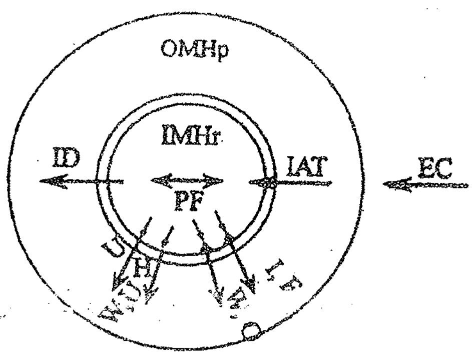
Osmoregulation :

Osmoregulation in teleost fishes whether they live in fresh water or sea its physiological activity is very closely related to their survival. In fishes the kidneys plays an important role in osmoregulation, but major portion of the Osmoregulatory functions are carried out by other organs such as the gills, the integument and even the intestine.

Osmoregulation may be defined as "the ability to maintain a suitable internal environment in the face of osmotic stress". As a consequence there is always difference between the optimal intracellular and extracellular concentrations of ions. In the fish body, number of mechanism take place to solve osmotic problems and regulate the difference.

Problems of Osmoregulation :

Generally fish lives in an osmotic steady state inspite of frequent variations in osmotic balance. This is, on the average, the input and output is equal over a long period sums up zero.



Principal process of osmoregulation in fresh water fishes. EC, ecological condition; I, ion; IAT, ion active transfer; ID, ion diffusion; IMR, inner medium hypertonic; O, osmosys; OMPH, outer medium hypertonic; PF, physiological factor; U, urine; W, water

The osmotic exchanges that take place between the fish and its environments may be of two types –

1. **Obligatory exchange –**

   It occurs in response to physiological factors over which animal has little or no physiological control and

2. **Regulatory exchange –**

   These are the exchanges while are physiologically well controlled and help in the maintenance of internal homeostasis.

Factors affecting Obligatory exchange

1. **Gradient Between the Extracellular Compartment and the Environment :**

   The greater the ionic differences between the body fluid and external medium, the greater the tendency for net diffusion to low concentrations. Thus a bony fish in a sea water is affected by the problem of lossing water in to the pypertonic sea water.

2. **Surface / Volume ratio :**

   Generally the animal with small body size desicates more rapidly than a large animal of same shape.

3. **Permeability of the Gills :**

   Fish gills are necessarily permeable to water and solutes as they are the main site of exchange of oxygen and carbondioxide between the blood and the water. Active transport of salts also takes place in the gills. Euryhaline fishes are well adapted to salt water by reduced permeability to water.

4. **Feeding :**

   Fishes takes water and solute along with the feeding. A gill takes high quantity of salt than water at the time of feeding on sea shore invertebrates, these fishes, therefore must have some special device to excrete excess of salt. However, a fresh water fish ingest large amount of water than salt and thus needs special means of salt conservation.

5. **Osmoregulators and Osmoconfirmers :**

   Osmoregulators are those animals who can maintain the internal osmolarity different form the medium in which they live. The fishes except the hagfish are generally true Osmoregulators, maintaining the concentrations of body fluid. In these fishes which migrate between fresh and salt waters, the changing osmotic stress due to environmental changes is overcome with the help of endocrine mechanism. (Table-1)

Table 1 : Approximate composition of extracellular fluids of teleostean fishes (Concentration in milliomoles per litre of water)

Species	Habitat	Milli	Na+	K+	Ca^{++}	Mg^{+}	Cl^{-}	SO_4^{--}
Paralichthys (flounder)	Sea water	337	180	4	3	1	160	2
Carrassius	Fresh water	293	142	2	6	3	107	–

Source - Schmidt-Niselsen, and Mackay, 1972; Prossor, 1973.

Osmoconfirmers are those animals who are unable to control osmotic state of their body fluids but confirms to the osmolarity of the ambient medium. Majority of fishes either live in fresh water or salt water. Due to various physiological process metabolic wastes are removed from the body in vertebrates by gut, skin and by kidneys. But in fishes and aquatic animals their gills and oral membranes are permeable both to water and salts in marine environments, salt is more in water against the salt inside the body fluid hence water moves out due to the process of osmosis. The osmosis may be defined as "if two solutions of different concentrations are separated by a semipermesble membrane, the solvents from the less concentrated part will move through the membrane in to more concentrated solutions". The water will move inside the body due to osmosis through partially permeable membrane.

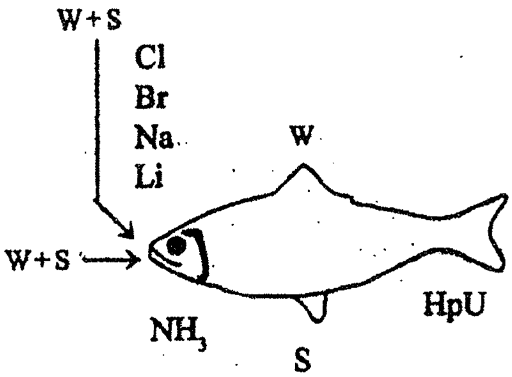
Osmoregulation in fresh-water fishes :

The body fluid of fresh water fishes is generally hyperosmotic to their aqueous medium. Thus they are posed with two types of osmoregulatory problems –

1. Because of hyperosmotic body fluid they are subjected to swelling by movement of water in to their body owing to osmotic gradient.

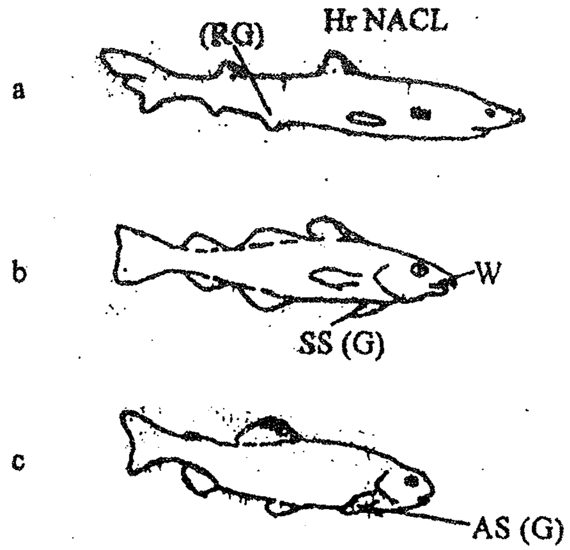
2. Since, the surrounding medium has low salt concentration, they are faced with disappearance of their body salts by continual loss to the environment.

Thus freshwater fishes must present net gain of water and net loss of salts. Net intake of water is prevented by kidney as it produces a dilute, more copious urine.



Osmoregulatory inflow and outflow of salts and water in a fresh water fish. HpU, hyponone urine; S, salt; W, water; W+S, water and salt

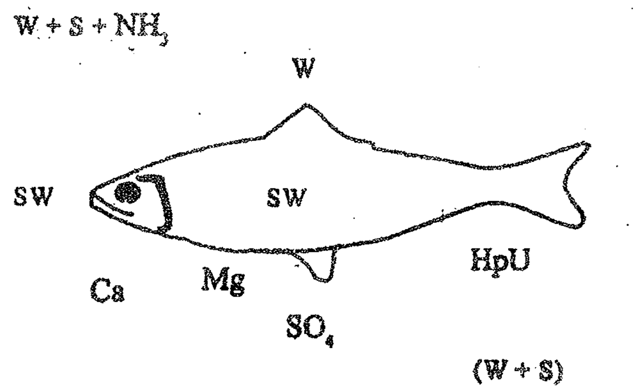
The useful salts are largely retained by reabsorption in to the blood in the tubules of kidneys, and a dilute urine is excreted. Although some salts are also removed along with urine which creates torrential loss of some biologically important salts such as KCl, NaCl, $CaCl_2$ and $mgcl_2$ which are replaced in various parts. Fresh water fishes have remarkable capacity to extract Na^+ & Cl^- through their gills from surrounding water having less than I/L NaCl, even through the plasma concentration of the salt exceeds 100 m M/L NaCl. Thus NaCl actively transported in the gills against a concentration gradient in excess of 100 times. In these fishes the salt loss and water uptake are reduced by the integument considerable with low permeability or impermeability to both water and salt also by not drinking the water.



Exchange of water and salt in some fishes. (a) marine elasmobranch does not dring water and has isotonic urine. (b) marine teleost drinks water and has isotonic urine. (c) fresh water teleost drinks no water and has strongly hypotonic urine. ASG_y absorbs salt with gill; Hr Nacl (RG), hypertonic Nacl from rectal gland; SS (G), secretes salts from gill; W, water.

Osmoregulation in marine water fishes :

In marine fishes, the concentration of body fluid and marine water is almost similar. Therefore, they do not require much energy for maintenance of osmolarity of their body fluid. The classic example is hagfish, Myxine whose plasma is isosmotic to the environment. Hagfish maintains the concentration of Ca^{++}, mg^{++} and SO_4 = significantly lower and Na^+ & Cl^- higher in comparison to sea water. Other marine water fishes, such as sharks rays, skates and primitive coelacanth, Latimaria, have plasma while is isosmotic to sea water. They differ from the hagfish in having capacity to maintain very lower electrolyte concentrations. They also have difference with organic osmolytes like Urea and trimethylamine oxide. Kidneys of coelacanth and elasmobranchs excretes excess of inorganic salts such as NaCl. Also rectal gland located located at the end of alimentary canal takes part in the excretion of NaCl. Modern bony fishes have the body fluid hypotonic to sea-water, so they have tendency to lose water to the surroundings particularly from gill via epithelium. The lost volume of water is replaced by drinking salt water. About 70-80% sea-water containing NaCl and KCl enters the blodo stream by absorption across the intestinal epithelium. However, most of the divalent cations like Ca^{++}, Mg^{++} and SO_4= which are left in the gut are finally excreted out. Excess salts absorbed along with sea water is ultimately removed from the blood with the helps of gills by the active transport of Na^+ and Cl^- sometimes K^+ and eliminated in to the sea-water. However, divalent ions are secreted in to the kidney.



Osmotic regulation in marine boney fishes. HpU, hypotonic urine; SW, sea water; W + S + NH_3 water, salt and ammonia; W, water

Thus Urine is isosmotic to the blood but put rich in those salts particularly Mg^{++}, Ca^{++} and SO_4= which osmotic actions of gills and kidney in marine teleosts resulted in the net water that is hypotonic both to the ingested water and Urine. By using similar mechanisms some teleost species such as the salmon of pacific northwest maintain more or less constant plasma osmolarity inspite or being migratory between marine and fresh water environment.

Control of Osmoregulation :

The concentration and dilution of Urine is controlled by hormones, which affects the rate of renal filtration by changing the blood pressure and thus control the quantity of Urine. Hormones also influence the rate of diffusion and absorption across the gill epithelium. Thyroid gland and suprarenal bodies secretes adrenocortical hormones which control osmoregulation in fishes.

Further Reading :

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4. Comparative animal physiology. Schmidt – Nielsen, B.M. and W.C. Mackay.
5. Biology of the Vertebrates. Herbert E. Walter & Leonard P. Sayles.
6. Elements of Chordate Anatomy Charles K. Weichert & William Presch.

Questions :

1. How many types of kidney generally found in terrestrial vertebrates? Mention the anatomical structures any two of them.
2. How many types of kidney generally found in terrestrial vertebrates? Mention the anatomical structures any two of them.
3. What do you mean by Osmoregulation? Describe the Osmoregulation process in Salmon.
4. Describe the Osmoregulation process of Rhacophorus. And add a note on Osmoconfirmers.
5. Compare the female genital duct of Monotremes and Placental Mammals.

VIDYASAGAR UNIVERSITY

DIRECTORATE OF DISTANCE EDUCATION
MIDNAPORE - 721 102

M.Sc. in ZOOLOGY

Part – I

Paper - I : Group – A : Unit – II

Module – 6

Syllabus :

1. Anatomy of Respiratory organs.
2. General Consideration of Organs of hearing, balance and echolocation.
3. Structure and modification of jaw suspension.

1. Anatomy of Respiratory Organs :

In Vertebrates there are two phase of respiration, external and internal. The term external respiration denotes the exchange of gases between the blood and environment. Internal respiration refers to the gaseous exchange between the blood and the tissues or cells of the body.

Respiratory organs are present in vertebrates, serving to facilitate the external phase of respiration. Certain requirements are demanded of respiratory organs:

(1) A large, vascular surface area must be provided so that an ample capillary network can be expased to the environment;

(2) The membranous surfaces through which gaseous exchange occurs must be moist at all times and thin enough to permit the passage of gases;

(3) Provision must be made for renewing the supply of the oxygen – containing medium (air or water) which comes in contact with the respiratory surface and for removing the carbon dioxide given off from that surface; and

(4) Blood in the capillary network must circulate freely.

With few exception the organs of respiration in vertebrates are related to the pharynx in their development. In some forms, notably amphibians, the skin itself is an important respiratory organ.

NASAL PASSAGES :

In air-breathing vertebrates there is a close association between the olfactory organs and the organs of respiration. In lower aquatic forms, however, these structures are usually completely divorced from one another. The advantages of a close relationship between the organs of smell and those of respiration should be obvious. When the air is drawn into the lungs, volatile substances carried by the air may stimulate the sensory endings of the olfactory nerves situated in the nasal passages.

COMPARATIVE ANATOMY OF NASAL PASSAGES

Cyclostomes :

In the lamprey an unpaired nasai aperture on the top of the head leads to a blind olfactory sac from which a nasopharyngeal pouch extends ventrally. Thsi complex serves as an olfactory apparatus and has no connection with the pharynx or with respiration. The hagfish has a similar apparatus, but the nasopharyngeal pouch connects with the pharynx and furnishes a passage whereby a current of water reaches the pharynx and gills via the olfactory apparatus.

Fishes :

In most fishes there is no connection between nostrils and mouth cavity. In some elasmo branchs, however, an oronasal groove on each side forms a channel connecting the olfactory pit and mouth. This fore shadows the appearance of a direct connection between the two in higher forms. It is in the fishes of the subclass sarcopterygii that for the first time a direct connection exists between nasal and mouth cavities in the form of a pair of closed tubes. The opening to the outside are the external nares; those opening into the mouth are the internal nares, or choanae.

Amphibians :

The nasal passages of amplibians are short and well developed, the internal nares being located just inside the upper jaw. In many urodele larvae and in anuran tadoples, valves around the internal nares control the direction of flow of water. At the time of metamorphosis in most urodele, and with the appearance of lungs, smooth-muscle fibres developed around the external nares, thus providing a means of regulation of the aperture for opening and closing. This is the first instance in which atmospheric air is drawn into the nasal passages. In adult anurans, a small projection, the tuberculum prelinguale at the tip of the lower jaw is thrust forward and upward for closing their nostrils.

Reptiles :

In reptiles, there is a tendency toward elongation of the nasal passages. This is brought about by the development of pair of palatal folds, horizontal, shelflike projections of the premanillary, maxillary, vomer, palatine, and even of the pterygoid bones. Only in crocodilians among reptiles do the processes from the two side fuse along the median line, thus forming a bony secondary palate which separates the nasal passages from the mouth cavity. The internal nares communicate with the mouth cavity posterior to the secondary palate.

Birds :

The external nares of birds are usually located at the base of the beak, although those of the kiwi are placed almost at the tip. The secondary palate is incomplete. The choanae lie above the palatal folds. The nasal passages of birds are relatively short. Three conchae, supported by turbinate bones, are present in birds. Only the most posterior concha is covered with olfactory epithelium.

Mammals :

The nasal passages of mammals have been elongated and are larger and more complicated than those of lower forms. The nasal passages of mammals are divided into three general regions: vestibular, respiratory and olfactory. The vestibular region lined with skin, leads from the outside to the inner mucous membrane..Hair and sebaceous glands are abundant in this area. The respiratory region is fined with respiratory epithelium, a ciliated, pseudostratified, columner epithilium rich in goblet cells. The lateral and ventral nasal conchae are covered with respiratory epithilium which keeps the nasal passages moist. The mucous membrane lining the nasal cavities is highly vascular. The olfactory region cooupics the innermost upper recesses. It is covered with olfactory epithilium, which contains nerve endings for the sense of smell.

PHARYNGEAL POUCHES :

In the embryos of all chordatas a services of pouches develops on either side of the pharynx. These endodermal structures push through the mesenchyme until they come in contact with invaginated visceral furrows of the outer ectoderm. The pharyngeal pouches arise in succession in an anterior-posterior direction. They develop in such a manner as to become successing smaller first to last, and the pharynx, therefore, is funnel shaped, (Fig.1) tapering toward the oesophagus.

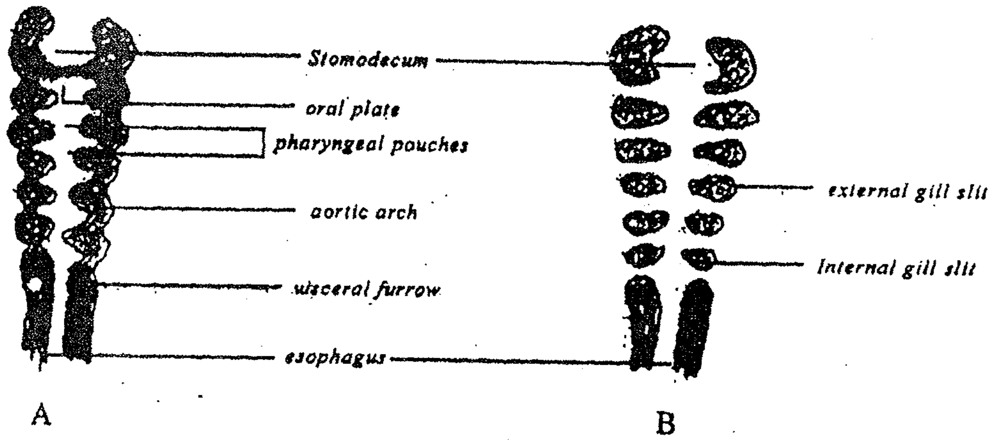

Fig : Diagram showing of pharyngeal pouches : A. during development ; B. after connection with the outside has been established and the oral plate disappeared.

Except in amniotes, perforations usually occur where endoderm and ectoderm come in contact. Even in amniotes, however, temporary openings are occasionally established. The visceral, or pharyngeal pouches are then called clefts. The openings connecting the pharynx proper with the clefts are called internal gill slits; those connecting the clefts with the outside are external gill slits. The number of pharyngeal pouches, or clefts, is greater in the lower groups of vertabrates and least in higher classes.

Pharyngeal pouches are of greatest significance in lower aquatic vertebrates since they bear gills and are directly concerned with respiration. Those of amniotes do not bear gills and generally disappear, except for the first, which becomes the Eustachian tube and middle ear on each side.

The visceral clefts are separated from one another by septa, which are mesodermal structure covered with epithilium derived either from ectoderm or endoderm, depending upon whether it is toward the exterior or interior surface. Within each septum lies a cartilaginous or bony barlike structure, the visceral arch. This serves to support the septum. Blood vessels called aortic arches branches from the ventral aorta and course through the septa, as do branches of certain cranial nerves.

The visceral arches, which make up the so called visceral skeleton, are modified in higher vertebrates to form various portions of the skeleton in the head and neck region.

GILLS :

Gills are composed of numerous gill filaments or gill lamellae, which are thin-walled extensions of epithelial surfaces. Each contains a vascular network. Blood is brought very close to the surface, thus fecilitating ready exchange of gases. In tehir aggregate gills present a relatively large surface for respiratory exchange.

Types of gills :

Gills are of two general types, external and internal. External gills develop from the integument covering the outer surfaces of visceral arches. They are usually branched, filamentous structures covered entirely with ectoderm and are not related to the visceral pouches. Internal gills are usually composed of a series of parallel gill lamellae, although in a few forms they may be filamentous. They may be borne on both sides of an interbranchial septum, but in some cases are present on one side alone. A series of lamellae on one side of an interbranchial septum is turned a half gill or hemibranch. Two hemibranch enclossing between them an interbranchial septum make up a complete gill, or holobranch. Two hemibranches bounding a gill cleft thus belong to different holobranchs. It is generally assumed that internal gills are covered entirely with endoderm, but there is considerable controversy on this point, and the question of extact origin has ot been completely clarified. Some fishes have both external and internal gills.

COMPARATIVE ANATOMY OF GILLS :

Amphioxus :

The pharynx of amphioxus is provided with large numbers of vertically elongated gill clefts. The gill clefts are separated by primary gill bars. During development a secondary, or tongue bar grows down between two primary gill bars and thus divided each primary gill cleft in two. Latter on, small crossbars appear connecting one primary bar with the next. There are no filaments or lamellae; the blood vessels course through the pharyngeal bars. A few of the anterior gill silts for a time open directly to the outside. With the development of the ectoderm-lined atrium, however, the pharynx no longer forms a direct connection with the outside and all gill clefts then open into the atrial cavity, or peripharyngeal chamber. A single opening, the atriopore, connects the atrium to the outside. It is located on the ventral side about two-thirds of the way back.

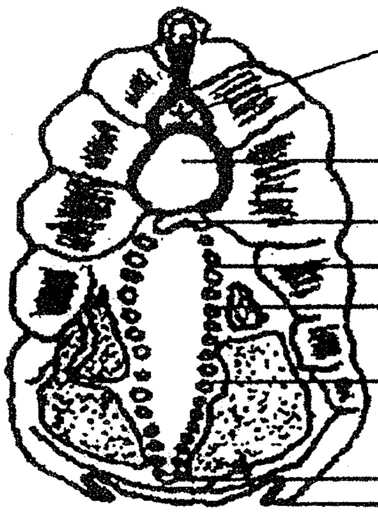

Fig. : Partly dissected amphioxus from the left side illustrating the vertical gill clefts.

Cyclotomes :

In lamprey eight pairs of pharyngeal pouches begin to develop, but the first pair flattens out before long and disappears. Seven pairs of puches remain, each with its internal and external gill slits. At this stage the pharynx connects with the mouth in front and with the esophagus behind. The esophagus and pharnyx become separated in such a manner that each has its own connection with the mouth. The oesophagus then lies dorsal to the pharynx. The latter becomes a blind pouch, the opening of which is guarded by a velum. Seven pairs of gill clefts, which are rather large and spherical. The lamellae are arranged in a more or less circular fashion, but, nevertheless, each gill clefts is borrdered by a hemibranch on both anterior and posterior walls. There are thus 14 hemibranchs on each side but only 6 holobranchs, since the first and last hemibranchs are not parts of holobranchs.

In the hagfish the pharynx connects the mouth and esophagus. Six pairs of gill pouches and internal gill slits are present, but only a single pair of external openings exists. These are situated near the midventral line at some distance from the anterior end. In *Myxine* an oesophageo-uetaneous duct connects the oesophagus with the common exit on the left side. It is similar to a gill cleft but lacks gills.

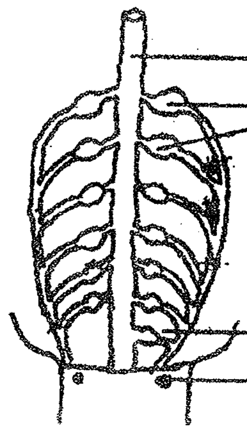

Fig.: Diagram showing relation of gill pouches to the hagfish, *Myxine*, to the pharynx and to the single pair of external apparatus.

Fishes :

Two types of internal gills are to be found in fishes. The first are more primitive, type is found in elasmorbanches and in this group the interbranchial septa are well developed and extend beyond the hemibranchs. Each bends posteriorly at its distal end in such a manner that a row of separate external gill slits is formed. Small cartilaginous gill rays in the form of a single row project from each visceral arch into the interbranchial septum to which they give support. Rigid comblike gill rakers usually project from the gill arches. They prevent food from entering the gill clefts.

The second type of gill is found in the remaining fishes. In these the interbranchial septa are reduced to verying degreees and the hemibranchs project into a single branchial chamber on each side. Two rows of gill rays may be present. The septum of hyoid arch is enormously developed and extends caudad as the operculum; this covers the branchial chambers, which thus opens to the outside through a single gill aperture. Teleosts have four complete holobranchs on each side. No hemibranchs is present on the posterior wall of the last gill cleft except in *Protopterus*. Usually a pliant branchiostegal membrane extends from the operculum to the body wall.

In most elasmobranchs and a few other fishes (Acipenser, Polyodon and Ploylerus) the first gill pouch has become modifed and opens to the outside by means of a spiracle. Rudimentary gill lamellae may be located on the anterior wall of the spiracle. Since the blood supplying these lamellae has been oxygenated, they do not perform a respiratory function. These are called false gill or pseudobranch.

The number of gills and gill clefts varies among fishes. There is some confusion as to just what each represents, since different authors use different number in designating them.

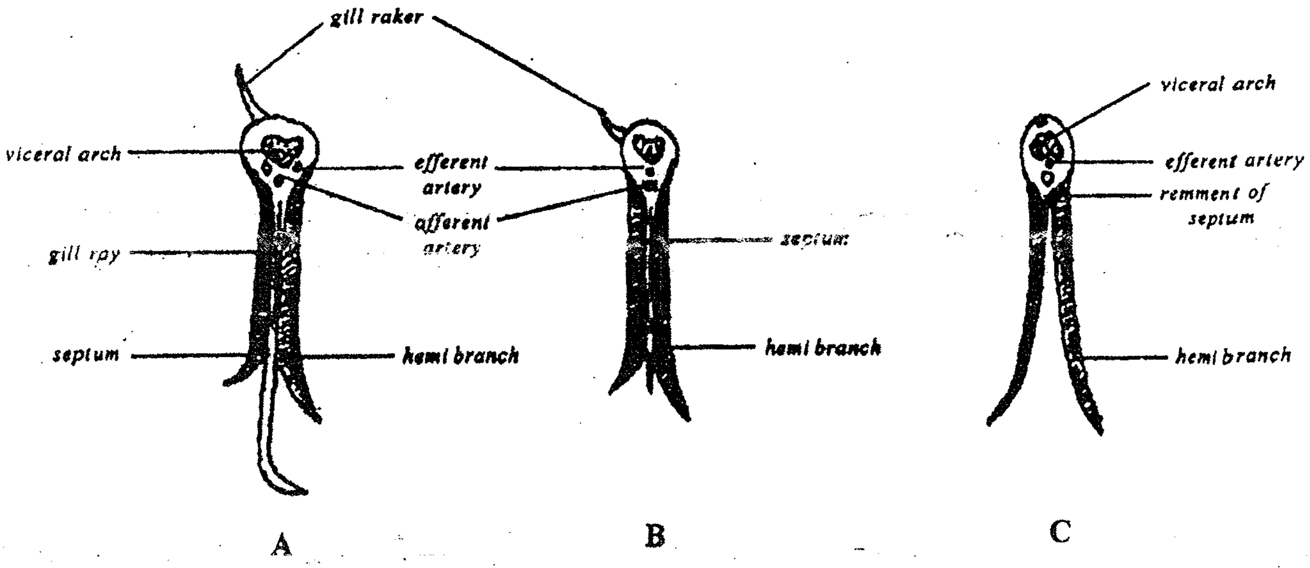

Fig. : Types of fish gills : A. elasmobranch ; B. chimaera ; C. teleost.

Amphibians :

Laval amphibians use external integumentary gills, in additionto the skin, as organs of respiration. The external gills of amphibians consists of tufts of filaments with bases on the third, fourth and fifth visceral arches. The gills are cevered with ciliated epithilium. In the larvae of anurans an operculum develops shortly after the external gills appear. The operculum grows posteriorly, covering the gills, gill clefts, and the region from which the forelimbs will later develop. It then fuses with the body, behind and below the gill region, in such a manner that the gills are confined to an operculum chamber. A small opercular apeture connects the opercular chamber with the outside. The external gills soon degenerate, and a new set of gills develops. Even though these are located within the opercular cavity and are often referred to as internal gills, their homology with internal gills of fishes is questionable. They are actually covered with ectoderm and should be considered as integumentary derivatives. An opercular fold also forms in urodele amphibians but it is much reduced in size and consists of a mere increase immediately anterior to the gill region.

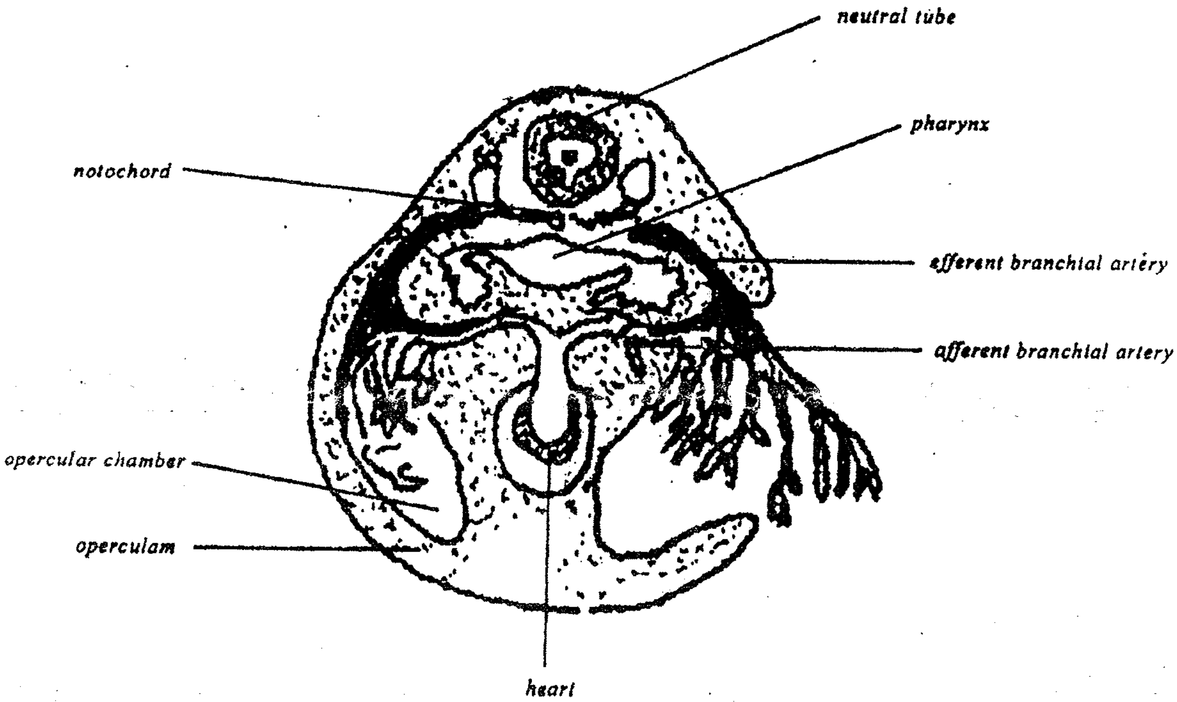

Fig. : Diagram showing relations of external gills of anuran larva before (right) and after (left) the operculum has grown back to enclose the gills in an opercular chamber.

SWIM BLADDERS :

A swim bladder may be single or bilobed and may open into the digestive tract dorsally, ventrally, or not at all. In some of lower fishes the swim bladder functions chiefly as an accessory respiratory organ. It may be Large and extened the length of the body cavity or may be so small as to be practically indistinguishable. The peritoneium covers its ventral surface. Swim bladders which retain the open penumatic duct, or connection with the digestive tract, are said to be physostomous; those which are completely lacking are physoclistus. Only a few physostomous fishes use the swim bladder for respiration. The swim bladder is a gas-filled chamber. In air breathing fishes the swim bladder is lined with low septa and may exhibit thousands of tiny air sacs like tetrapod lungs, they are supplied by arteries arising from the sixth embryonic aortic arch; and in dipnoans the venus return is to the left atrium, as in tetrapods.

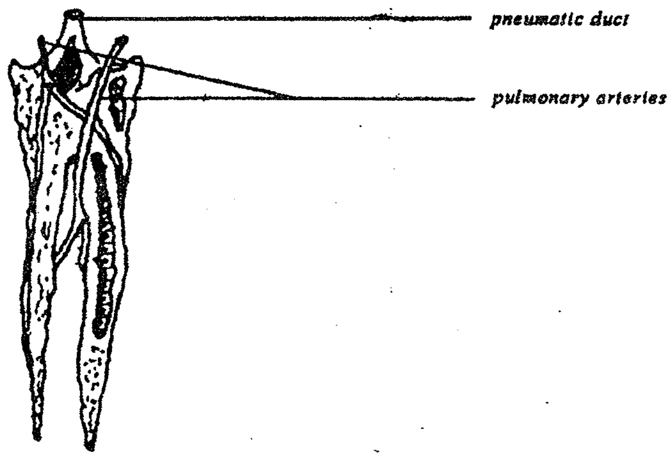

Fig. : Swim bladders of Protopterus.

An oropharyngeal pump forces air from the oropharyngeal cavity into the swim bladder. Expulsion of air from the bladder to the oropharynx is a result of the vaccum created by the oropheryngeal floor while the mouth and nares are closed, elasticity of the bladder, contraction of smooth muscles in its walls and pressure on the body wall exerted by the surrounding water.

LUNGS AND DUCTS :

The diverticulum which in the embryo gives rise to lungs grows out from the floor of pharynx posterior to the last pair of gill pouches. It soon divides into lung buds, which give rise to the bronchi and lungs. The original unpaired duct which connects the lungs to the pharynx becomes the trachea. In many tetrapods its anterior end becomes modified to form a voice box, or larynx, which opens into the pharynx through a slitlike glottis, the walls of which are supported by cartilages.

Larynx :

The skeleton elements supporitng the walls of the larynx are derivatives of certain visceral arches which have become modified. No such structures are to be found in association with the pneumatic ducts of fishes.

In amphibians such as *Necturus* a pair of lateral cartilages bounds the glottis. In other amphibians the lateral cartilages are supplanted by an upper pair of arytenoid cartilages, bounding the glottis, and a lower pair of cricoid cartilages. The latter may fuse to form a cartilagineous ring located within the walls of the larnyx. In anurans two thickend riges of tissue, composed of elastic fibres, project into the cavity of the larynx. These are the vocal cords.

In reptiles the skeleton support consists of a pair of arytenoid cartilages and an incomplete cricoid ring. In crocodilians another element, the thyroid cartilage, is present. A fold of tissue anterior to the glottis in certain lizards and turtles may present the begining of an epiglottis.

In birds larynx is poorly developed and incapable of producing sounds, Another structure, the syrinx, located at the lower end of the trachea is responsible for sound production. Arytenoid cartilages, sometimes ossified, guard the glottis. In some birds the cricoids have separated into additional procriocoids.

In mammals larynx is more complicated and consists of thyroid cartilage, located on the ventral side of the larynx, arytenoid cartilages makes up the posterior portion and criciod makes up the posterodorsal part. Arytenoid and thyroid cartilages articulate with the cricoid. Small corniculate and cuneiform cartilages are sometimes present in close association with the arytenoids. The portion of the larynx in fornt of the trure vocal cords is called the vestibule. A pair of crescentic false vocal cords (ventricular folds) extends into the vestibule for a short distance.

Trachea and bronchi :

The trachea is the main trunk of a system of tubes through air passes between larynx and lungs. It is a cartilagenous and membranes tube, the wall of which are composed of fibrous and muscular tissue stiffened by cartilages with prevent it from collapsing. The trachea is lined with mucous membrane the epithelium of which is composed of columnar-ciliated and mucus-secreting cells. The trachea, in general, divides at its lower end into two bronchi which lead directly to the lungs, but in certain mammals like pigs, whales, a third, the apical bronchus arises independently from the right side of the trachea anterior to the main bifurcation. Cartilagenous rings support the walls of the bronchi in mammals.

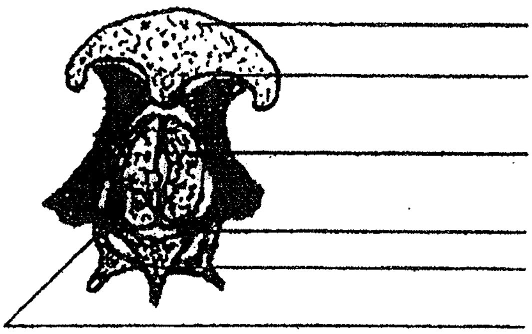

Fig.- Dorsal view of Laryngeal Cartilages of frog Black represented bone, stippled ares cartilage

Lungs :

The lungs of terrestrial vertebrates are saclike structures, the walls of which in most cases are subdivide. The actual respiratory surface of the lung (except in birds) is composed of minute chambers called alveoli.

In amphibians the lungs are relatively simple in structure. In urodeles the lungs consists of a pair of elongated sacs, the left often being longer than the right. In some the lining is smooth, but in others alveoli are present. In frogs and toads the lining is more complex since the wall is thrown into numerous infundibular folds, which in turn are lined with alveoli.

In reptiles the lungs exhibit a wide range of complexity. The simpliest condition is found in *Sphenodon*, in which lungs are simple sacs uniformly lined with infundibula. In lizards, septa or partitions, divide the cavity of the lungs into chambers which communicate with another. In chameleons several thin-walled sac like diverticula come off the distal portion of the lung. Only the proximal end is spongy. The deverticula seem to fore shadow the structure of air sacs found in birds.

In birds the lungs are small, very vascular, and capable of little expansion, being firmly attached to the ribs and thoracic vertabrae. The lower surface of each lung is covered by a membrane into which are inserted muscles arising from the ribs. The portion of bronchus within the lung proper is called mesobronchus. A number of secondary bronchi arise from it. These then branch into numerous small tubes of rather uniform diameters, called parabronchi, which form loops connecting with other secondary bronchi; surrounding each parabronchus are large number of minute tubules, the air capillaries, which form anastomosing networks and loops with each other and open into the parabronchi. The lining of the air capillaries makes up the actual respiratory surface. The mesobronchus and several secondary bronchi continue through the walls of the lung and expand into air sacs, which ramify among the visceral and even enter the cavities of several bones. The air sacs do not furnish a respiratory surface, since their walls are smooth and have a poor blood supply.

In mammals the original lung buds divide many times to form primary, secondary, tertiary etc. bronchi. The smaller bronchi give rise to bronchioles. The terminal bronchioles usually divide into two or more respiratory bronchioles, which then branch into several alveolar ducts. From these arise alveolar sacs (infundibula) lines with alveoli. A single bronchiole and its branches togather form a unit called a lobule. In some species lobules are separated by connective tissue septa. Recent studies

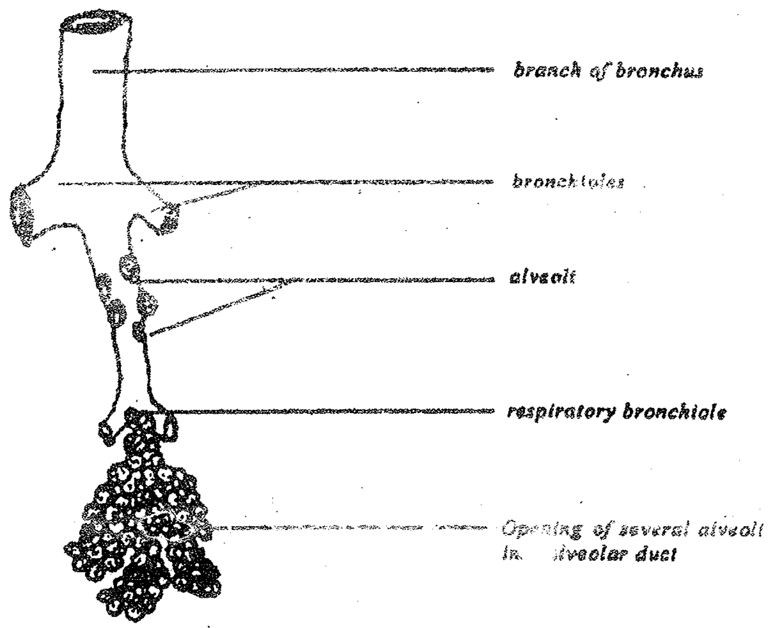

Fig. : Diagram showing terminal branching of a small bronchus in a typical mammalian lung.

using the electron microscope, have revealed details of structure of the interalveolar wall or septum. Despite the thinness of the wall, there are, between the air in an alveolus and the blood in an underlying capillary, the cytoplasm of the epithiliel cells lining the alveolus; the basement membrane of the capillary endothelium; and the cytoplasm of the endothelial cells of the capillary. The entire surface of the lung is covered with serous membrane. the visceral pleura. In most mammals the lungs ae subdivided into lobes, the number verying somewhat in different species.

2. General Consideration of Organs of hearing, balance and echolocation :

The Vertebrate ear usually functions in a dual capacity, serving, at least in higher forms, both as an organ of heraing and of equilibrium or balancing. The structures responsible for this are to be found in all vertabrates with but little variation. The portion of the ear concerned with hearing first begins to differentiate in fishes and becomes more and more complex as the evolutionary scale ascended.

When referring to the ear, our attension is usually directed to the special apparatus found in higher vertebrates for reception of sound waves and their transmission to sensory receptors located in the head. In mammals this apparatus is composed of three portions referred to, respectively, as the outer, middle, and internal ears. The outer and middle ears are concerned only with receiving, amplifying, and transmitting sound waves. They are lacking in cyclotomes, fishes, salamanders, and some others. It is the inner ear in which the sensory cells with long hairlike processes act as receptors. The latter so closely resembles the sensory neuromasts of the lateral-line system that a close relationship is highly suggestive. For this and other reasons the senses of balancing and hearing and of the lateral line are often referred to altogather as the acousticolateral system.

ACOUSTICOLATERAL ORGANS :

The lateral-line system of the acousticolateral sense organs occurs only in cyclostomes, fishes, and aquatic amphibians. Among the functions ascribed to the lateral-line organs, which are sometimes referred to as reheoreceptors, are reception of deep vibrations in the water and of stimuli caused by currents or movements of water, including those minor local currents produced by the animal itself.

The lateral-line system is a somatic sensory system supplied by branches of three cranial nerves, the seventh, ninth and tenth. All three nerves bear ganglia derived in part from thickened placodes in the skin. Because the inner ears arise from similar placodes and because the sensory cells of the inner ear are rather similar in structure to neuromasts of the lateral-line system, the term acousticolateral sustem is used to embrace both systems.

The importance of the lateral-line organs in connection with the aquatic mode of life is indicated by their highly developed supply of branches of cranial nerves and by the fact that they have entirely disappeared in terrestrial forms.

THE EAR :

The epithilium lining the internal ear is of ectodermal origin and first arises as a thickend placode in the superficial ectoderm of the head. Each of the paried placodes invaginates in the form of an auditory pit, which soon closes over to form a hollow auditory vesicle. It loses its connection with the superficial ectoderm, lies close too the brain, and is entirely surrounded by mesenchyme. Extensive changes occur as the octocyst develops further. Its various elements of fibrous connective tissue make up a delicate and complex structure, the membranous labyrinth. This consists of a closed series of tubes and scas lined with epithlium of ectodermal origin.

The primary importance of the internal ear seems at first to have been in balancing, the reception of sound appear later in vertebrate evolution.

Balancing :

The typical membranous labyrinth consists of two chamberlike enlargements, an upper utriculus and a lower sacculus, connected byy a constricted area, the sacculourtricular duct. A dorsomedial evagination of the oticyst, the endolymphatic duct, joins either the sacculus or the sacculourtricular duct. Three narrow tubes, the semicircular ducts, connects at both ends with the utriculus. They are arrenged in planes approximately at right angles to one another and are called external, anterior, and posterior semicircular ducts. The external ducts lies in a horizontal plane, the other two being vertical and at right angles to each other. At its lower end each duct bears an enlargement, the ampulla. The ampulla of the horizontal duct is situated anteriorly close to that of the anterior duct. In lower forms a slight projection of the ventral wall of the scculus may be present. This is the lagena, the forerunner of the auditory portion of the ear of higher forms.

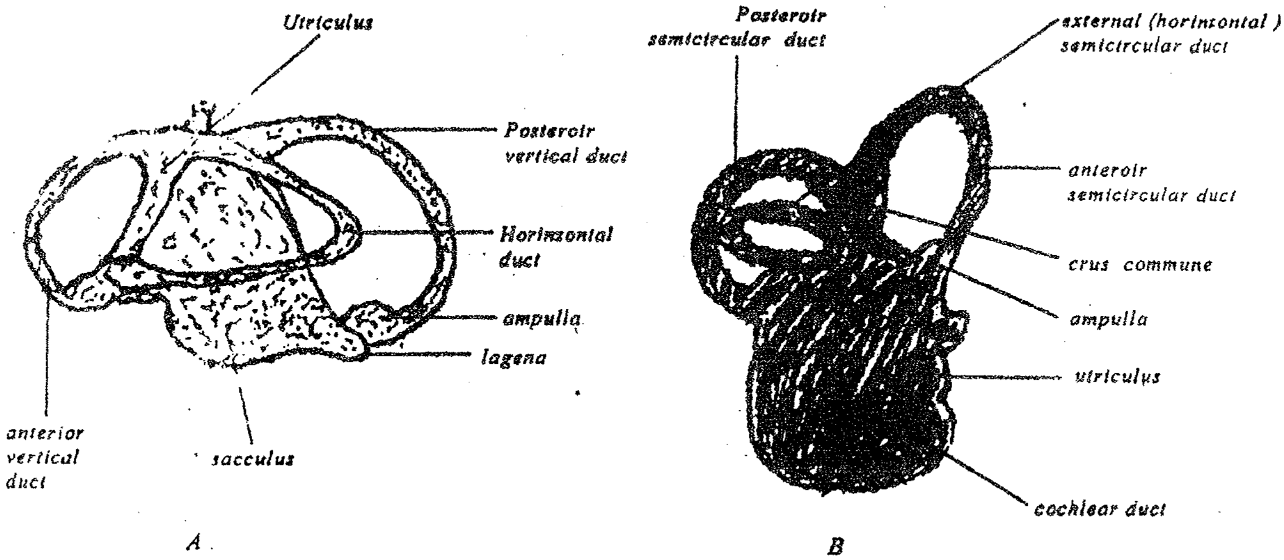

Fig. **Membranous labyrinth : A. dog-fish. B. rabbit.**

The membranous labyrinth is filled with enendolymph, a fluid the viscosity of which is 2 to 3 time that of water. Almost completely surrounding the membranous labyrinth is the perilymphatic space, filled with fluid perilymph, which is actually cerebrospinal fluid. Surrounded the perilymphatic space is cartilage or bone, depending upon the species. In higher forms a bony labyrinth, situated in the temporal bone, encloses the membranous labyrinth and follow all its configurations. The membranous labyrinth in certain places. The semicircular canals are those portions of the bony labyrinth which surrounded the semicircular ducts. They are filled with perilymph.

The actual receptors for the sense of balancing or equilibrium are elevated patches of sensory cells, the cristae ampullares (acousticae) and the maculae acoustiae. The former are located in the ampullae of the semicircular ducts. They are made up of supporting cells and neuromast cells provided with long processes. The maculae, of which there are typically two, are also composed of supporting cells and neuromast cells, the latter bearing short, hair-like process. One, the macula utriculi, lies in the wall of the utriculus; the other, the macula sacculi; is located in the wall of the saculus. In those vertebrates having a lagena, a third macula, the lagena, lies at its base. Both cristae and maculae are innervated by fibers of the vestibular branch of the acoustic nerve (VIII). A thickend mass forms in connection with each macula and covers its surface. This otolithic membrane is composed of gelatinous material into which group of "hairs" from the neuromast cells penetrate. Small crystalline bodies called otoconia are deposited in the outer part of the otolithic membrane. They are composed of a mixture of calcium carbonate and protein. These deposits may be rather extensive, each forming a compact mass, the otolith.

Movements of the endolymph affect the cristae, stimulating the sensory hair cells, thus setting up impulses transmitted to the brain by branches of the acoustic nerve. The cristae give an awareness of movement (kinetic sense), being effected by rotational movements.

Changes in position of the otoliths associated with the macula, in response to gravitational forces, affect the hair cells and give information regarding the position of the body when at rest (stair sense) or of changes in velocity.

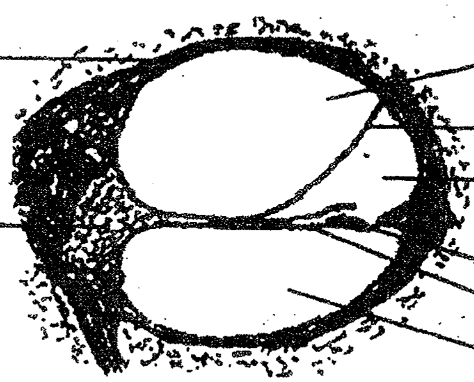

Fig: Semidiagrammatic section through mammalian cochlea, showing the three surrounded by the bony labyrinth.

Hearing :

The development of inner ear, indicates that it may have originated phylogenetically as a specialized section of the anterior part of the lateral-line system which sank down into the skull. There is some evidence that in fishes part of the internal ear became associated with sound.

Teleosts of the order cypriniformes have a chain of small bones, the Weberian ossicioes interposed between the swim bladder and the perilymphatic space, thus relating the function of the swim bladder with the auditory senses. Weberian ossides are derived from the four most anterior vertebrae. In other fishes direct connections may exist between the swim bladder and the inner ears via a long anterior extension of the air bladder which lies along the membrane system of the ear.

In tetrapods the lagena is drawn out or lengthined, to form cochlear duct, and the sensory basilar papilla elaborated into the organ of Corti, which is the actual receptor organs to assume a helical form in mammals. The degree of coiling varies, reaching its epitome in the alpaca, in which it makes five distinct turns. In man only 2 $^{3}/_{4}$ turns are present. The cochlear duct is fastened to the bony labyrinth on either side but is divided into three longitudinal spaces, or chambers, called the scalae. The upper one is the scala vestibuli and the lower the scala tympani. These are filled with perilymph. Between the two is the scala media, or cochlear duct. It is filled with endolymph. The three scalae together make up the cochlea. The floor of the scala media is called the basilar membrane. This separates the endolymph in the scala media from the perilymph in the scala tympani. The thin, sloping roof of the scala media is referred to as the vestibular, or Reissner's membrane. It separates the endolymph in the scala media from the perilymph in the scala vestibuli. At the apex of the cochlea the scala vestibuli is continuous with the scala tympani. The point of junction is the helicotrema. The scala media comes to a point and ends blindly at the helicotrema.

The basilar membrane supports the organ of Corti. The latter is composed of numerous neuromast cells which have connections at their bases with dendrites of the cochlear branch of the auditory nerve. The organ of corti in birds, although structurally different from that of mammals, appears to serve the same function.

Echolocation :

Echolocation means the process of determination the distance of an object by means of sound echo. This sound-based distance sensing system is used by some adult rodents, few marsupials, dermopterans, pinnipeds, many insectivores, microchiropterans bats and odontocete cetaceans.

Morphology adaptation for echolocation :

1) **Nasal Leaf :** Most of the chiropterians have a special folding of epidermis which originates from the lower portion of the nose and surrounds the mouth. While producing sound the nasal leaf encircled the mouth in such that the sound produced is not disappeared in any way. Produced sound goes straight to the object in front of source.

2) **Modified pinna :** In most chiropterans the pinna acts as the recipient of the echo. The pinna is very long and broad and the concha is deeply invaginated. The nerve cells are present in the

lower epidermal region which act as translator of the received sound wave. this modified pinna is supposed to be most effective for echolocation.

*Fig : Modifications of the nose and Pinna of the little brown bat, **Myotis lucifugus**. This modification helps bat to receive refleeted sound during echolocation.*

Bat echolocation :

The echolocation behavior is used by bats for navigation and for capturing food. By use of electronic transducers capable of detection of high frequency sound, a three phase hunting pattern used by bats has been established.

The initial search phase is characterized by fairly straight flight and the emission of ten or so pulsed sounds separated by silent periods of more than milliseconds. Each of the 10 pulses in a call is about 2 milliseconds in duration, and each pulse contributes a downward sweep of frequencies at about 85 KHz and ending near 35 KHz (human audible range is in between 20 Hz to 20 KHz). These bat calls are therefore frequency modulated (FM).

The second phase of hunting pattern begins as a bat detects an insect. Fruit files and mosquitoes can be detected from a distance of about a meter. The interval between pulses shortens, the silent intervals falling to less than 10 millisecond, for *M. lucifagus* one hundred. One hundred cries per second, each lasting only 0.5 to 1 millisecond are typical as the bat alters its flight path to intercept its prey.

Finally, the terminal phase of the hunt is characterized by a buzz-like emission of ultrasound. The intervals between pulses are less than 10 milliseconds, the pulse duration is about, o.5 millisecond, and the frequencies drop to 25 to 30 KHz. When the bat is written a few millimeters of the prey. If often scoops with a wing or with the membrane between it legs and pulls the insect toward the mouth.

To accomplish these amazing flats, bats must hear and recognize high-frequency echoes bounced off the bodies of insects, determine target direction and distance with great accuracy and be able to orient, approach, and capture the insect even though it may be moving. How do they do it?

The bat larynx is typpacilly mammalian. The layrynx is an organ capable of producing sounds of complex frequency and temporal modulation and variation. Modulation of the tension on the vocal cords and entire larynx, the amount of air expelled per unit time through the structure and sometimes by extra taryngeal resonating chamber. Bats produce echolocation sounds without major modification of the enlarged and the fleshy fold of vocal cords are exceptionally thin. The sounds produced by the larynx are emitted through the open mouth or the nose depending on the family of bat. Mouth calls have a wide angle of dispersion (180 degrees or more). They have epidermal flaps and a nostril spacing that concentrates and focuses the sound in a narrow come in front of the bat. The calls travel through the air in redially expending waves at about 34 centimeters per millisecond. Because of dispersion pattern, the amount of sound energy striking a target decreases as the square ofo the distance traveled. A small objects intercepts very little sound energy and thus can reflect very little. An objects size indicated by frequencies in the echo; large objects reflect longer wavelengths (lower frequencies) than small ones. The extremely high frequencies of the emited callss are necessary to detect very small objects. The character of the reflecting surface is indicated by the charecter of the echo. A smooth hard surface such as the exoskeleton of a beetle returns a sharp echo, whereas a blurried echo indicates a rough surface like the body of a mouth. The time required for an echo to return is directly proportional to the distance from the bat to othe target, and the changes in return time between successive calls can indicate the relative movement of the bat and its target. Perception of the direction of a returning echo is aided by the large, complex pinnae and by a neural mechanism known as contralateral inhibition. Stimulation of cells sensitive to a particular frequency in the inner ear on one side of the head produces a transient descensitization of the cells that respond to the same frequency in the ear on the other side of the head. The effect of that desensitization is to increase the contrast between the intensity of sound perceived by the two ears and thus to permit more precise determination of the direction of an echo.

3. Structure and modification of jaw suspension :

The vertabrate skull is derived morphologically from two sources: The neurocranium which surrounds the anterior end of nerve tube and the splanchnocranium which encircles the anterior end if the digestive tube. The splanchnocranial elements called viceral bars become united with one another to form the viceral arches. There are four to nine visceral arches in vertebrates. Of the visceral arches,the first is known as mandibular arch and the second is known as hyoid arch. The rests are known as branchial arches.

The mandibular or first visceral arch is very much modified. It is divided on each side into a dorsal palatopterygoiquadrate bar and a ventral Meckel's cartilage. The mouth cavity is bounded by these components. In all vertabrates except the aganathas, the mandibular arch becomes midified into jaws. The dorsal component of mandibular arch become the upper jaw and the ventral component, the Meckle's cartilages form the lower jaw. The palatopterygoiquadrate bar and Meckle's cartilage join at a sharp angle, located posteriorly of the mouth.

In bony fishes, centres of ossification in the posterior portion of the palatopterygoquadrate bar give rise to such cartilage bones as metapterygoid and quadrate. The anterior part of the bar is reduced and replaced or invested by such membrane bones as the palatine and pterygoid. In elasmo branches the visceral skeleton is typically composed of seven cartilaginous visceral arches surroounding the anterior part of the digestive tract and furnishing support to the gills. The first or mandibular arch is larger and from it both upper and lower jaws are derived. The upper or dorsal palatopterygoquadrate bar articulated posteriorly to the Mackle's cartilage located ventrally. Both cartilages are suspended by a ligaments attachment form the hyomandibular cartilages of the hyoid arch, which is turn is attached to the otic region of the chondrocranium. This is the hyastic method of jaw attachment. Below the hyomandibular cartilage the remainder of the hyoid arch consists of a ceratophyl cartilage and a basihyal which units the ceratohyals of the two sides ventrally.

In holocephalians the skull is composed entirely of cartilage. The Entire palatopterygoquadrate bar is immovabley fused to the cranium. The lower jaws is supended from the quadrate region, and the hyoid arch plays no part in jaw suspension. This is a variation of the autostylic method of jaw suspension. In tetrapods other than mammals a quadrate bone, with which the lower jaw articulates, is also formed by direct ossification of the posterior end of the palatopterygoquadrate bar. An epipterygoid, corresponding to the metapterygiod of fishes, develops anterior to the quadrate. The quadrate forms a firm union with the otic region of the chondrocranium. This method of suspending the jaws via the quadrate is termed the autostylic methods of jaw suspension, in contrast to the hyostylic methods in which suspension is by means of the hyomandibular.

In jay primitive sharks a type of jaw suspension is found where both the palatopterygoquadrate bar and hyomandibular cartilage of the hyoid arch are united with the otic region of the chondrocranium. This type of suspension of jaw is called amphistylic method.

In higher vertebrates the original Meckle's cartilage forming the lawer jaw becomes much modified with bony skeletons. The posterior region is usually replaced by a cartilage bone, the articular. This forms an articulation with the quadrate. In salientic amphibians at the point whee the two halves of the lower jaw join in front, a small cartilage bone, the mentomeckelian, develops on either side. The remainder of Meckle's cartilage serves as a core about which several membrane bones form a sheath.

The separate elements which, for the part enter this complex are (1) an anterior dentary (dental), surrounding Meckle's cartilage; (2) a median splenia; (3) a ventral angular; (4) a posteriolateral suprangular; (5) a dorsolateral coronoid; (6) a gonial lying below and to the median side of the articular.

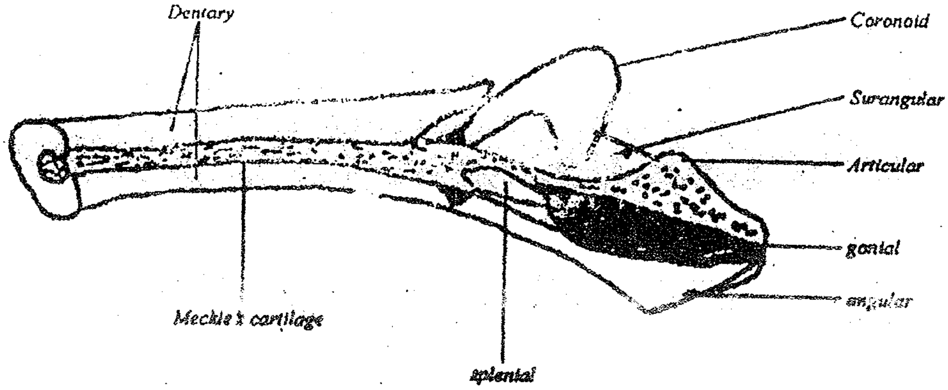

Fig. : Position of membrane bones forming about Meckle's cartilage in the development of the lower jaw.

Many modifications of the bones present. They exist as separate elements in amphibians and reptiles, but in birds they begin to unite. In mammals the lowr jaw consists of a single bone, the mandible. It represents the dentary of lower forms, the other elements having been lost except for the articular, which has become the malleus, one of the auditory ossciles.

In tetrapodes below mammals in the evolutionary scale, the articular bone of the lower jaw articulates with the quadrate of the upper jaw. Both of these are cartilage bones. In mammals the articular and quadrate are modifed to form malleus and incus respectively. A new articulation of the lower jaw with the squamosal, a mambrane bone of the maxillary arch is then established. This occurs only in mammals. Despite this difference the method of jaw suspension in mammals is considered to be autostylic by many authrorities. Others believe that a distinction should be made and have applied the terms craniostylic and amphicraniostylic to the mammalian method.

The hyoid or second visceral arch does not become so highly modigied as the mandibular arch during its evolutionary history. In elasmobranchs it is usually composed of three cartolages, a dorsal hyomandibular, a lower ceratohyal and a small ventral, medium basihyal which serves to unite the cerotohyals fothe two sides. In higher fishes several cartilage bone may be derived from the hyoid arch, although their appearance and number are highly variable. In general they are named as follows in a dorsoventral sequence : hyomandibular, interhyal, epihyal, ceratohyal and hypohyal. A small median basihyal units the hypohyals of the two sides. A syspletic bone, derived from the hyomandibular and found only in teleost fishes, extends forward from the ventral end of the hyomandibular near its junction with the interhyal and articulates with the quadrate. In tetrapods the hyomandibular is reduced and gives rise to the columella, or to the stapes of the middle ear.

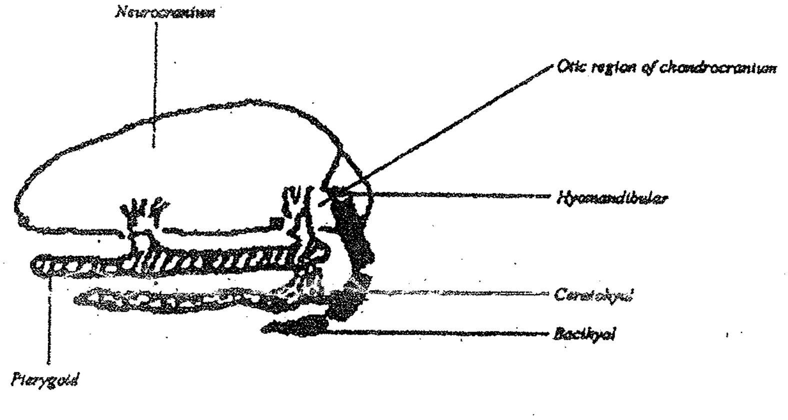

Fig. : Amphistylic type of jaw suspension.
(Primitive Shark)

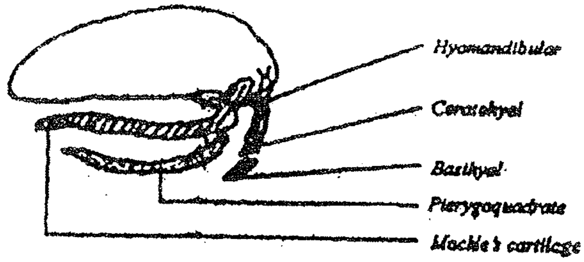

Fig. : Hyostylic jaw suspension (Bony fish, some elasmobranch)

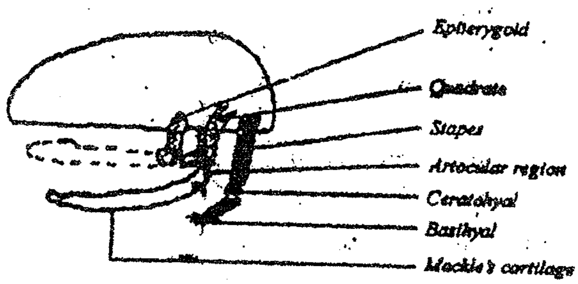

Fig. : Autostylic suspension (Tetrapods)

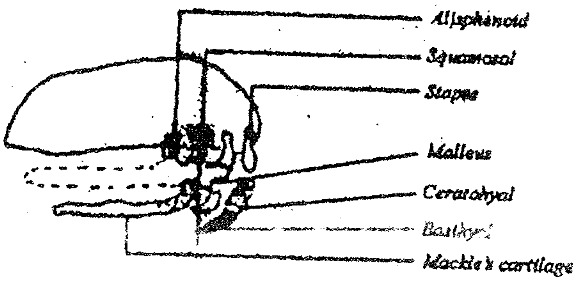

Fig. : Variation of autostylic (Mammals)

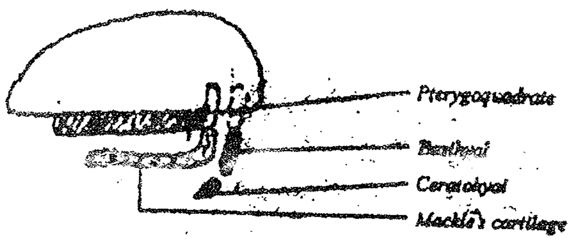

Fig. : Variation of autostylic (Holocephali)

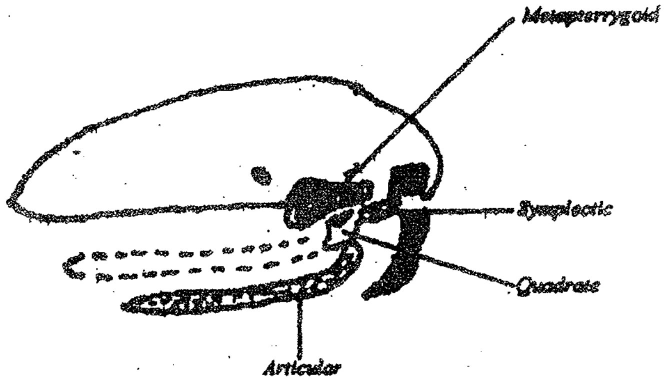

Fig. : ***Variation of hyostylic (Hyocraniostylic) (Mammals, tetrapods)***

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VIDYASAGAR UNIVERSITY

DIRECTORATE OF DISTANCE EDUCATION
MIDNAPORE - 721 102

M. Sc. in ZOOLOGY

Paper - I, Part-I, Group-B, Unit - I

Module No. 7

Topic : General characters and classification of class insecta upto orders; Insect's digestive system with special emphasis on midgut, filter chamber and peritrophic membrane 'insects' neuroendocrine system (integument), moulting and metamorphosis.

GENERAL CHARACTERS AND CLASSIFICATION UPTO ORDERS OF INSECTS

What is Entomology : It is a branch of zoology which deals with insects. It aims at understanding their body organizations and functions, their habits, behaviour, relation to one another and to the surroundings in which they live, their classification, development, distribution, origin, past history and economic importance.

General Characters of Insects

i) Body divisible into three parts – Head, Therax and abdomen with relatively though integument.
ii) Three pairs of externally jointed legs and one or two pairs of wings confined to the thorax.
iii) One pair of compound eyes.
iv) One pair of antennae.
v) A variable number of simple eyes or the ocelli (1 – 3) are present on the head.
vi) Head is formed by the fusion of six anterior segments in course of development of insects.
vii) The thorax is three segmented and the abdomen is with eleven segments.
viii) The mouth, composed of specialised mouth-parts opens in the head and anus at the posterior end of the body.
ix) The alimentary canal is differentiated into foregut, midgut and hindgut.
x) Open circulatory system with dorsal tubular heart in pericardial space with paired segmental ostia but without arteries or veins.
xi) Respiration is by tracheal system.
xii) Exeretion is by malpighian tubules.
xiii) The sexes are separate and respiration in many cases take place parthenogenetically.
xiv) The nervous system is with ventral nerve cord, with three paired ganglia in the thorax and one pair of ganglia in each abdominal segment, except the last.

xv) The sense organs include simple and compound eyes, olfactory, tactile and auditory organs.
xvi) Light and sound producing organs are not uncommon.
xvii) Development often with pronounced metamorphosis.

Insects are the most dominant group of animals on the earth at present. The total number of species of insets so far described from the world exceeds one and a half millions representing nearly 90% of the animal kingdom. The single order coleoptera or beetles alone consists of over 3,70,000 named species. Even the one family Curculionidae or Weevils includes more than 60,000 known species while Carabidae or ground beetles, number about 25,000 species. This remarkable diversity of insects generates interest to consider some attributes which have probably helped the members of this class to attain their dominant position in the animal kingdom.

(a) ***Small Size*** : The great majority of insects are quite small, require little food and can easily seek shelter from adverse weather and enemies by entering crevices, hiding under the bark of trees and fallen leaves.

(b) ***Shape*** : Variable shapes of insects are advantageous for their abundance. Some insects are spherical, others are flattened like a leaf or elongated like a stick and still others have different shapes clothed with hairs, scales, spines, horns and other such appendage.

(c) ***Strong Exoskeleton*** : The Chitinous exoskeleton combined with the small size gives the insects great physical strength and allows numerous modifications in the configuration of the body. Because the exoskeleton is rigid and inextensible, the growing insect must shed it periodically during time of moulting.

(d) ***High mobility through flight*** : Insects are very mobile creatures and can easily seek food and mates, escape from their enemies and disperse for fresh colonization. Apart from flying, they can also run, jump or take long leaps with great agility and strength.

(e) ***Adaptability*** : No other class of animals has no thoroughly invaded and colonized the globe as the insects. Their distribution ranges from the poles to the equator; every species of flowering plant provides food for one or more kind of insect while decomposing organic materials attract and support many thousands of different species. Many species are parasites on or within the bodies of other insects or different animals including vertebrates. The soil and freshwater supports their own characteristic insect fauna. Diversity of insects in marine environment has not yet been explored properly. Some species can withstand temperatures of about – 50°C while others live in hot springs at over 40°C or in desert with more than 50°C day temperature. Hibernation, aestivation and diapause are different physiological mechanisms which insects adopt to over-come temperature related problems.

(f) ***Efficient Water Conservation*** : Insects resist desiccation by various modifications of the exoskeleton and also by conserving body water. The cuticle is provided with a thin layer of waxy material which greatly reduces transpiration from the surface of the body and the openings of the tracheal system, known as spiracles, are provided with closing mechanisms. They can retain metabolic water in the body by avoiding liquid excretion and void crystalline uric acid instead.

(g) ***Tracheal respiration*** : The characteristic tracheal respiratory system of insects tends to limit and requires modifications to offset this disadvantage and to restrict water loss. In other respects, however, the tracheal respiration is very efficient and the direct carriage of gaseous oxygen to within very short distances of the respiring tissues had enabled insects to evolve the very high rates of metabolic activities needed to achieve rapid flight.

(h) ***Rapid Reproduction*** : Their powers of reproduction are astonishing. Most of the insects feed on plants, [illegible] which have a short seasonal growth. They are adapted to complete the life cycle within that period and produce progeny prolifically.

(i) ***Complete Metamorphosis :*** The more highly evolved types of insect life-cycle entail a transition from the immature juvenile stages (Larvae → pupa → adult in holometabolus insects and nymphs → adult in heimetabolus insects). In both the cases, it allows the juvenile and adult to exploit different food resources and occupy different ecological niches.

Remarks : All the above mentioned factors and their role in insects' life help explaining why they have persisted from pre-carboniferous times with increasing diversity, far beyond that of any other groups of animals.

ANATOMICAL EXCELLENCE OF INSECTS :

Segmentation and Body Regions:

The body of an insect is essentially double tube-one within the other. The outer tube represents the body wall while the inner one is the alimentary canal. The former is primitively divided into a metameric series of cylindrical parts, the segments separated by segmental membranes. This metameric segmentation started with developing embryo manifests itself in some internal organs. Thus, the body musculature, nervous system, tracheal system and heart all show, to varying degrees, a longitudinal repetition of parts.

The Body regions:

The insect body consists of 20 primitive segments all of which may be apparent in the embryo, grouped into three well defined regions or tagmata – the head, thorax and abdomen. The head is formed of six segments, thorax consists of three segments, each of these carries a pair of legs and the last two segments are endowed with a pair of wings in pterygote insects. The abdomen consists of 11 segments and a terminal non-segmental telson.

The division of a segment:

In most insects, each segment is divisible into three regions viz. a dorsal (tergum); a ventral (sternum) and a lateral region (pleuron). In many soft-bodied larvae, and other Diptera, the cuticle is membranous and each segment is simple ring without division into separate areas.

THE HEAD AND ITS APPENDAGES :

The head is the anterior-most part of the body. It bears the mouth parts and important sense organs. On the outside it is marked by grooves of which indicate ridges on the inside, and some of these inflexions extend deep into the head, fusing with each other to form an internal skeleton.

The insect's head is formed by the fusion of six body segments. At an early period of development, the insects' embryo becomes differentiated into a broad unsegmented procephalon and a long unsegmented trunk region. The procephalon soon develops into three primary cephalic segments, which fuse with three simultaneously formed trunk segments in order to form the head of insects. The six segments constituting the head (Fig. 1) of insects are as follows :-

i) The preantennal segment – that bears the compound eyes.
ii) The antennal segment.
iii) The intercalary segment that bears no appendages and is homologous with the second pair of antennae of crustacea.
iv) The mandibular segment.
v) The maxillary segment.
vi) The labial segment.

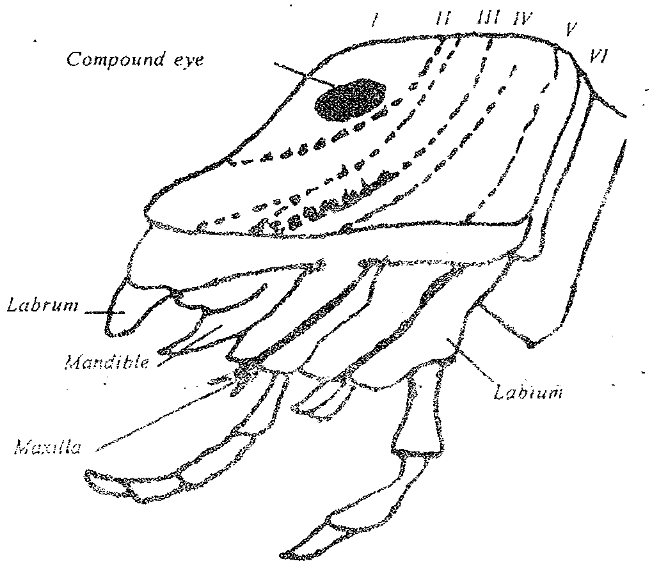


Fig. I Diagrametric representation of different segments of insects head

STRUCTURAL PECULIARITIES OF INSECTS' HEAD

The head of the adult insects bear no visible lines of fusion of the component segments. The sclerotized head capsule is open behind and below. Its ventral margin functions as the articulating surface for the mouthparts. The sclerotic wall serves not only to protect the internal organs of the head, but also provides attachment to the muscles of the mouth parts and pharynx.

The followings are among the more important of the cephalic sutures :- (Fig. II & III)

1. The epicranial suture – typically in the form of an inverted 'Y' along which the skin ruptures at the time of moulting.
2. The occipital suture runs across the back of the head and strengthens the posterior part of the cephalic capsule.
3. The postoccipital suture lies close to the posterior margin of the head that indicates the line of the fusion of the maxillary and the labial segments.
4. The epistomal suture acts as a brace between the anterior mandibular articulations.
5. The subgenal suture strengthens the lateral margin of the head above the mandibular articulations which is a continuation of the epistomal suture to the postoccipital suture.
6. The circumocular suture strengthens the rim of the eye and may develop into a deep flange protecting the inner side of the eye.
7. The sub-occular suture connects the subgenal suture with the circumocular suture.
8. The circumantennal suture strengthens the head at the point of insertion of the antenna.

AREAS OF THE HEAD :

1. The front of the head, the frontoclypeal area is divided by the epistomal sulcus into the frons above and the clypeus below.
2. Dorsally, the frons continues into the vertex and posteriorly this is separated from the occiput by the occipital sulcus.

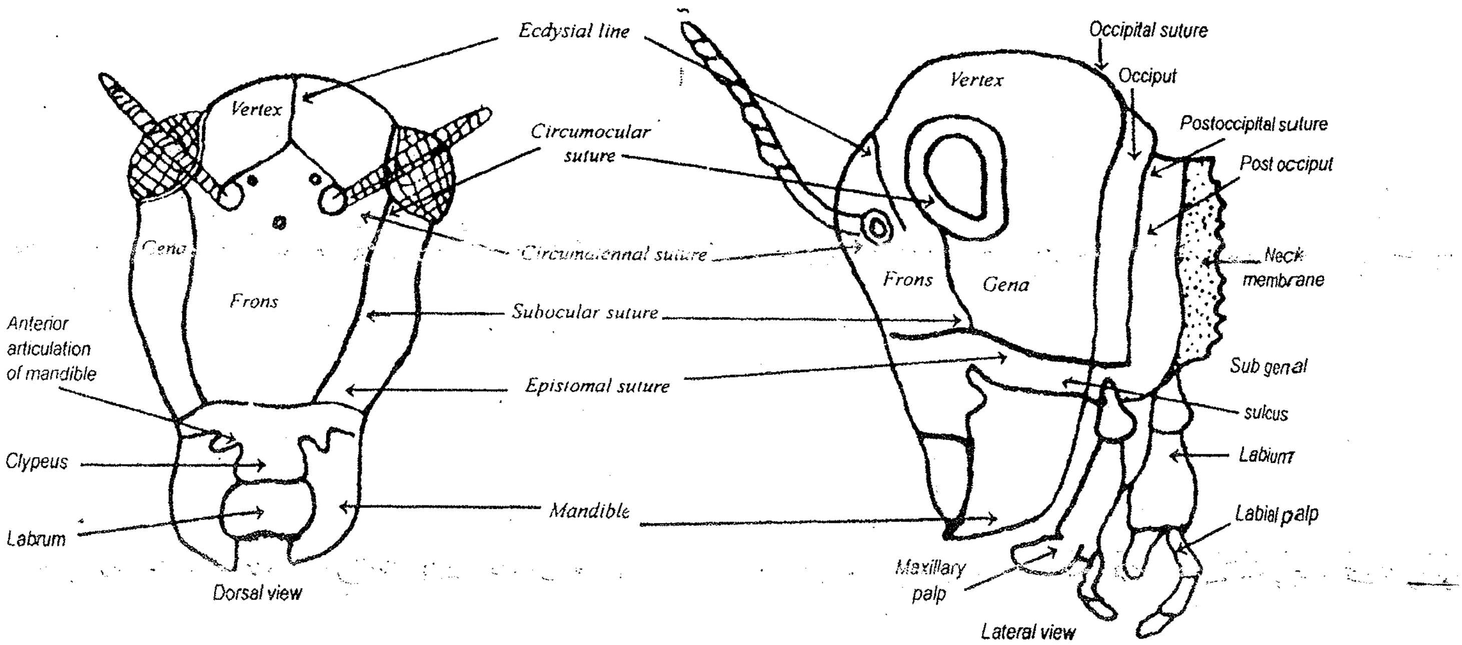


Fig. II & III : Detailed structures within insect's head.

3. The occiput is divided from the postocciput behind it by the postoccipital suture where the back of the head where it joins the neck is an opening – the occipital foramen through which the alimentary canal, nerve –cord and some muscles pass into the thorax.
4. The lateral area of the head beneath the eye is called the gena, from which the sub-gena is cut-off below the subgenal sulcus and the postgena behind by the occipital sulcus.

THE THORAX AND ITS APPENDAGES:

The thorax is the most muscular portion of the insect body and consists of three segments – prothorax, mesothorax, and metathorax which are more or less immovably attached with one another.

THE LEGS :

In most insects all three segments bear a pair of legs excepting larval Diptera, larval Hymenoptera, larval coleoptera and a small number of insects which are apodus. The development of longer legs to facilitate fast running necessitates a reduction in the number of legs for functional efficiency and six is the smallest number which gives continuous stability during movement at a variety of speeds. Mechanical efficiency also requires the placing of these legs close together behind the head and it is believed that as a result of these mechanical and functional requirements, the insect thorax was evolved. (Manton, 1953, 1977)

The six basic segments of a typical leg consist of coxa, trochanter, femur. tibia, tarsus and pretarsus (Fig. IV) – (1) The coxa in the form of a truncated cone and articulates basally with the wall of the thorax. (2) The trochanter – is a small segment with a dicondylic articulation with the coxa such that it can only move vertically. (3) The femur is often small in larval insects, but in most adults, it is the largest and stoutest part of the leg. (4) The tibia is the long shank of the leg articulating with the femur by a dicondylic joint so that it moves in a vertical plane. (5) The tarsus is usually simple but in most insects it becomes sub-divided into two to five tarsomeres. The basic insects walking legs may be modified in various ways to serve a number of functions like jumping, swimming, digging, grooming and stridulation.

WINGS :

The adult insects have two pairs of wings articulating with the thorax and consisting of flattened lobes of the integument supported by hollow veins. Fully developed and functional wings occur only in adult insects, although the developing wings may be present in the larvae. In hemimetabolus larvae they are visible as external pads but they develop internally in holometabolous forms.

The fully developed wings of all insects appear as thin, rigid flaps arising dorsolaterally from between the pleura and nota of the meso and metathoracic segments. Each wing consists of a thin membrane supported by a system of tubular veins. The membrane is formed by two layers of integument closely apposed. The veins in the wings are formed when the layers remain separate and the cuticle in the region is heavily sclerotised. Within each of the major vein, is present atleast a nerve and a trachea. As the cavities of the veins are connected with the haemocoel, the haemolymph can circulate round the wings.

On the anterior margin of the wing in some groups is present a pigmented spot, known as Pterostigma, which helps movement of wings. This is present in both pairs of wings of Odonota and on the forwings of many Hymenoptera, Psocoptera, Megaloptera and Mecoptera.

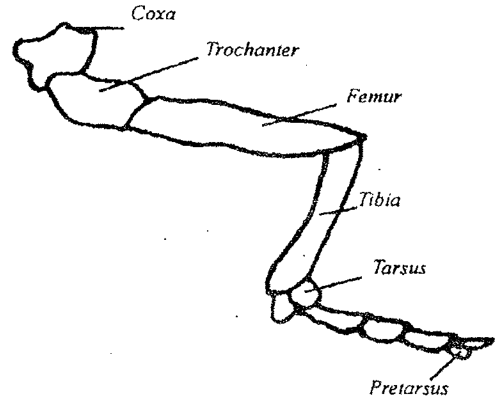


Fig. IV : Different parts of insect's legs

DIFFERENT REGIONS IN THE WING :

Each wing of an insect has the anterior costal margin, the outer opical margin and the posterior anal margin. The angle at the base of the costal margin is called humeral angle and that between the costal and apical margin is called the apical angle (Fig. –V).

VENATION OF THE WINGS:

Wing venation is extremely variable among insects and is important in classification of insects. In most living insects, the venation consists of a number of well-marked longitudinal veins along the length of the wing and connected by a variable number of cross veins (Fig. V). The venation comprises six principal longitudinal yeins viz. the costa (C), the radius (R) and the medius (M) formed around the branches of the anterior wing trachea and cubitus (Cu), the penultimate (P) and the ultimate (U) formed around the branches of the posterior trachea. Each of these main veins forks near the base into a subvein.

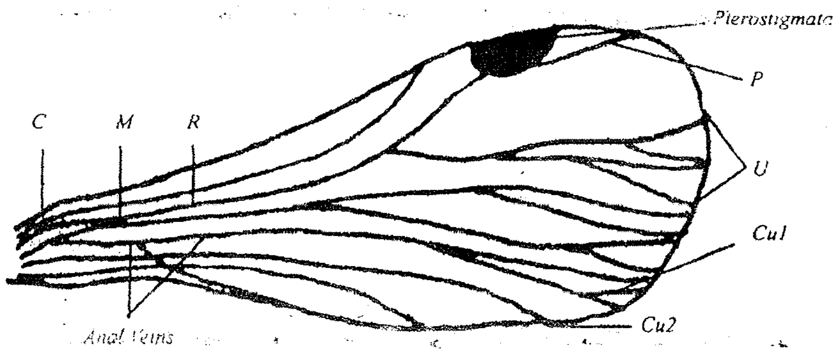


Fig. V : Insects wings.

MODIFICATION OF THE WINGS

The surface of the wing membrane is often set with small non-innervated spine called microtrichia as found in Trichoptera. In Lepidoptera, the wings are clothed with scales. These vary in form from typical hair like structures to flat plates and they usually cover the body as well as wings. Pigments in the scales are responsible for the colours of many lepidoptera – the pegments being in the wall or in the cavity of scale. In many insects which have the fore wings hardened, such as Orthoptera and Coleoptera, the forewing is wholly pigmented.

Besides, in primitive insects, the two pairs of wings are equally large, semi-circular membranous structures, with the costal veins in the middle, a complete set of other veins and an infinite number of the ultimate veins. Modern insects have eliminated the precostal area, as in efficient flight the principal stress is received by the front margin of the wing. The middle part of the wing is elongated. The anal area is reduced and the anterior veins have greatly fused together.

The modifications for efficient flight also include a differentiation in size and form of the fore and hind wings.

REDUCTION OF FORE WINGS

In many insects like Blattaria, Acridodea, Odonata, Coleoptera etc. the fore wing is as a rule smaller than the hind wing. When the fore wing is greatly reduced and instead of taking an active part in flight they serve as a protective cover for the delicate hind wing when at rest and is known as elytra in Coleoptera. In Strepsitera the fore wing is reduced to haltare like stumps, in Orthoptera as leathery tegmina, and in Hemiptera as semi elytra. In some parasitic insects like bedbug, lice, fleas etc. have lost their forewings completely.

REDUCTION OF HIND WINGS

The hind wings have been reduced to a mere stub -- haltere in Diptera. In Lepidoptera and Hymenoptera the hind wing is greatly reduced and flight is effectively undertaken by forewings.

EVOLUTIONARY SIGNIFICANCE OF REDUCTION OF WINGS

In the course of their evolution, insects have reduced and lost their wings many times, so that we find numerous apterous forms in typically winged groups. Some groups lost their wings very early in the phylogeny of insecta and others are loosing wings at present. There is a tendency even in nearly all modern orders to specialise into apterous forms viz. Blattaria, Isoptera, Psocoptera, Orthoptera, Dermaptera, Lepidoptera and Diptera. It is noticed in all of these groups transition from the fully winged through subpterous to the completely apterous condition. In Diptera alone over 400 species show evidence of progressive loss of wings resulting in micropterous (smaller than normal and not fitted for flight) brachypterous (smaller, not fitted for flight but broad, shorter than abdomen); stenopterous (very narrow and not fitted for flight) and apterous (completely reduced to scale).

Apterous condition is associated with alteration of generation viz. Aphids. Reduction and loss of wings are often results of specialised mode of life like parasitism, life in isolated oceanic islands, on alpine zones of high mountains, extremely cold and windy habitats, subterranean mode of life etc.

THE ABDOMEN AND GENITALIA

The insect abdomen is segmental origin, consisting of a series of similar segments (11 segments) and a terminal non segmental telson. A typical abdominal segment contains a well tergum and sternun connected laterally by the pleural membrane. In the embryos of many insects each abdominal segment bears a pair of appendages, a varying number of which are retained in a reduced or highly modified condition in young and adult Apterygotes. The order Protura retain a distinct telson and is peculiar in showing anamorphosis -- the newly hatched stage has eight segments and telson, but subsequent stages acquire another three segments which develop from the front of the telson. The collembola also display an unusual condition by possessing only six abdominal segments both in the embryo and afterwards. In the order Dipluzra, sternum bears styles but the coxites of which fused with the sterna. In Thysanura, the pleural sclerites representing the expanded limb bases remain distinct. In general, first 11 abdominal segments are without appendages but aquatic larvae often have segmental gills while many holometabolus larvae especially amongst the Diptera and Lepidoptera, have lobe –like abdominal legs, called pro-legs.

EXTERNAL GENITALIA

In both sexes these are usually said to be derived from highly modified abdominal appendages. In the male the genital segment is the ninth abdominal one and its appendages typically form the genitalia. When complete these consist of (a) a pair of lateral claspers which grip the female in copulation and between which lies (b) the median aedeagus or penis which is flanked by (c) a pair of parameres. In the female, the paired appendages of the genital segments (eighth and ninth) then typically form the ovipositor or egg-laying organ. Generally, the ovipositor consists of three paired valves associated basally with one or two pairs of small plate-like sclerites often formerly referred to as valvifers. In higher Hymenoptera (wasps and bees) the oviposter is no longer used for laying eggs but has become modified to form a poison injecting apparatus-sting.

CLASSIFICATION OF INSECTS

The classification of insects into various orders is based on the presence or absence of wings and their venation, the type of mouthparts, the type of metamorphosis and the characteristics of antenae and tarsi. The undermentioned classificatory scheme is based on Richards and Davies (1997).

The class insecta has two sub classes :

I. ***Apterygota :-*** The wingless insects include.

1. Thysanura
2. Diplura
3. Protura
4. Collembola

II. ***Pterygota:-*** The winged insects are placed in two divisions.

A. ***Exopterygota :***

i) Metamorphosis is with nymphal stages and there is rarely a pupal instar.

ii) Wings developed externally.

The orders included in this are :-

5. Ephemeroptera
6. Plecoptera
7. Odonata
8. Orthoptera
9. Grylloblattoidea
10. Phasmida
11. Dermaptera
12. Embioptera
13. Dictyoptera
14. Isoptera
15. Zoraptera
16. Psocoptera
17. Mallophaga
18. Siphunculata
19. Hemiptera
20. Thysanoptera

B. Endopterygota

i) Metamorphosis is with larval stages and there is a pupal stage.

ii) Wings developed internally.

The orders included in this division are

21. Neuroptera
22. Mecoptera
23. Lepidoptera
24. Trichoptera
25. Diptera
26. Siphonaptera
27. Hymenoptera
28. Coleoptera
29. Strepsitera

CLASSIFICATION OF INSECTS WITH CHARACTERS

***Apterygote Insects* : Order – 1 Thysanura (Bristle – Tails)**

i) Ectognathous mouthparts – adapted for bitting; head bradly sessile and very little movable.

ii) Antennae many segmented (more than 30)

iii) Tarsi with 2-5 segments.

iv) Abdomen 11 segmented with a variable number of lateral, styliform pregenital appendages.

v) Metamorphosis absent or insignificantly visible. **Example – Silver Fish.**

Order – 2 : *Diplura* (Diplos – double; oura – a tail)

1. Mostly unsegmented insects without eyes; Head oval and subdivided by ecdysial line.
2. Entognathus mouthparts adapted for biting.
3. Antennae many segmented.
4. Abdomen 11-segmented terminating in a paired cerci of variable form or unjointed forceps.
5. Tarsi one segmented.
6. No ovipositor.
7. Malpighian tubules vestigial or absent.

Example : About 600 species are known; all are soil inhabiting *e.g. Heterojapyx* sp (largest species)

Order – 3: *Protura* (Protos-first; oura-a tail)

1. Minute colourless insects without eyes or antennae: Head pyriform and narrowing anteriorly.
2. Entognathus mouthparts for piercing.
3. Abdomen 11 segmented with a definite telson.
4. Cerci absent.

Example : *Acerentomon doderoi.*

Order – 4 :*Collembola* (Spring-tails)

1. Very small with entognathus, bitting mouth parts; head freely movable.
2. Antennae 4-segmented – the first 3 segments with intrinsic muscles.
3. Compound eyes absent.
4. Abdomen 6 – segmented sometimes fused together – 1st segment with a sucker – like ventral tube and 4th usually with a forked springing organ.

Example : *Tomocerus*

Pterygot insects :

Exopterygota

Order – 5 : *Ephemeroptera* (Ephemeros – living a day; pteron – a wing)

1. Short lived.
2. Minute antennae (setaceous) and atrophied mouthparts.
3. Wing membranous, hind pair reduced.
4. Abdomen with a slender, many jointed cerci usually accompanied by a median caudal filament.
5. Nymphs aquatic with filamentous tracheal gills.

Example : *Mayflies*

Order – 6 : *Odonata* **(Odontos-a tooth)**

1. Predacious insects with bitting mouth parts endowed with toothed mandibles.
2. Bitting mouthparts – strongly toothed.
3. Two equal or subequal pairs of elongate, membranous wings with numerous cross veins; each wing with a pterostigmata
4. Antennae very short and filiform.
5. Eyes very large and prominent.
6. Cerci small – one segmented.

Example – Dragonflies

Order – 7 : ***Plecoptera*** **(Plekein – to fold; pteron – a wing)**

1. Soft bodied with long thread – like antennae and cerci.
2. Tarse three segmented.
3. Wings membranous – hind pairs with enlarged anal lobe.
4. Bitting mouth parts -- with four – lobed ligula.
5. Nymphs aquatic with filamentous tufted gills.

Example : Stonflies

Order – 8 : *Grylloblattoidea*

1. Apterous.
2. Reduced eyes, no ocelli.
3. Antennae moderately long, many segmented & filiform.
4. Mandibulate mouthparts – adapted for chewing.
5. Legs approximately similar to each other with 5 segmented tarsi.
6. Females with well developed long ovipositor.
7. Male genitalia asymmetrical.
8. Cerci long, 8 segmented.

Example : Small order with only eight species in three genera – **found mainly in the rocky mountains /hilly tracts – Example : *Grylloblatta* sp.**

Order – 9 : *Orthoptera* **(Orthos – Straight; Pteron – a wing)**

1. Mandibulate mouthparts for bitting.
2. Fore wings modified into tegmina that lie straight.
3. Hind limbs usually enlarged modified for jumping.
4. Tarsi 3-4 segmented.
5. Female with well developed ovipositor.
6. Short unsegment cerci.
7. Specialised auditory and stridulatory organs frequently developed.

Example : Grassoppers, Locusts & Crickets

Order – 10 : *Phasmida* (Phasma- an apparition)

1. Large, apterous or winged insects, more rarely depressed & leaf – like.
2. Mouth parts for bitting.
3. Prothorax short, meso and metathorax usually elongate.
4. Legs similar to one another, tarsi almost always 5 – segmented.
5. Cerci short – unsegmented.
6. Ovipositor complete but concealed.

Example : Stick and leaf insects (Phyllium sp)

Order – 11 : *Dermaptera* (derma – skin; pteron –wing)

1. Elongated insects with typical mouth parts.
2. Fore wings modified into very short tegmina devoid of veins.
3. Hind wings semicircular, membranous, with the veins highly modified and disposed radially.
4. Tarsi 3-segmented.
5. Cerci unjointed and almost always modified into heavily selerotized forceps.
6. Ovipositor reduced or absent.

Example : Earwigs *(Forficula auricularia)*

Order – 12 : Embioptera (Web-spinners – genus, Embia; pteron – a wing)

1. Gregarious insects living in silken tunnels.
2. Elongated and soft bodied.
3. Bitting mouthparts.
4. Tarsi 3 segmented and first segment of the first pair is swallen and carries silk glands.
5. Females apterous.
6. Cerci 2- segmented, generally asymmetrical in the male.

Example : *Embia major*

Order – 13 : Dictyoptera (Dictyon – a network; pteron – a wing)

1. Mandibulate mouthparts.
2. Antennae filliform with numerous segments.

3. Fore wings are thickened to form tegmina.
4. Coxae large and the tarsi 5-segmented.
5. Cerci many segmented.

Example : Cockroaches, Mantids.

Order – 14 : Isoptera (isos – equal; pteron – a wing)

1. Social and polymorphic species living in large communities composed of reporductive forms together with numerous apterous, sterile soldiers and workers.
2. Bitting mouthparts.
3. Wings very similar, elongate and membranous.
4. Tarsi always four segmented.
5. Cerci very short.

Example : Termite.

Order – 15 : Zoraptera (Zoros – Pure; apteros – wingless)

1. Winged or apterous insects with 9-segmented moniliform antennae.
2. Y-shaped epicranial suture present.
3. Tarsi with 2- segments.
4. Cerci very short, 1 –segmented.
5. Ovipositor absent.

Example : *Zorotypus guineensis*

Order – 16 : Psocoptera (Genus Psocus; Pteros –wing)

1. Insects with long filliform antennae of 12 – 50 segments.
2. Y-shaped epicranial suture present.
3. Venation reduced and seldom with cross veins.
4. Maxilla with a rod like lacinia.
5. Tarsi 2 or 3 segmented.
6. Labial palps much reduced.
7. Cerci absent.

Example : Book Lice.

Order – 17 : Mallophaga or Phthiraptera (Phtheir – Louse; aptera – without wings)

1. Apterous insects living as ectoparasites.
2. Eyes reduced; No Ocelli.
3. Antennae 3 – 5 segmented.

4. Tarsi 1 – 2 segmented, terminated by single or paired claws.
5. Thoracic spiracles ventral.
6. Cerci absent.

Example-_ Bitting lice or bird lice.

Order – 18 : Siphunculata (Siphunculus – little tube)

1. Apterous insects living as ectoparasites of mammals.
2. Eyes reduced or absent, ocelli absent.
3. Antennae 3 to 5 segmented.
4. Mouth highly modified for piercing and sucking.
5. Thoracic segments fused.
6. Tarsi 1 – segmented.
7. Thoracic spiracles dorsal.
8. Cerci absent.

Example : *Pediculus* sp.

19. Order : Hemiptera (Hemi-half; Pteron-wing)

1. Two pairs of wings usually present; the anterior pair most often of harder consistency than the posterior pair, either uniformly so (Homoptera) or with the apical portion more membranous than the remainder (Heteroptera)
2. Mouth parts piercing and suctorial, palpi atrophied; the labium in the form of a dorsally grooved sheath receiving two pairs of bristle like stylets (modified mandible and maxillae)

Example :

Cotton stainer – Dysdercus

Leaf hoppers – (Jassidae and related family)

Plant Lice – Aphidoidea

Scale Insects and Mealy bugs (Coccoidea)

20. Order – 20 : Thysanoptera (thusanos – a fringe; pteron – a wing)

1. Small slender bodied insects with short 6 to 10 segmented antennae and asymmetrical piercing mouth parts.
2. Very narrow wings with long hair fringes and reduced venation
3. Tarsi very short – 1 or 2 segmented.
4. Cerci absent.

ENDOPTERYGOTA

Order – 21 : Neuroptera (neuron – a nverve; pteron – a wing)

1. Small to rather large soft-bodied insects with usually elongate antennae.
2. Two pairs of very similar wings, with prominent venation characterised by many accessory branches

and cross veins.
3. Abdomen without any cerci.
4. The aquatic forms usually with abdominal gills.

Example : Alder – flies, Lacewings etc.

Order – 22 : Mecoptera (Mekos – length ; Pteron – a wing)

1. Soft bodied, small sized insects with elongate, filiform antennae.
2. Head usually produced into a vertically deflected rostrum with bitting mouth parts.
3. Ligula absent.
4. Abdomen elongate with short cerci.

Example : Scorpion-flies (mekos-length; pteron – wing)

Order – 23 : Lepidoptera (lepidos-a scale; pteron-a wing)

1. Insects with 2 pairs of membranous wings – cross veins few in number.
2. The body, wings and uppendages clothed with broad scales.
3. Mouth parts with suctorial probisis formed principally by maxillae, mandibles almost vestigial or absent.
4. Larvae usually with 8 pairs of limbs.
5. Pupae usually adecticous, obtect usually in coceon.

Example : Butterflies & Moths

Order – 24 : Trichoptera (trichos-hair; pteron-a wing)

1. Small to moderate sized moth like insects with setaceous antennae.
2. Mandibles vestigial or absent; maxillae single lobed with elongate palpi.
3. Wings membranous, more or less densely hairy; fore wings elongate, hind wings broader with a folding anal area.
4. Tarsi 5 segmented.
5. Body terminated by hooked caudal appendages.

Example : Caddis Flies.

Order – 25 : Diptera (Dis-two; Pteron-a wing)

1. Insects with a single pair of membranous wings; the hind pair modified into halters.
2. Mouth parts for piercing and sucking; modified to form a proboscis.
3. Prothorax and metathorax small, fused with large mesothorax.
4. Tarsi commonly 5 – segmented.
5. Lorvae apodous, vermiform terrestrial, aquatic or parasetic.

Example : True flies

Order – 26 : Siphonoptera (Siphon – a tube; apteros – wingless)

1. Small, apterous, laterally compressed insects whose adults are ectoparasites of worm-blooded animals.
2. Eyes absent; 2 ocelli usually present.
3. Antennae short and stout.
4. Mouth parts for piercing and sucking.
5. Tarsi 5 – segmented.
6. Larvae free-living-vermiform (apodus)
7. Pupa and ecticous, exarate in silken locoons.

Example : Flea.

Order – 27 : Hymenoptera (hymen- a membrane; pteron – a wing)

1. Two pairs of membranous wings, venation greatly reduced.
2. Hind wing smaller than the fore pair, interlocked with the latter by means of hooklets.
3. Mouthparts adapted for bitting, lapping or sucking also.
4. The abdomen usually basally constricted and its first segment fused with the metathorax.
5. An ovipositor always present and modified for piercing and stinging.
6. Larvae generally apodus with a difinite head

Example : Ants, Bees, Wasps

Order – 28 : Coleoptera (Koleos – a sheath; pteron – a wing)

1. Small to large insects whose fore-wings, not used in flight are modified into hrony or leathery elytra which almost always meet to form a straight mid-dorsal suture.
2. Hind wings membranous, folded beneath the elytra.
3. Mouthparts adapted for bitting.
4. Prothorax large and mobile; mesothorax much reduced

Example : Beetles.

Order – 29 : Strepsitera (Strepsis – a twisting; pteron – a wing)

1. Small, Females remain as degenerate endoparasitic insects; males free living.
2. Mouthparts of a digenerate bitting type.
3. Fore-wings modified into small club-like processes.
4. Hind wings large and fan-shaped.
5. Trochanter absent.

Example : Stylops.

Insect's digestive system with special emphasis on midgut, filter-chamber and peritrophic membrane

Division of the Alimentary canal :

The Alimentary canal is divisible into three primary regions according to their embryonic development /origin.

i) The foregut arises as an anterior ectodermal invagination (Stomodaeum).

ii) The hindgut as a similar posterior invagination (Proctodaeum).

iii) The midgut which connects the two develops as an endodermal sac (mesenteron).

These differences in embryonic origin result in marked histological differences in the structure of midgut, as compared with other regions. The fore and hind guts are lined with cuticle while the midgut is devoid of it. In may insects these regions are subdivided into various functional parts, of which the most usual are the pharynx, oesophagus, crop and proventriculus in the foregut, the caeca and ventriculus in the midgut, and pylorus, ileum and rectum in the hindgut. The gut is supported in the body by muscles anteriorly and posteriorly but elsewhere its coils are supported by connective tissue and tracheal branches.

The length of the gut is roughly correlated with diet. The insects feeding on a largely protein diet tend to have a shorter gut than those feeding on carbohydrates. All segments of the gut show peristaltic and churning movements which serve to mix the contents and carry them along. The digestive enrymes are secreted partly by the salivary glands' but chiefly by the mid intestine. All segments of the gut may take part in absorption to a varying extent.

THE FOREGUT

The following layers passing from within outwards, are generally recognizable in walls of the fore-gut.

i) The innermost cuticle lined layer, known as the intima.

ii) The thin epithelial layer, secreting the intima.

iii) The basement membrane, supporting the epidermal layer.

iv) The longitudinal muscles.

v) The circular muscles.

vi) Outside the muscle layer, is a delicate connective tissue sheath bearing nerves and tracheae.

FORE-GUT

The fore gut is divisible into the following regions :

1. Pre oral food cavity (buccal cavity) :

This cavity is the space lying between the mouthparts and the labrum. In insects with mandibulate mouth parts, this space is divided by the hypopharynx into an anterior cibarium and a posterior salivarium.

The cibarium may form a small pouch for the temporary storage of food or is modified into a sucking pump as in Thysanoptera, Hemiptera and others. The salivarium may also undergo modifications into the salivary syringe of the Hemiptera and the silk regulators of Lepidopteran larvae.

2. **Pharynx:**

The buccal cavity forming the commencement of the foregut, is followed by the pharynx with an elaborate musculature concerned with the ingestion and deglutition of the food. These muscles are best developed where the pharynx participates in the formation of a well developed sucking pump (Lepidoptera, Hymenoptera, Neuroptera etc.).

3. **Oesophagus:**

The oesophagus is an undifferentiated part of the foregut serving to pass food back-from the pharynx to the crop.

4. **Crop:**

The crop is an enlargement of the posterior portion of the oesophagus. It is extremely variable in form and functions mainly as a food reservoir though digestion occurs when its contents are mixed with salivary enzymes and some lipids may be absorbed there (Eisner 1955). In *Periplaneta*, its movements are under nervous control and emptying depends on the osmotic pressure of its contents and when it does not contain any food, it is filled with air (Davey and Treherne, 1963). In some insects (Diptera, Isoptera, Coleoptera etc.) the crop develops as dilatation of the oesophagus and is connected with it by a narrow tube.

5. **Proventriculus:**

The proventriculus is situated behind the crop and is best developed in Orthoptera, Coleoptera, Mecoptera, Odonata, Isoptera and various Hymenoptera but is reduced to a valve in the honey-bee and most Diptera. In the cockroach and cricket, the intima in the proventriculus is developed into six strong plates or teeth, which serve to break up the food. Sometimes, the proventriculus serves simply as a valve, retaining food in the crop while permitting the forward passage of enzymes.

MID GUT

This region of the alimentary canal is often referred to as the stomach or ventriculus and its shape and capacity vary greatly. It may be sac-like, coiled, tubular or divided into two or more well-defined regions as in the Heteroptera.

Histology:

i) Internally, the midgut is lined with epithelial cells devoid of cuticle which rest upon a basement membrane. In most insects, the epithelial cells are protected from the contents of the gut by a delicate detached sheath, the peritrophic membrane. In the epithelial layers, three main types of cells may be distinguished

(a) Columner (Cylindrical) cells – Enzymes.

(b) Regenerative cells for synthesis of new cells.

(c) Calyciform (goblet) cells for pumping excess K.

a) These columner cells are concerned with enzyme secretion and with the absorption of the products of digestion. The goblet cells are distributed between the columner cells in Caterpillers and Ephemeroptera and Plecoptera (Wigglesworth, 1965). The goblet cells are supposed to take important role in pumping excess potassium, derived from the food, out of the haemolymph (Smith, 1968; Wood et al., 1969). Midgut cells also play some part in excretion in Rhodnius. Here respiratory pigments are broken down in the cells to haematin, a verdohaem pigment and biliverdin. The later is accumulated and then discharged into the lumen of the gut for disposal. The goblet cells may also be concerned with deposit excretion. In Lepidoptera, metals and dyes accumulate in the goblet cavity and in the cytoplasm of the cell. These substances are discharged during moulting when the whole of the epithelium is renewed. When cells of the midgut degenerates or break down, new ones are formed by the division and differentiation of regenerative cells, which lie at base of the epithelium, either scattered or in groups as in Orthoptera. Sometimes, they occur at the bottom of folds or crypts in the epithelium and in many Coleoptera, these crypts are visible as small papillae on the outside of the midgut.

Ultrastructure of the columner epithelium :

The columner epithelial cells reveal complex ultrastructure as studied in Calliphora (De Preister, 1971) and the larvae of Hyalophora (Anderson and Harvery, 1966). The cytoplasm is divided basally into compartments by deep infoldings of the plasmamembrane and produced towards the lumen in an array of microvilli. These increase the surface area greatly and are covered by indistinct material that form the glycocalyx. Large amount of rough endoplasmic reticulum are present in the columner cells, with microtubules and mitochondria).

ii) The epithelial layer is followed by the muscle layers which is differentiated into an inner circular muscle layer and an outer longitudinal muscle layers.

iv) The muscle layers are bounded by a delicate connective tissue sheath.

Anatomical differentiation :

Anatomically the midgut is usually a simple tube, undifferentiated except for the presence of four, six or eight caeca at the anterior end. In Diptera, the midgut is differentiated into an anterior cardiac chamber (Snoedgrass, 1935) and a long ventriculus. In Heteroptera, there are four regions, the last giving rise to numerous caeca which house bacteria. The remainder of the midgut is a long straight tube composed of two segments; an anterior in which the cells are absorbtive cells and a posterior in which the cells are regarded as secretory cells.

In Homoptera, Heteroptera which feed on plant fluids and in Lepidoptera, Hymenoptera and Diptera which feed on nector, modifications of the gut occur which provide for the elimination of excess water taken in. This is necessary in order to avoid excessive dilution of the haemolymph and to concentrate the food so as to facilitate enzyme activity. This fluid is stored in the crop, which is lined by the impermeable cuticle and from which small quantities are passed back to the midgut as they are required. In those insects, feeding on the fluid rich xylem of the plant, the extensive elaboration of the midgut has developed to ensure the rapid elimination of excess water (Marshall and Cheung, 1974). In Homoptera, and in some other groups of insects, the terminal region o. the midgut comes into intimate relation with the anterior part of the midgut and the proximal parts of the Malpighean tubules and chamber is formed known as 'filter chamber'. These arrangements are supposed to enable the excess fluid in the food to pass directly from the first part to the last of the mid intestine, without general dilution of the haemolymph.

Functional differentiation :

In different insects, the midgut is functionally differentiated into different parts as regards the absorption of nutrients, secretion of enzymes and also on histochemical grounds.

In most Nematocerous larvae, such as *Ptychoptera, Anopheles, Culex* the zone is followed by a group of caeca in which both secretion and absorption are believed to take place. In the larva of *Aedes* after feeding on carbohydrates and certain amino acids, there is a massive deposition of glycogen in the epithelium of the posterior half of the midgut and small amount appears in the cells of the gastric caeca. In the tsetse-fly *Glossina,* the blood is thickened to a suitable consistency by the absorption of water in the anterior half of the midgut while the blood is blackened by the action of the enzymes secreted from the middle section and the narrow posterior segment is responsible for absorption;

There regions - a sac like region in which the ingested food is concentrated, a tubular region which is the chief site of digestion and a third region specialised for absorption.

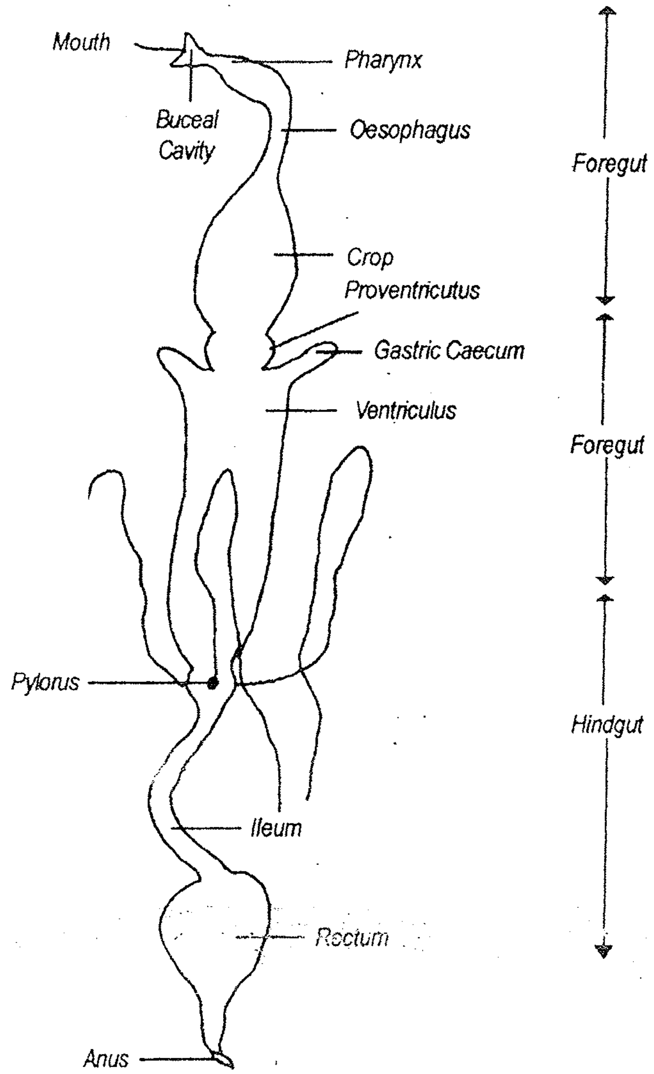
Structural details of peritrophic membrane and its function :

The peritrophic membrane forms a delicate lining layer to the midgut and is found in most insects, whether they eat solid food or feed only on fluids. It is apparently not present in many insects feeding on plant juices, notably the Homoptera and Heteroptera, while in Diptera it is only formed as a result of gut distension, usually following feeding. The membrane nearly always contains chitin and protein (Richards and Richards, 1977). The peritrophic membrane is not a continuation of the stomodael intima but is derived from the mesodermal epithelium.

Types of peritrophic membrane :

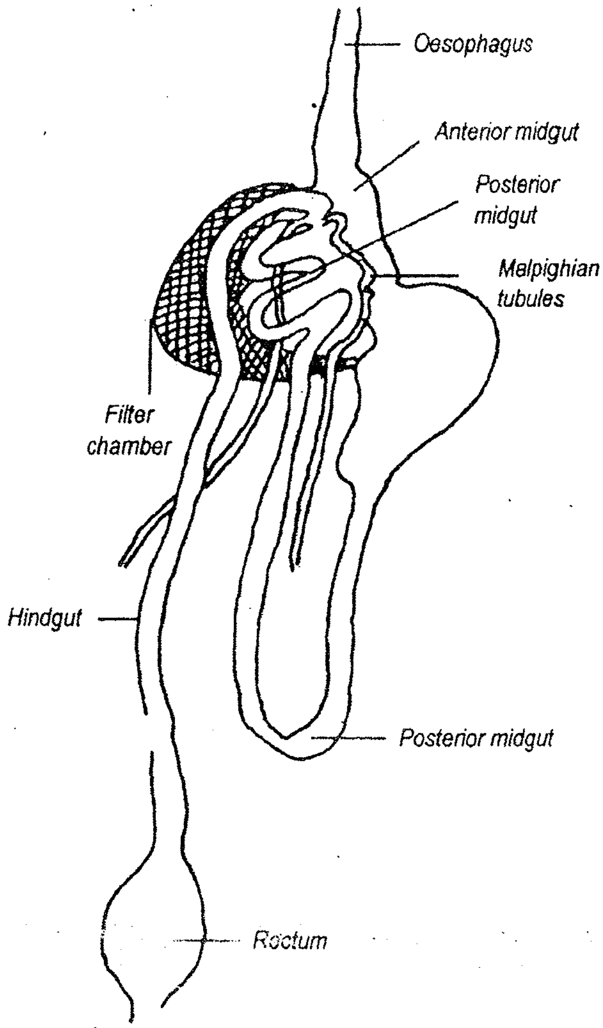
There are two types of peritrophic membrane, formed in two different ways. In the first type, (e.g. Phasmids, Ephemeroptera, Odonata, Lepidoptera, Hymenoptera, Hemiptera) the membrane is made up of concentric lamellae, independent or loosely attached to one another. It is produced by the separation of thin sheets, from the surface of the cells throughout the length of the midgut. The midgut cells generally bear a

Fig. - 2



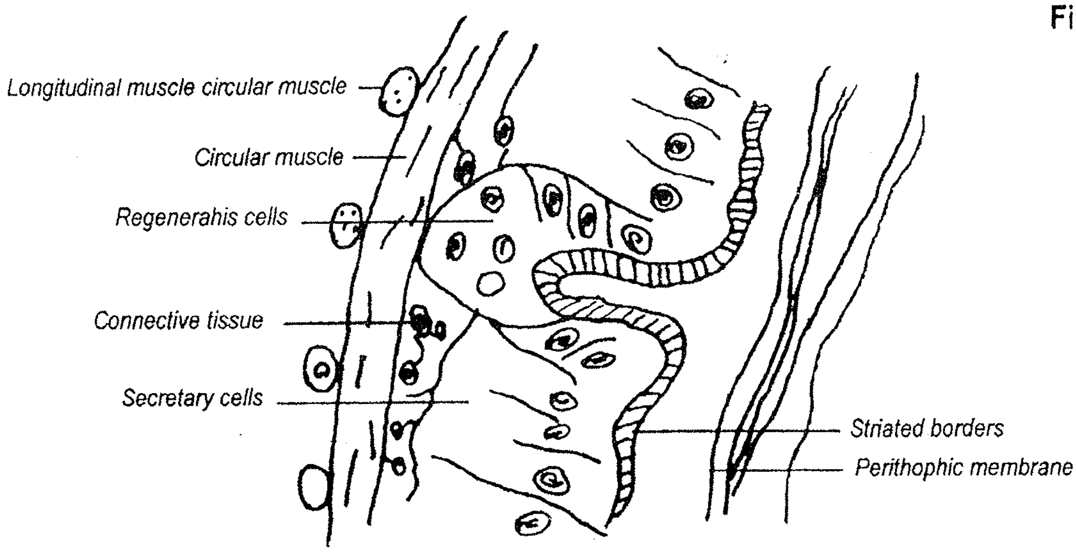
Subdivisions of the insect's alimentary canal

Fig. - 3



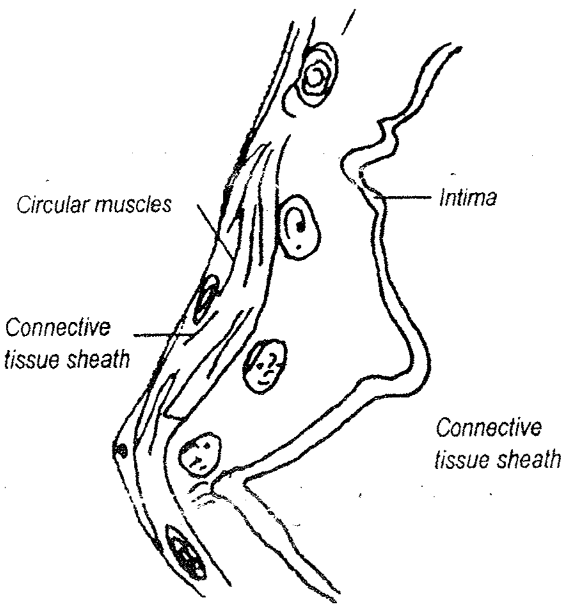
Filter chamber of insects

Fig. - 4

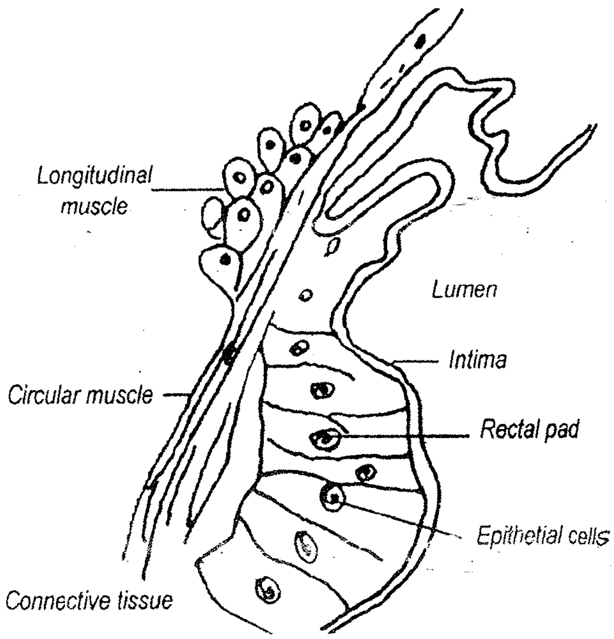


Magnified view of the section of the midgut.

Fig. - 5



Section of ileum (magnified)



Section of rectum.

striated border and in these insects each new sheet appears as a limiting membrane at the surface of this border, which is raised and detached by the pouring out of secretion below it. In the larvae of the wasp and bee, at least half a dozen membranes of this kind are set free each day and since in these larvae, the mid-gut forms a closed sac, the contents of the gut come to be invested in a great number of superimposed envelops.

In the second type (e.g. larvae & adults of Diptera, Isoptera), the peritrophic membrane consists of a single uniform layer. It is secreted in viscous form by a group of cells at the anterior limit of the mid-gut, passes through an annular cleft between the oesophageal invagination and the midgut and in so doing solidifies to form a homogeneous tube. This second type of peritrophic membrane is always of uniform circumference throughout its length.

Composition of the peritrophic membrane :

Electron microscopic examination on peritrophic membrane reveals that it consists of a fibrous network with a thin film in between. The fibrillar strands of less than $100A^0$ are commonly oriented at 60^0 to one another in superimposed layers, to give perfect hexagonal symmetry or the fibrils may be irregularly arranged. The amorphous film between them is removed by proteinase. The peritrophic membrane is made up of chitin with protein incorporated in it. The chitin content of the membrane in different insects ranges from 3.7% - 12.9% and the protein content from 21% - 47%. The remainder of the dry weight is probably made up of other mucopolysaccharides. The glycogen in the midgut cells of many insects may contribute to the formation of the membrane.

The pores in the fibrilar network are upto 0.2 μm across and a thin, structureless film is stretched across them (Mercer and Day, 1952). The fibrils forming the network are approximately 10 mm in diameter and each strand of the net is made up of about four such fibrils. It is possible that the microvilli of the midgut cells form a template on which the fibrils are laid down so that a network is formed (Mercer and Day, 1952).

Functions of Peritrophic membrane :

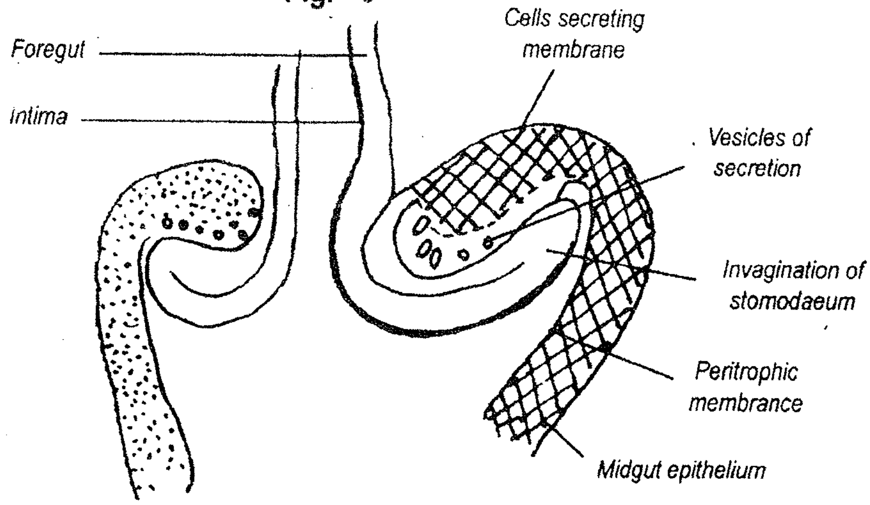
The peritrophic membrane is generally regarded as protecting the mid-gut cells from abrasion by hard fragments in the food, but it is apparently absent from adult Mecoptera which also eat solid food and is commonly present in fluid feeders, where the problem of abrasion does not arise. Absorption may be facilitated if the products of digestion pass into the relatively static fluid outside the membrane from the faster moving liquid within the lumen. In the blowfly larva food passes through the gut, within the membrane, at the rate of about 50m/h, but the peritrophic membrane is only produced at about 5mm/h so that the fluid between it and the epithelium is relatively still.

The membrane probably acts as a barrier to micro-organisms thus reducing infection of the tissues.

Hind-gut:

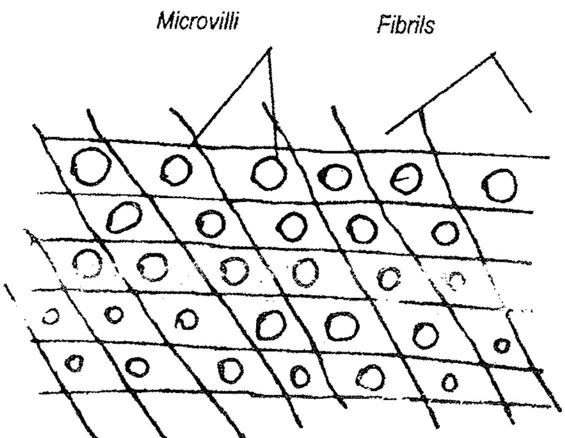
The hindgut consists of the same layers as the foregut except that its circular muscles are developed to a varying degree both inside and outside the layer of longitudinal muscles. Moreover, the epithelial cells are usually larger and they often show a conspicuous vertical striations of the inner border. The cuticle is thinner and, unlike the of the foregut, it is readily permeable to water.

Fig. - 6



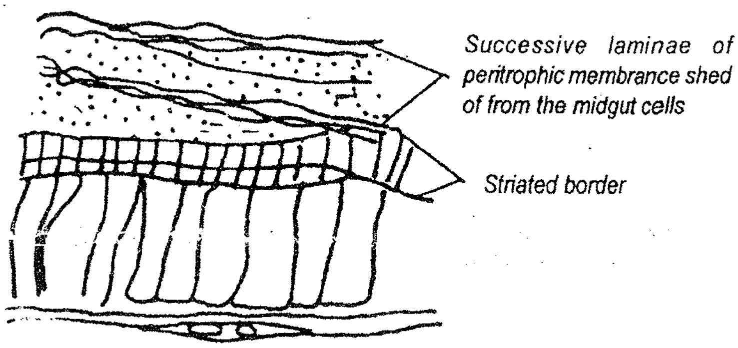
Junction of foregut and midgut showing the origin of peritrophic membrane.

Fig. - 7



Surface section of midgut epithelial cells

Fig. - 8



Hind gut :

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Zonation in Hind-gut :

The commencement of the hindgut is normally marked by a pyloric valve and the insertion of the malpighian tubules. Three regions are generally recognigable (1) The Ileum (2) Colon and (3) Rectum. The cuticular lining of the ileum and colon is often thrown into folds and provided with hair like projections. The ileum is usually differentiated from the colon by its long tubuler shape and sometimes by the presence of caecum in the colon as in Lepidoptera, Coleoptera etc. The rectum is a more or less globular or pyriform chamber, generally provided with a variable number of inwardly projecting papillae. These are termed as rectal glands and are composed of a single layer of tall columner epithelial cells. There are usually six rectal pads extending longitudinally along the rectum. The pads have a good tracheal supply indicating a high level of metabolism.

Function of the hind-gut and rectal glands :

When the pyloric valve is closed, the hind gut receives only the contents of the Malpighian tubes. Normally the pyloric sphincter opens from time to time and admits a portion of the midgut contents which are usually fluid. Thus the most obvious function of the hind-gut in many insects is the absorption of water and the fluid contents become progressively drier as they pass along the hindgut. In the rectum, the fluid contents are converted into a more or less dry pellets before they are discharged through the anus.

In Heteroptera it is suggested tha the ileum is concerned with the removal of water from the haemolymph (Goodchild, 1963) and in blowfly larvae certain cells are concerned in the excretion of ammonia (Waterhouse, 1957). The hormone proctodone is secreted by the cells of the ileum of Ostrinia.

The rectal glands are important in the reabsorption of water, salts and amino acids from the urine (Ramsay, 1958). In addition in some aquatic insects, such as larval Anisoptera and Helodidae, there are tracheal gills in the rectum, help respiration. In larval Anisoptera, water is pumped in and out of the rectum so that the water round the gills is constantly renewed and by the forcible ejection of water, the insect is able to propel itself forwards rapidly. In Dytiscid larvae, the capacious hind gut takes in water to split the old cuticle at ecdysis.

STRUCTURAL EXCELLENCE OF INTEGUMENT OF INSECTS

The physiology of growth in insects is so profoundly influenced by the properties of their integument – it becomes a very interesting and characteristic parts of insects body. It consists of a single layer of epidermal cells which is present on the surface of the animal and it gives rise to a number of important components like – the buccal cavity and foregut, the trachae, the lower genital ducts and the multiferious glands that upon the surface.

Epidermis :

The epidermis is seen in its full development only when the new cuticle is being laid down.(Fig. 9) The apical part of the epidermal cell is striated with extensions into the vertical filaments (pore canals) of the cuticle. Differentiation from the epidermis are the dermal glands which send fine ducts through the cuticle and the oenocytes which may remain applied to its lower surface. The epidermis rests upon a basement membrane probably formed from the condensed processes of epidermal cells with haemocytes adherent to its lower surface and contributing to its substance.

Cuticle :

The cuticle covering the epidermis may be excessively delicate pellicle or a thick, dense, horny armour such as that which encases the thorax and appendages of many beetles. It consists of three main layers

i) An outer thin refractile membrane (in few microns in thickness) sometimes darkely pigmented, often called the epicuticle.

ii) Below this is a rigid layer, black or amber coloured called the exocuticle. It composes one half to one twelfth of the total thickness.

iii) Finally there is a thick colourless elastic layer, the endocuticle which makes up the greater part of the entire structure.

iv) Finally there is commonly a distinct layer between cuticle and epidermis containing a mucoid component and serving to unite cells and cuticle, this is called the subcuticle.

Epicuticle :

It is a complex structure made up of several layers. Histologically, it is sometimes possible to recognize at least three layers.

a) a layer of variable thickness, the 'cuticulin' layer which is the refractile epicuticle. Cuticulin is composed of lipoprotein.

b) A layer of wax (0.25 μ thick).

c) A very thin covering layer of 'cement' which may be detached by treatment with wax solvents.

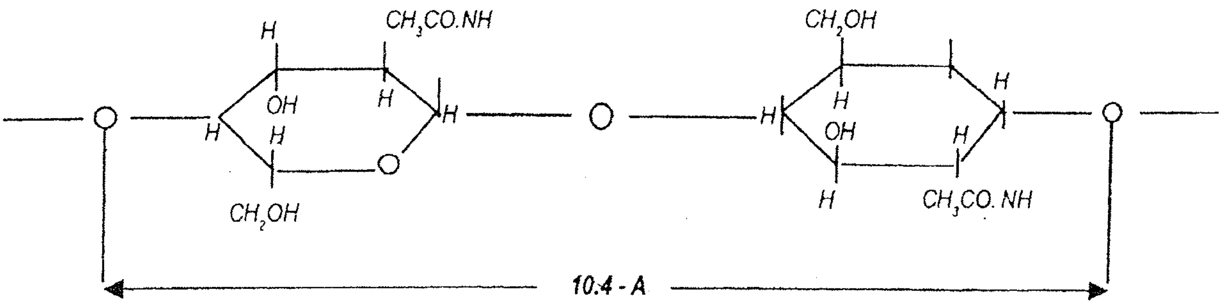
Endocuticle and exocuticle and their modifications :

The endocuticle is usually made up of obvious horizontal lamellae. They represent the layers of cuticle deposited on successive days. Rigidity in the cuticle is commonly supplied by the hardness of the exocuticle. Sometimes the cuticle is modified to form cuticlular spines, each attached to the margins of a socket by a thin flexible membrane. The exo & endocuticle are traversed by mumeroas vertical lines – called 'pore canals' by Leydig (1855) and were regarded by him as filamentous processes of cytoplasm from the epidermal cells, around which the non-living substance of the cuticle was secretred.

Chemical composition

A. Chitin

The best-known constituent of the cuticle is the nitrogenous polysaccharide, named chitin. Chitin has the empirical formula $(C_8H_{13}O_5N)_x$



Chitin is insoluble in water, alcohol, ether and other organic solvents, dilute acids, dilute and concentrated alkalis. The mode of synthesis of chitin is not fully known but there is evidence that Uridine diphosphate N-acetyl-glucosamine is the immediate precursor. There is evidence also that chitin may contain small amount of glucosamine residues in addition to the usual N-acetyl-glucosamine.

Chitin is usually the main constituent of the endocuticle of which it forms about 60 percent of the dry weight in Periplaneta. It is present also in the exocuticle to the extent of the 22 per cent in Periplanata but it is completely absent from the epicuticle.

B. Protein :

The bulk of the non-chitinous material in the cuticle is protein which vaires from 25 to 37% of the dry weight. The extractable protein in the cuticle is arthropodin the character of which remain same in different insects and it is soluble in hot water. Another protein of a very different kind is a constant component of the cuticle-the rubber like resilin. Resilin provides the elasticity of the thorax of flying insects.

Lime in the cuticle :

In a few aquatic insects lime is deposited in the cuticle. In the larva of *Sargus* and other Stratiomyids, the lime is in the form of warts laid down in shallow pits at the time of moulting and intimately mixed with the organic substance of the cuticle.

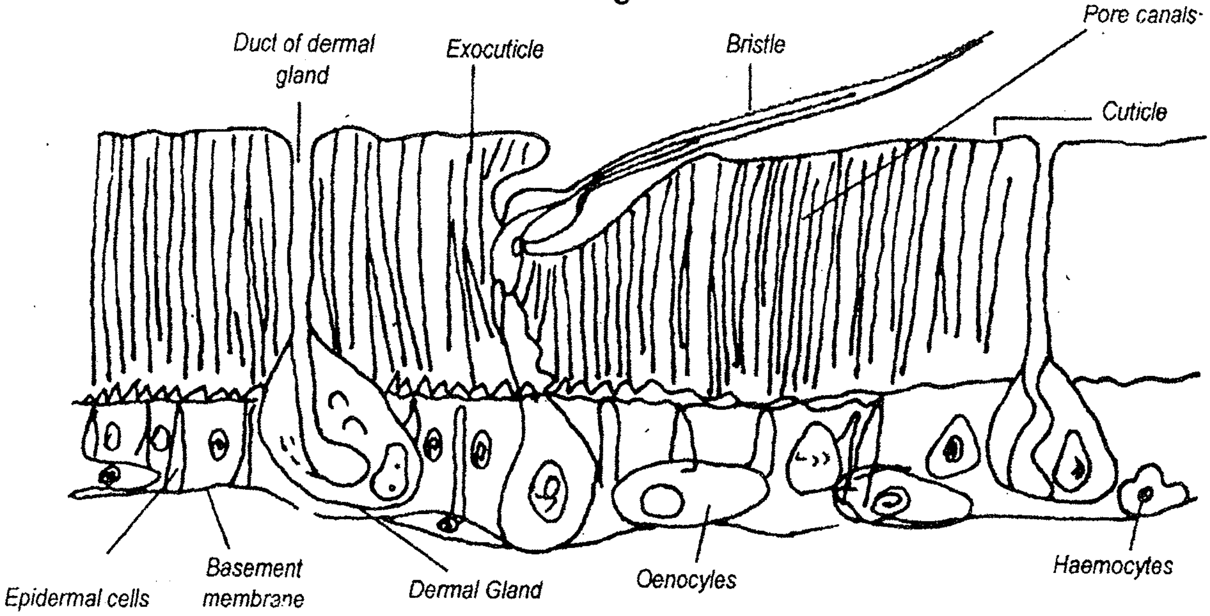
Formation of new cuticle :

In the process of moulting the epidermal cells which become greatly enlarged at this times, separate themselves from the old cuticle. The cytoplasmic processes being withdrawn from the pore canals dispose themselves to provide the proper form for the next instar and proceed to lay down the new integument.

They first secret the cuticulin layer of the epicuticle. It then expands and is thrown into the folds. Immediately before the deposition of the cuticulin layer, the oenocytes become enormously enlarged and lobulated. They are concerned in the synthesis of the lipoprotein-droplets of which pass from the oenocytes through cytoplasmic filaments to the epidermal cells.

The subsequent changes in the epicuticle take place while the chitinous layers are being deposited. Within few hours before moulting the wax layer is laid down. The cement layer is discharged from the dermal glands and poured over the surface of the wax just before or just after moulting. After the formation of the epicuticle, the procuticle is formed.

Fig. - 9



Section through integument showing its different parts

Moulting fluid :

When the epidermal cells sells separate from the old cuticle and begin to secrete the new, the space between the two cuticles in occupied by a thin plasma. In the later stages of moulting, this space is filled by an abundant fluid, the moulting or ecdysal fluid. The chief function of the moulting fluid is to digest and dissolve the inner layers of the old cuticle.

It is a neutral salt-free fluid with proteins in solution which contains a protease and a chitinase. The moulting fluid attacks only the endocuticle and the exocuticel is unaffected. By this process, 86% of the cuticle is absorbed and a thin membrane of epicuticle is shed of.

An important function of the moulting fluid is to serve as a lubricant when the insects slides out of its skin. This moist layer will certainly keep the old cuticle soft and supple but by the time, it is cast off almost all the moulting fluid has disappeared and the surface of the new skin is dry.

Mechanism of moulting :

1. It is often claimed that moulting is a process of excretion which serves to eliminate waste products.

2. But the greater part of the cuticle is reabsorbed into the body and only the indigestible sclerotin and cuticulin are shed.
3. The digestion of the endocuticle serves an important purpose besides conservation of its substance. For, in the young stages of all insects there is an ecdysal line along which the cuticle splits most- readily at moulting. It is usually a 'T' shaped line on head and thorax which apears white in pigmented insects because here the exocuticle is wanting and the endocuticle extends up to the epicuticle. Consequently when the endocuticle has been dissolved the ecdysial line constitutes a line of weakness where the slightest pressure will cause the cuticle to rupture.

Mechanism of excaping during moulting :

Like the insect hatching out from the egg, the moulting insect contracts the abdomen and drives the body fluid into the head and thorax. The pressure so created splits the cuticle along the ecdysal line and the insect slowly draws itself out often aided by gravity. For many, insects hang head downwards while they moult. The dorso-ventral and intersegmental muscles of the abdomen provide the pressure needed for moulting.

Hardening and darkening of cuticle :

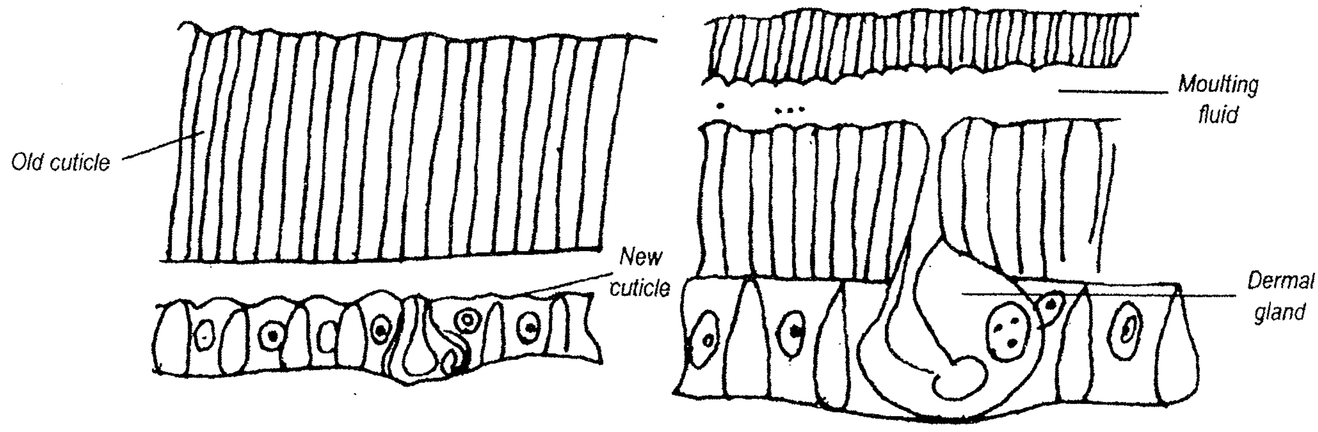
Cuticle of the newly moulted insect is generally colourless, always quite soft. During the next hour or so it hardens and darkens. It has been suggested that the neurosecretary cells in the central nervous system may be responsible for the hormonal stimulus inducing these changes.

Hardening and darkening result from the tanning of the proteins to form sclerotin and cuticulin. The phenolic substances concerned are derived from tyrosine. In the presence of oxygen which is necessary for the hardening of the cuticle and the enzyme polyphenol oxidase, which is plentiful in the cuticle of arthropods the quinones which tan the proteins are produced. These changes may occur in an epicuticle separated from the epidermal cells by considerable thickness of endocuticle. The simultaneous darkening of the cuticle is due largely to the tanned protein, partly to associated melanin.

Loss of water during moult :

1) Since the water proofing wax is not laid down until shortly before the old skin is cast, the question arises whether moulting involves a serious loss of water.
2) Although the water loss in different insects vary from one another, it does not pose any serious problem to them.
3) Thus the impermeability of the cuticle to water in these terrestrial insects is almost fully established by the time the skin is cast. But in some aquatic insects it seems to remain permeable longer.
4) There is no increased evaporation before and after moulting, although the old cuticle may be becoming excessively thin. This demonstrates that it is the outermost layers of the cuticle which are responsible for its impermeability.

Fig. - 10



New epicuticle formed

Digestion and absorption of old endocuticle almost complete

Neuro – Endocrine System :

Alike vertebrate system, in invertebrate also there is a second type of neurons besides the ordinary one. The ordinary one is engaging with the propagation of nerve impulses and secretion of neuro-transmitter. But this second one differs from them in containing a secondary product that is readily stainable. It is reffered to as a neuro-secretion and the cells, are known as N.S. cells.

The importance of the concept of neurosicretion is that it extends the endocrine activity to the nervous system, thereby bringing into close association of two modes of co-ordination - chemical and neural that were previously regarded as distinct.

Difference between Neurohumors and neurohormones :

Acetylchotine is known as neurohumors while Neurosecretion is as neurohormon. N.S. materials like the neurohumors arise in the cell body, pass down the axon and is released from nerve endings. The fundamental difference is that it is not restricted to local or transitory action. Indeed it passes into blood stream and circulates round the body to produce specific physiological effects at points that may be remote from the region of its relaese.

Staining of N.S.M. :

1. The pars intercerebralis is full of N.S.C. and when stained by CAHP (chrome alum haematoxylene phloxin) appears as blue-black showing granular N.S.M.
2. When stained with A.F. (aldehyde fushsin); appears purple.
3. A school of Indian Neurobiologists (Dogra and Tandon, 1964) stained N.S.C. by vital dyes.

The various N.S. cells stain at a time differently by a certain dye depending upon the NSM present. This indicates that secretory cycle is not same in all cells at same time.

Classification of N.S.C. (Fig. - 11)

A. According to colouration

The colouration of cells gives an idea for classification :

i) Some cells have huge N.S.M.

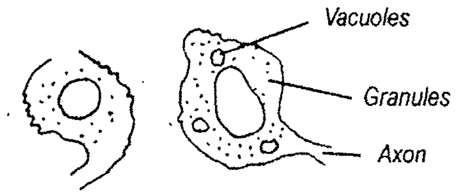
ii) Some cells have moderate N.S.M.

B. According to size

According to size, the cells may be classified as 'a', 'b' and 'c' types. It is found that a number of 'a' type of cells has different grades of N.S.M. This gives the idea that all the 'a' type of cells have not the same physiological state at a particular time.

From this we can interpret that cells have the stages of synthesis, storage transport and release mechanisms.

Fig. 11



Origin of N.S.C. :

N.S.C. is originated not from an or as ordinary neurone. Physiologically it is originated much earlier than the ordinary ones.

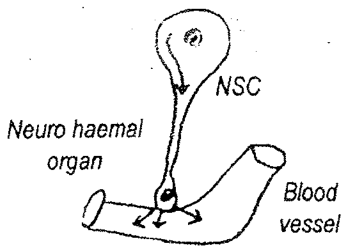
Neurohaemal Organ :

Synthesis, storage & transport of NSM occur itself but extra ganglionic structure and extra cerebralic structure should necessary temporarily for the secretory materials to get into touch of blood and thus to the target tissue. For this, neurohaemal organ is important and neuro-secretory action comes out.

Definition :

Neurohaemal organ is an elaborated neural structure which is closely associated with the blood vessels, imparting the storage and releasing function. However, neuro-haemal organ may be defined as a bundle of expanded so many neurosecretory axon terminals forming a plate like structure on the principal blood vessel where diffusion of NSM takes place.

Fig. - 12



Neurohaemal organ in Insects:

Corpus Cardiacum

Location:

This principal NH organs are small paired, bluish in appearance and is located immediately behind the brain, between the anterior end of the dorsal vein and the oesophagus in front of corpora allata with which they are connected by nervi allati.

Morphology :

They are usually fused medially and in some cases fused with corpora allata. They are fused with the hypocerebral ganglion at the lower end.

Innervation :

They are innervated by two pairs of nerves from the brain, the nervi corporum cardiacum interni and nervi corporum cardiacum externi which are composed of respectively the axons of the median and lateral groups of NSC of the pars intercerebralis.

The cropus cardiacum is composed of two parts:

1) The nervous part (originally the corpora cardiaca are supposed to be modified nerve ganglia as they originated from the cells of stomodeal walls in a fashion like the origin of dorsal sympathetic nervous system.) and
2) The glandular part.

Histology :

Besides neurons, the following types of cells are observed.

i) The Chromophilic cells –I :

Cytoplasm is not stained. They from the main connective tissue in the corpus cardiacum in which there are scattered cells of other types.

ii) The Chomophilic cells – II :

Cytoplasm is deeply stained furnished with pseudopodia like processes.

A large portion of the cardiacum is made up of swollen axon terminals entering from the brain. The neuro-secretory product may accumulate there or be released immediately into the haemolymph. A small amount of the NSM has been shown to pass through corpora cardiaca into corpora allata via nervi allati.

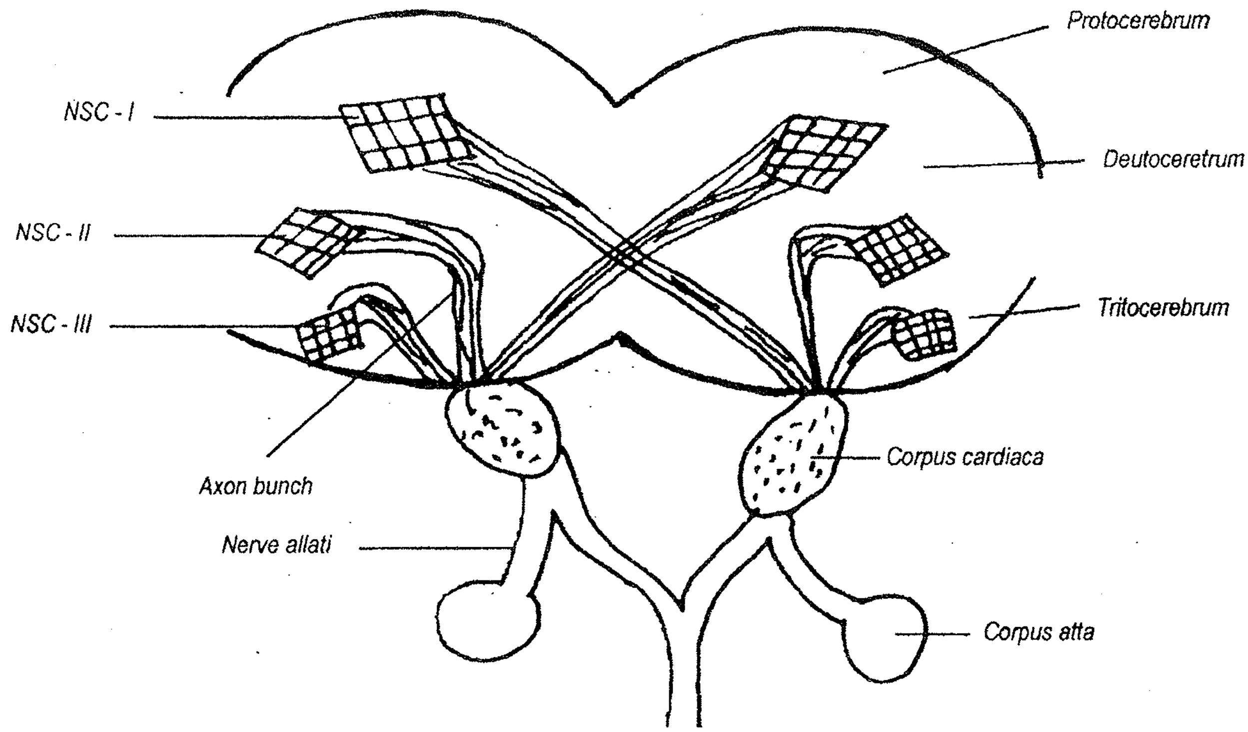
Function:

Johanssen (1958) assumed the corpora cardiaca to have two functions.

1) The storage and mixing of the product of different groups and types of NSC.
2) The production of a separate hormone of its own.

Note :

Cameron (1953) showed that the corpora cardiaca produced a spherical active substances (parthodiphenol) which is quite different from the neurosecretion and affects the heart-beat or perislatic movement. Generally, it has a releasing function into haemolymph.



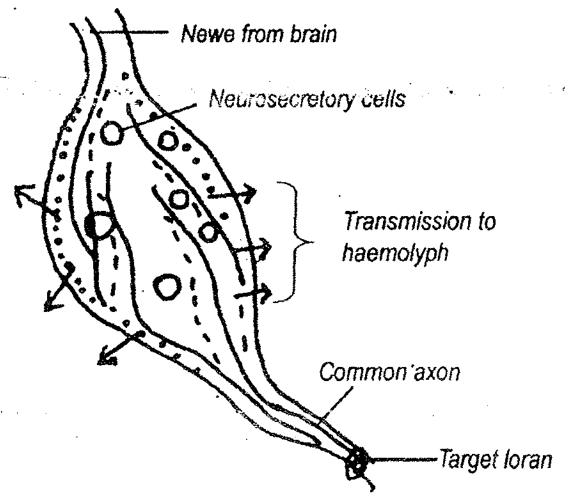


Fig. - 13

Remark :

In addition to the neurohaemal role of the cardiacum, an additional function has been suggested on the basis of the epitheloid elements which appear to be secretory in nature and undergo a cycle of activity. In Lepidoptera, the secretory cells are few but in Aerididae, they form rather large areas somewhat separated from the neurohaemal region.

Although no function can be associated with their presence, true nerve cells have been reported in cardiacum of a few species. This is in accordance with the accepted ontogeny of the organ and also supports the conclusion that the cardiacum is not an ordinary ganglion.

It is to be concluded that corpora – cardiaca have raised its magnitude of its own list of functions, and developed its structural consistence to multidirectional efficiency, either to endocrinal or norendocrinal function.

Products of corpora cardiaca :

Concentrated extracts of corpora cardiaca of *Periplaneta* have adrenaline like properties in mammals. Serotonin (5-hydroxytryptamine) has been extracted from the central nervous system. Concentrated extracts of the cropus cardiacum of the *Periplaneta* cause decreased frequency of spontaneous nerve impulses in the isolated nerve cord of the cockroach.

Corpus allatum :

Corpus allatum is a glandular organ closely associated with the corpus cardiacum. The corpora allata arise by budding of epidermal cells between the mandibular and maxillary segments. The corpora allata are innervated by the nerve which has traversed the corpus cardiacum.

The corpus allatum secretes the juvenile hormone, neotenin which maintains the larval characters in the young insects. It ensures the deposition of yolk in the developing egg. It also induces the type of behaviour appropriate to the type of growth or reproductive activity and has some general effects on metabolism.

The active corpus allatum consists of closely packed cells with much homogeneous cytoplasm. The inactive gland is usually smaller; the cells are shrunken with vacuoles between them. Both light and electron microscopic studies show neurosencretory granules in the nerve axons entering the corpus allatum.

Thoracic glands:

Thoracic glands arise in the embryo from an ingrowth of ectodermal cells at the base of the second maxilla. The thoracic glands are closely associated with the tracheal system. They are richly innervated from suboesophageal, prothoracic and mesothoracic ganglia.

After activation by the hormone from the neurosecretory cells in the brain, the thoracic glands secrete the moulting hormone.

Neuroendocrine Integration in moulting and metamorphosis in Insects (Role of Juvenile hormone and Moulting hormone)

Moulting is primarily a mechanism of growth, conditioned by the properties of the cuticle in which old skeleton is shed with the formation of a new one of greater dimension, thereby providing room for further growth. Metamorphosis refers to the change in the form of animals from one stage (juvenile) to another stage (adult) with the attainment of new characteristics or with the retaintion of old characters.

Studies of hormonal co-ordination in insects have largely centered around moulting and growth. Insects grow towards moulting through nymphal stage on insects. At the end of each instar, moulting occurs, the odd skeleton is shed with the formation of a new one of greater demensions, thereby providing room for further body growth. The final moult then becomes important for it is the period of the insects' life cycle in which adult characters are formed with the concurrent loss of specific juvenile features i.e. metamorphosis. In insects, metamorphosis are of two types :

(i) Hemimetabolous:

If the juvenile has not deviated greatly from the adult or the structural details of juveniles are more or less like that of adult e.g. cokroaches, Temites, Grassoppers.

(ii) Holometabolous :

When the structural details of juveniles are quite different from that of adults. The life cycle is characterised by several larval and pupal stages.

Endocrinology of growth and development :

Three endocrine sources are instrumental for the growth and development of Insects. These are

i) The brain with neurosecretary cells (NSC)

ii) Ecdysal or Prothoracic gland.

iii) Corpora allata.

The role of the NSC in the brain is the prime movers in both moulting and metamorphosis.

Initiation of moulting :

Moulting is initiated by the activation of prothoracic gland or the ecdysal gland. Wigglesworth's parabolic and decapitation experiments over the insects *Rhodnius prolixus* (1964) outlined the pathway of moulting and metamorphosis (Fig. –14).

1. NSC in the protocerebrum upon proper stimulation produce ecdysiotrophin which passes to the neurohaemal organ by axon transport.
2. In blood sucking Rhodnius, the stretching of the larval abdomen, by a meal of blood, provides a nerve stimulation to the brain. In locust, the chewing and swelling processes may accomplish the same effect.

In moth, temperature may stimulate the NSC. The external factors then causes the stimulation of N.S.C. of brains of insects through extrinsic and intrinsic stretch receptors.

3. The activated NSC produce ecdysiotrophin which is stored in corpora cardiacum and from here it is released into haemolymph and induce the ecdysal gland to secrete moulting hormone (MH).
4. Being stimulated by ecdysiotrophin, the ecdysal gland synthesise and release ecdyson or MH. ($C_{27}H_{44}O_6$) which initiates the process of moulting. With the release of MH into haemolymph, the epidermis is stimulated to moult and at the same time body tissues are caused to differentiate in the direction of adult structures.

The most common procedure of activating ecdysial gland is through ecdysiotrophin from corpora cardiaca of insects. But there are other possibilities also –

a) Innervation of gland by one or several type of neurosecretory granules, originating in the ventral nerve cord.
b) Stimulation by MH itself.
c) Stimulation or inhibition by JH.

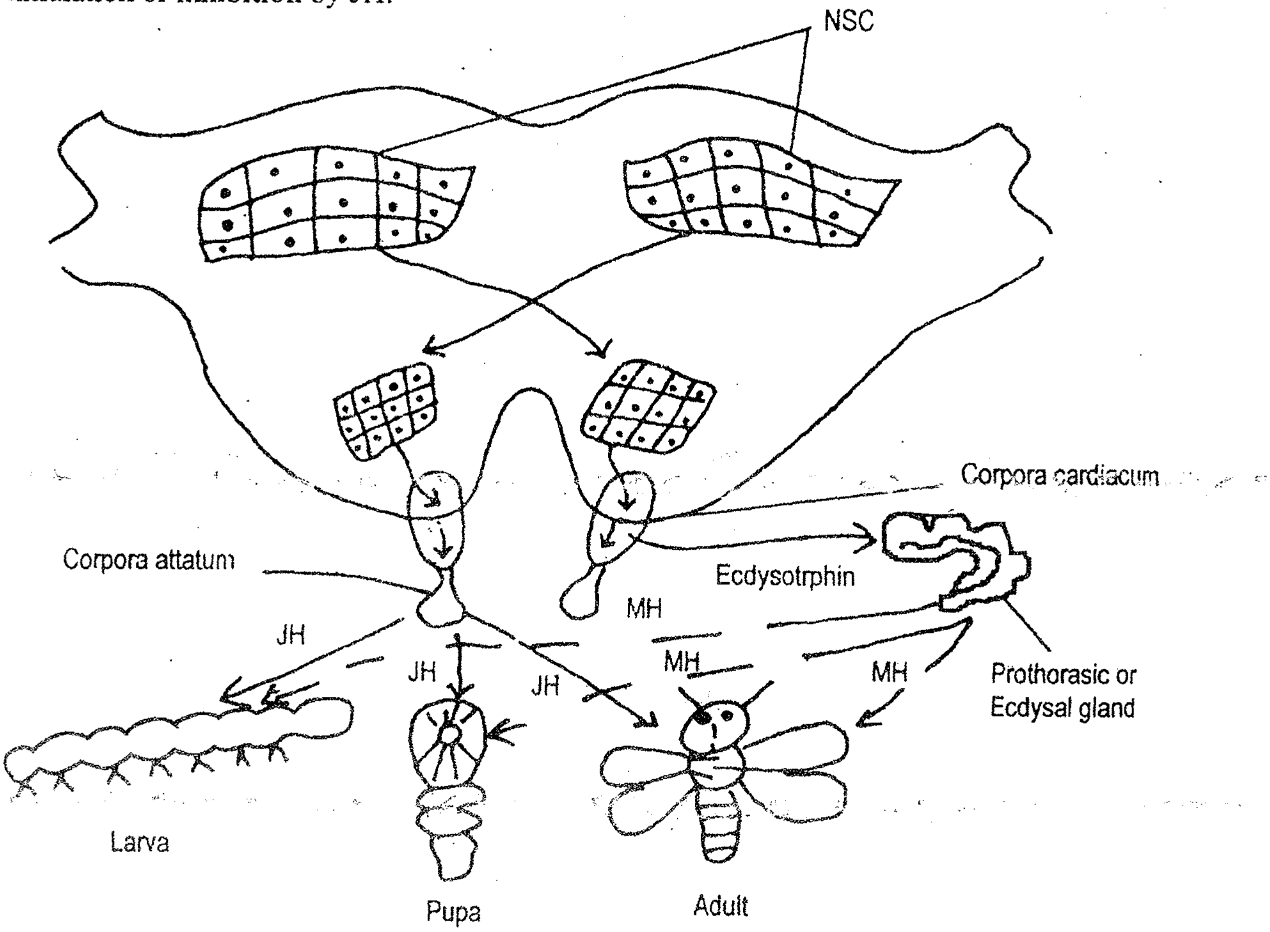


Fig. 14

Metamorphosis in Insects and Neuroendocrine system:

Insects have to pass through some larval instars during their growth and development. The moult at the end of the last instar involves metamorphosis for the adult stage. Transformation that takes place at the metamorphosis, is the function of an epithelial endocrine gland, the corpora allatum. When JH from CA is released into haemolymp, it will retain the juvenile characters of the insects. This is the normal course of events during which the insects' cells are dependant upon multiple set of genes which are to be expressed successively during the life cycle with the production of immature and mature characters. The stimulus determining which set of genes will be expressed is the internal hormonal milieu (Fig. –15).

The different events which have been found to occur during the course of insects' metamorphosis can be summarised as mentioned below.

1. During the first larval instar, a stable ratio of MH and JH comes in action.
2. The gradual increased activity of Prothoracic gland in accordance with the progressive development against the less activity of corpora allata results in the switching over the ratio of $\frac{MH}{JH}$ and this ultimately gives, rise to moulting of larva and thus the second instars appears.
3. During this 2nd instar and also in other instar, the changed ratio of $\frac{MH}{JH}$ tends to have the primary ratio.

   But again another hyperactivity of prothoracic gland results a sudden increase in the ratio $\frac{MH}{JH}$, attaining the next instar. These mode of transformations from one instar to other, constitute the charactristics of metamorophosis. From this, it is naturally found that the concentration of MH gradually increased throughout the post embryonic development.

   In pupal stage, or latter in pre-ecdysal stage, the ratio of $\frac{MH}{JH}$ becomes highest – JH remains in least concentration and MH remains in highest concentration.
4. After the pre-ecdysal stage i.e. in the adult stage, the prothoracic gland is attrophied and corpora allata begins to increase in size, so that MH triter starts to slope down and subsequently reach to almost nil. In the haemolymph then JH triter begins to increase but its function then possibly are changed from moulting.

Remark :

From an endocrimological point of view, the difference between the moulting and metamorphosis is the concentration of JH in the haemolymph. Prior to each moult in the immature stages, the moult which occurs without any JH influence, brings forth metamorphosis or the formation of the adult.

Experimental evidence to show the effect of MH & JH over moulting and metamorphosis :

Wigglesworth (1964) clearly outlined the effect of MH and JH by his parabolic and decapitation experiments.

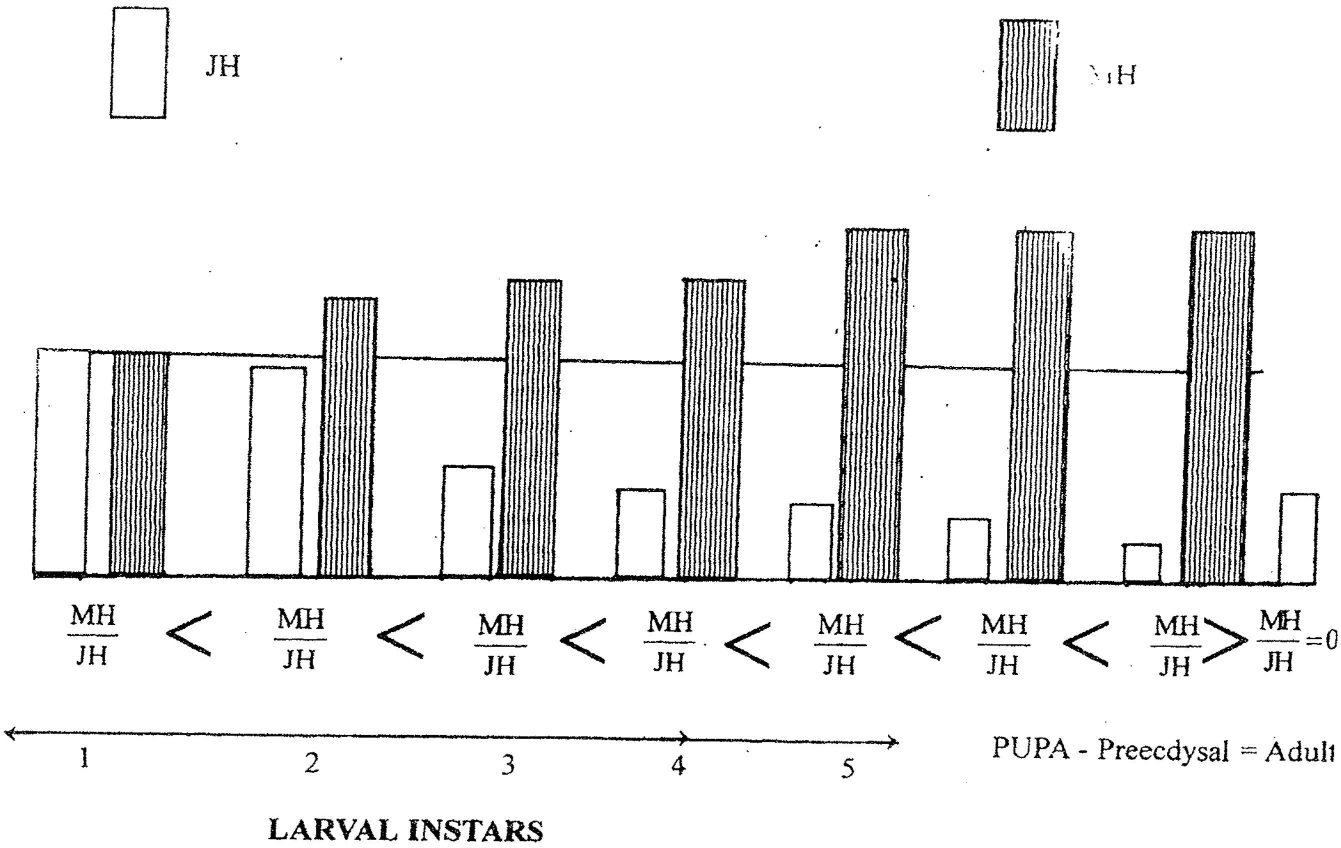


Fig. 15

Effect of MH :

Tus decapited *Rhodnius prolixus*, are joined together by their cut surface. If a animal is decapited before a critical period, it will not moult. Critical period means the brain hormone has to exert its action upon the ecdysal gland for several days before the gland can come into full secretory activity and release adequate amount of MH.

The presence of MH in the blood can be determined by uniting in parabiosis two decapited larvae, one of which has been decapited before and another after the critical period. Both will moult, although the former would not have done it, had it been kept in isolation. The united insects have a common circulation and a common share of MH derived from the larva that was decapited after the critical period.

Effect of JH :

This can be demonstrated by the parabiotic union of a 1st instar decapitated larval stage with the 5th instar moulting larva. The second category undergoes, usual metamorphosis as it is expected, but so also does the first category 1st instar larva also transformes into a small and precocious adult. This is because it is under the influence of MH of the moulting insects and has no source of the JH to permit the expression of larval structures. Conversely, a 4th instar larva, decapitated after the critical period can be united with a 5th instar one that has been decapited before the critical period. Thus, the 5th instar should start metamorphosis when it moults but does not infact do so because both JH and MH from the 4th instar are circulated in the 5th instar body.

VIDYASAGAR UNIVERSITY

DIRECTORATE OF DISTANCE EDUCATION
MIDNAPORE - 721 102

M.Sc. in ZOOLOGY

Part-I : Paper - I : Group-B : Unit-I
Topic - 3, 4 & 5

Module No. – 8

Topic – 3 : Social Organisation of termites; prospects and problems of sericulture in drought prone lateritic tracts of South West Bengal; Modern technologies in apiculture.

Topic – 4 : Biofertilisers with special emphasis to vermitechnology

Topic – 5 : Concept of culture and caputre fisheries of fin fishes and shell fishes – present status and prospects.

SOCIAL BEHAVIOUR OF TERMITES :

Introduction : The ability to distinguish the participants in an interaction in terms of their characteristics and through the nature of those interractions provides a basis for descriptions of social systems (Hinde, 1976). The main focal point of social systems are the interactions between individuals. Each individual has specific attributes as does each interaction. The social organisation in insects especially in termites, is fairly rigid and species specific.

Definition of sociality :

Social organisation refers to the organisation of a groups of organisms belonging to the same species in a cooperative manner. A simple definition is that when two or more animals live together, they constitute a social unit. Some animals are consistently social in that they form distinct and permanent units that are easily distinguished in time and space from other such units.

Degrees of sociality :

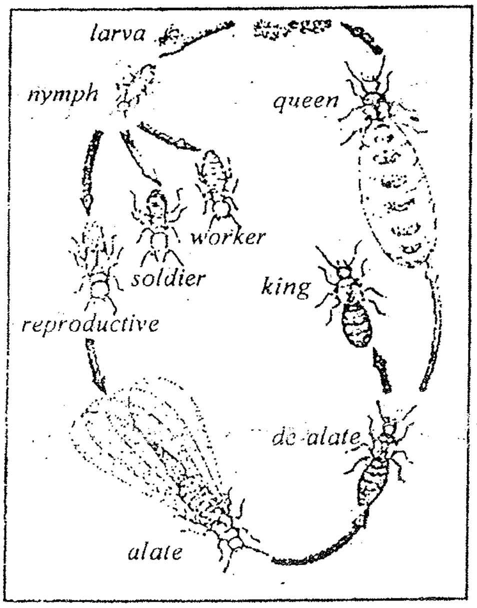
a) **Solitary** : no trace of social behaviour is found.
b) **Subsocial** : social behaviour is restricted only to the parental care of young.
c) **Communal** : members of the same generation share nest but without brood care.
d) **Quasisocial** : members of the same generation share nest and care for brood.
e) **Semisocial** : as is quasisocial but also has reproductive division of labour.
f) **Eusocial** : Eusocial represents the 'truly social' phase and possesses the following characteristics.
a) Individuals of the same species cooperate in case of young.
b) Reproductive division of labour

c) Overlap of at least two generations (offspring assist parents with care of young). This has resulted in the existence of adult offspring (usually sterile) and young offspring at the same time. Thus older sterile offspring aid their mother (or parents) in raising younger siblings.

Eusociality in Termites :

Termites belonging to the order isoptera under the class Insecta are eusocial. They are diploid and both sexes are equally involved in social behaviours. The most important factor that probably favoured the evolution of eusociality is the need to transmit symbiotic cellulose-digesting micro-organisms between individuals after hatching and each molt. Defence is considered as an important factor in the evolution of eusociality-termite colony is with one non-reproductive caste-the soldier. David Barash and Peter Lenz (1992) formulated one potential model for the evolution of eusociality in termites. The first step is dependent on the necessity of transfer of anaerobic symbionts; mothers are therefore are required to be present near their eggs and to transfer the symbionts upon eclosion. Cellulose digestion permits safe residence within food sources e.g. logs. A termite mother becomes larger as she feeds and can gain tremendously in egg-laying ability. For example, a queen *Macrotermes netalensis* can produce 36,000 eggs in a day.

A male is certainly more fit staying with a large egg-laying female than searching for a new mate. In present day termites, matings are monogamous and the male and female remain together throughout their lives. Monogamy means that offsprings are full siblings, further inclining towards non-reproductive castes to aid in the production of additional soldiers and workers and periodically in the production of sexual offsprings of the king and queen. Queens are intolerant of reproduction (unless they are ready to produce young that will disperse and breed) and transmit sterility pheromones to female workers. Kings likewise inhibit reproductive development in males. Termites eusociality is explained largely by parental manipulation of young and perhaps the benefits of kin selection to the non-reproductive castes.

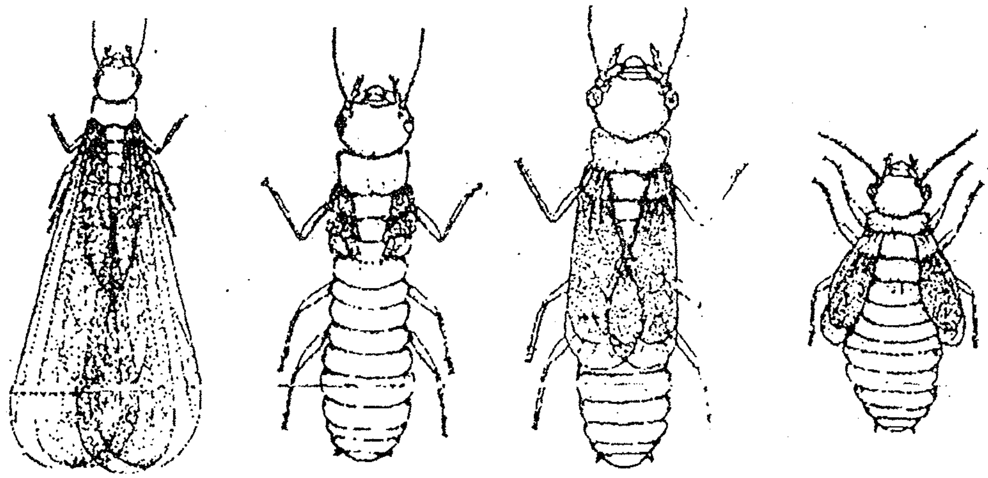


Life cycle of Termites :

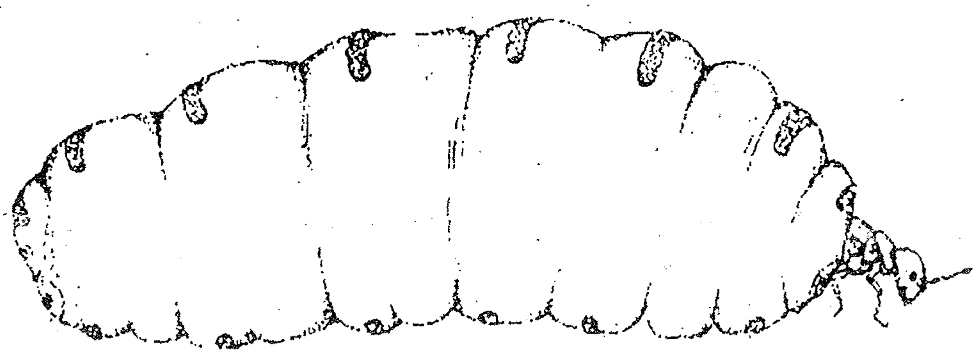
The simplified model of a termite life cycle shows the presence of three castes, the **reproductives**, the **soldiers** and the **workers**. As termites are hemimetabolous insects, the nymphs take part in the social life and have their specific role to perform.Once the caste of an individual is determined, development into other castes is still possible. Soldiers, being referred to as **intercastes** might turn into workers or even into reproductives, if there is a shortage of individuals of other castes. This process is controlled by **pheromones**. In the case of the queen, there is a specific 'queen' pheromone, preventing other individuals from turning into queens. Only if the queen is removed or dies, does the lack of the specific pheromone promote the development of a new queen.

Reproductives possess compound eyes and are more or less brown due to their sclerotized cuticle. Developing reproductives have wing buds, wings or wing stumps. Reproductives can be further divided into .

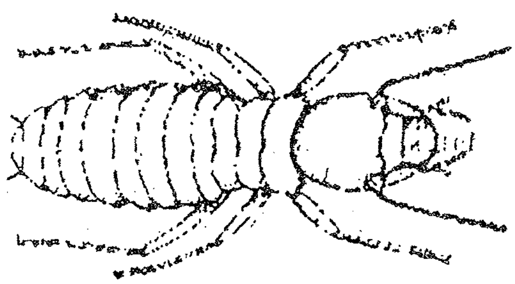
- **Alates,** the young winged reproductives of both sexes. From time to time about 100 to 1000 alates leave the colony for a mating and colonising flight. After mating a pair settles down at a suitable site like a rotting scar on a tree in order to establish a new colony.

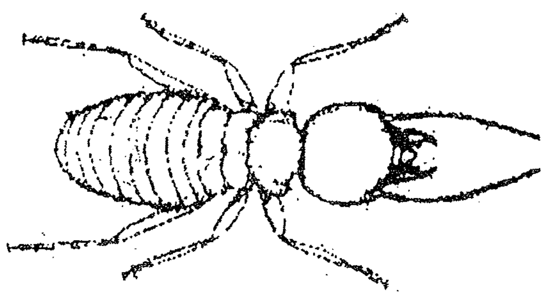


- **De-alates,** alates that cast their wings after the colonising flight and successively turn into queens and kings. Initially only a few eggs are laid and brought up by a female de-alate. As the number of individuals in the colony grows, the more workers are available to help the young queen to care for the brood. After three to five years the number of individuals is already so large, that the colony of a pest species can turn into the damaging stage.
- **Queen and king,** are the main reproductive individuals in a colony. Once there are many workers to help the queen, her only job is to produce a tremendous number of offspring. A large queen may lay more than 1000 eggs per day. The life span of a queen can be as much as 50 years.



- **Neotenics** assists the queen in laying eggs, once her productivity decreases. When the queen has died or deteriorated, one of the neotenics takes her place. That is the reason why the removal of a queen from her colony does not necessarily mean the end of the colony.





- **Workers** are sterile, wingless and blind males and females. Their cuticle is unpigmented and not hardened, therefore the animals are confined to a dark and moist environment. Workers build the nest and galleries, they fetch food, care for the brood and feed reproductives and soldiers. The workers' life span is one to two years.
- **Soldiers are**, like workers sterile, wingless and blind males and females with an unpigmented, unsclortized cuticle. Soldiers defend their colony from intruders by the use of powerful jaws and/or by ejecting a white sticky repellent from an opening on their head. Soldiers can't feed themselves, they have to be fed by workers. Usually the number of soldiers is much smaller than the number of workers. Soldiers can be **mandibulate** or **nasute**, depending on the species. Therefore soldiers can be used for the identification of termite species. The life span of the soldiers is one to two years.

III. Components of Sociality :

A. Division of labour (polyethism)

1. Age Polyethism
   a) temporal division of labour in which individuals pass through different forms of specialization as they age
   b) e.g., work honeybees (initially brood care, later foraging)
2. Caste Polyethism
   a) morphological castes are specialized to perform different functions
   b) ants : workers, soldiers, queens
   c) termites : larva (apterous nymph), nymph (brachypterous nymph), soldier, worker, primary and secondary reproductives

B. Communication

1. Action on the part of one organism that alters behaviour of another in an adaptive fashion
2. Essential for social organization
3. Characteristics of communication in social insects
   a) primary chemical (through pheromones)
   b) based on behaviours existing in some form in solitary and presocial insects

   c) Social activities are mass phenomena based on the integration of simpler individual behaviours
4. Functions of communication in social insects
   a) alarm
   b) simple attraction
   c) recruitment (e.g., to food or nest sites)
   d) grooming
   e) trophallaxis (exchange of oral of anal liquid)
   f) exchange of solid food
   g) group effects (e.g., nest building)
   h) recognition (nest mates, castes, dead and injured)
   i) caste determination
   j) control of competing reproductives
   k) territorial, home range, and nest markers
   l) sexual communication

C. Intelligence
   1. Insect intelligence is limited by size
   2. Need for higher intelligence for more complex behaviours (and possibly communication) in social setting

IV. Ecological and evolutionary considerations :

A. Social Homeostasis
   1. regulation of numbers and nest environment (homeostasis – maintaining a physiological steady state)
   2. environmental regulation – principally thermoregulation, some humidity regulation, also housecleaning behaviours
   3. numerical regulation – inhibiting oviposition of workers, inhibiting production of reproductives, killing extra reproductives, cannibalism (termites in genus *Zootermopsis* reared with nitrogen deficiency restore balance through cannibalism)

B. Features Leading to Ecological and Evolutionary Success
   1. Appointment of colony resources
      a) worker vs. brood production
   2. Control over available resources
      a) ability to regulate foraging, food storage, "agriculture" (fungus gardens)
   3. Long term fitness
      a) colony dispersal, longevity (through social homeostasis, for instance), nest construction
   4. Reduced risk from predators and parasites

C. Genetic Basis of Social Behaviour
   1. Must account for sterile castes and altruistic behaviour (self sacrifice for greater good)

2. Three principal hypotheses
   a) Mutualism – sociality arose because of adaptive advantages of societies; falls to account for sterility or altruism therefore unlikely as major factor
   b) Parental manipulation – one or both parents are able to neuter and control offspring to increase the parent's fitness
      (1) some evidence supports this hypothesis but not as exclusive explanation; may have been more important in the evolution of sociality, but no longer crucial in maintaining society
   c) Kin selection – by reducing individual chance of survival and reproduction are able to increase potential survival and reproduction of relatives with common genes
      (1) developed in mid 1960's but substantially criticized in 70's
      (2) Kin selection depends on principle of inclusive fitness
         (a) classical fitness – personal reproductive success of the genotype of interest
         (b) inclusive fitness – classical fitness plus influence of genotype on reproductive success of relatives
         (c) inclusive fitness depends on degree of relatedness

Prospects and problems of sericulture in drought prone lateritic tracts :

Sericulture is an agro-based cottage industry which deals with mulberry cultivation, rearing of silk worm, production of disease free silk worm seeds, production of commercial cocoons and therefrom raw-silk for its distribution and marketing.

Status of sericulture in India with brief historical background :

Silk is one of those rich productions of East, which even from ancient times has been valued by the nations of the West. There is no authentic information regarding the origin and use of silk. But it is confirmed that silkworm was originally a native of China from where it was spread to other countries of the world. However, several distinct species of silkworm are indigenous in India which are distinct from those of China. In India, the major silk producing states are Mysore, West Bengal, Jammu and Kashmir, Assam, Bihar, Orissa, Madhya Pradesh, U.P., Andhra Pradesh, Tamil Nadu, Punjab, Manipur, Tripura and Maharastra. Major silk producing districts of West Bengal are Malda, Murshidabad, Darjeeling, Coochbehar and Birbhum. Bihar has the oldest set up of silk-industry and produces all the varieties except Muga. Similarly Birbhum is the district which produces both Tasar & Mulberry like that of Midnapore, Bankura and Purulia districts where the tasar production is more than that of mulberry.

Different phases of mulbery sericulture :

a) Mulberry propagation and cultivation
b) Rearing of silk-worms
c) Production of disease free seeds
d) Production of cocoons

e) Mechanised reeling
f) Marketing

Mulberry propagation and cultivation :

It may be propagated either sexually or asexually. As sexual mode is prone to mixing up with different varieties, asexual mode of propagation (grafts or layers or cuttings) is normally practiced.

1) **Grafting :** The sceen of a high yielding or even exotic variety of mulberry is grafted with the stock of an indigenous variety.
2) **Layering :** In this method, the mature branches of the plant are bent down and their upper portion is buried in the soil, leaving the tip of branch above the soil. When the buried portion of the branch strikes root in the soil, it is severed off from the mother plant.
3) **Cuttings :** In this method about one year old mature branches are selected and cut into pieces each of about 15 cm long with three or four buds. These cuttings are planted in the fields and is allowed to grow to a height of 30 cm in the form of bush. This bush system of cultivation is very common in West Bengal and vields four to six crops in a year.

Rearing of mulberry silkworm :

For commercial rearing of mulberry silkworm, production and supply desease free seeds are necessary. It involves two operations viz. (1) Maintenance of the mother stocks of the desirable breeds of silkworms, and (2) Production of disease free seeds to be available to commercial rearers.

Rearing House : The rearing house should be well ventilated, spacious, clean having temperature and humidity in a conducive range.

Rearing equipments : This include Dallas, Chandrikies, shelves made up of bamboo. Thread nets, Banti, Wooden plates, Knife, Thermometer, Hygrometer, Formaline, Cunny bags and many other things.

Voltinism : Based on voltinism, the silkworms are classified into three groups –

Univoltine : One brooded silk worm hatches once in a year and is reared once in a year.

Bivoltine : Double brooded silkworm hatches twice in a year.

Note : Both the univoltine and bivoltine varieties of silkworms are reared in the hill areas during summer months and in plain during the winter seasons.

Multivoltine silkworms : They pass through successive cycles without rest and can be reared several times in a year.

Life cycle :

The silk worm's life starts from the egg. It is laid after the mother moth is fertilised. The eggs may be of different shapes, sizes and clour. These are two kinds of silkworm eggs – hibernating egg and other is the non-hibernating egg. Hibernating eggs may be treated with acid for artificial hatching. Onward development of developing embryo depends very much on pH, temp, humidity and light intensity of the environment. From the hatching to the appearance of pupal stage requires 20 to 25 days. The pupal stage lasts for 2-3 days. Transformation from cocoon to adult requires 10-12 days.

Sericulture in South West Bengal :

Sericulture in South West Bengal – especially in the districts like Midnapore, Purulia and Bankura faces some problems relating to their characteristic agroclimatic conditions. Large tracts of hilly lateritic soil endowed with less precipitation, high temperature, high humidity and lower soil pH. Besides, irrigation facilities are not upto the mark. In order to overcome those problems, some strategies are to be adopted to ensure the growth and propagation of sericulture in those districts.

Management of problems relating temperature :

Silkworm being a cold blooded animals is cabable of adjusting its requirement under fluctuating temperature of environment. It is well established that temperature plays a decisive role on growth, mortality, cocoon quality, fecundity, hatching, voltinism and future generations. The optimal ranges of temperature are of three kinds considering its effect on the physiology of silkworms viz. (1) the temperature which is harmless to the growth; (2) which is favourable for the healthy growth and (3) which is favourable for producing good quality cocoons. It is reported that the temperature which is harmless to the growth of silkworm ranges from 20-28°C. Beyond 30°C, as the physiological rate increases, the silkworms grow early and spin cocoons of lesser weight and inferior quality. From the resulting moths, the fecundity is also reduced to a considerable extent. At temperature below 20°C, as the physiological rate recedes, the worms consume less food and grow over longer period exhibiting dissimilar growth and succumbing to various diseases. The temperature which is favourable for the healthy growth of silkworm is 25°C for 1st to 3rd instars worms and 23°C – 24°C for late age worms. For obtaining good quality cocoons the temperature requirement is 28°C for first instar, 27°C for second instar, 26°C for third instar, 25°C for fourth instar and 23-24°C for fifth instar. It is also reported that under this temperature range, it not only reduces the larval duration but also the larval mortality. Besides, the silk synthesis and quality of cocoons vis-à-vis silk also increases. However, fluctuations of temperature in the environment beyond the range of 20-28°C is very much harmful in silkworm rearing. This can be achieved to some extent by regulating ventilators, windows and doors for rearing rooms. In south West Bengal, the temperature shoots up beyond 30°C and reaches upto 44°C in some time during summer season and drops below 10°C during winter season. In this condition, silk worm can not grow well and the chances of loosing crops are more. Under such circumstances, it is necessary to adjust the temperature of the rearing room. During summer, the day temperature is high and in night it is low. The windows should be kept open during night so that the cool south west wind gets in and bring down the temperature of the rearing room. During day time, doors and windows should be closed to avoid the entry of hot air in order to maintain the rearing room temperature as low as possible. During summer, roof of the rearing room made up of tin, asbestos or concrete gets heated and in order to prevent excessive heating of the roofs, provision of false roof with straw and coconut frands are useful.

For good, uniform and synchronous hatching of eggs provisions of optimal temperature and humidity condition is essential. At higher temperature, the embryonic development is quicker but the chances of embryo killing are more and even the hatched worms will be weak and light. Again, the seed cocoons are to be preserved at a temperature of 23⁰C – 25⁰C in grainages because the low temperature delays emergence of moth while the high temperature results in pupal mortality.

Management of problems relating to humidity :

Environmental humidity influences the growth of the silkworm largely. At higher relative humidity, the physiological rate increases reducing the larval duration while the larval period is delayed at low humidity. The optimum humidity for different stages of the silkworm is different as mentioned below.

1st stage	-	80% - 90%
2nd stage	-	75% - 85%
3rd stage	-	70% - 80%
4th stage	-	65% - 75%
5th stage	-	60% - 70%

High temperature and high percentage of humidity combiningly increase the percentage of rejection of the silkworm during the larval stages. The humidity requirement varies with stages of silkworms. Under above mentioned humidity range, the 1st to 3rd instars larval stages are being reared in paraffin paper cover surrounding by wet foam rubber strips is being practiced besides piling the rearing trays over one another to a convenient height. As the relative humidity rises during spining time, the cocoon quality is lowered since the worms are provoked for increased urination. The humidity fluctuates widely not only from season to season but also within a day during any season. The relative humidity of the rearing room can be regulated by closing the doors and windows when it rains to keep out humidity and opening them when there is no rain to bring down relative humidity. At the time of low atmospheric humidity, it is necessary to provide wet foam rubber strips around the rearing fed in between the paraffin sheets.

Again, an optimum humidity of 70-90% should be maintained in the grainage for easy emergence for moths and eggs laying.

Cultivation of food plants :

Development of sericulture and increased production of quality cocoons depend on the yield of better mulberry leaf. The maximum production of good quality mulberry leaf per unit area will lead to fulfil two most important objectives – (i) increased production of cocoons; (ii) reduced cost of production. Therefore in order to grow mulberry plants, either in the form of bush or in tree, the selection and preparation of plots are main prerequisites. Any land which does not enjoy prolonged innundation and also does not have steepy slope can be used for such plantation purpose. But land with clayey mixed loamy soil, have slightly acidic pH, scope for getting sufficient light and or etc. appears to be most suitable.

Cultivation of mulberry in droght prone areas :

Before undertaking plantation programme in the areas which are prone to higher temperature, humidity but less precipitation, the following measures are to be adopted :

A) **Selection of Land :** Land should be selected in moderately higher places.

B) **Preparation of Land :** Undulating tract of land should be levelled uniformly so that all the corners of the land after being irrigated may get uniform water supply. If the land is steepy, then it has to be divided into several small plots by constructing smalled sized earthen banks. Before the onset of monsoon, the land be prepared either deep digging or by deep ploughing upto a depth of 15″ in order to loosen the soil before planting. Weeds, stones, gravels, roots of other plants should be removed. Afterwards, a basal dose of 10 ton organic manure per acre of land (F.Y.M.; Vermicompost; Green manure) along with claye pond bottom soil (5 ton/ acre) should be applied. Now, a number small pits (1′ x 1′ x 1′) are to be prepared in a row with a gap of 2′ and the gap in between 2′-3′. Afterwards, the pits are to be filled up by organic manure and clay soil (2:1) along with a small amount of aldrine which is supposed to act as a repellent of termites.

C) **Plantation of cutting :** Cuttings collected from disease free plants with size of about 8″ to 10″ are to be planted diagonally in the already prepared pits so that their buds will remain always in a upward direction.

D) **Irrigation :** After plantation, if the prepared land contains some amount moisture (15-20%), one time irrigation is required. Afterwards, from December to May, in every month at least one time irrigation is necessary. In dry seasons, measures are to be taken to keep the water in between two rows of mulberry plants.

E) **Harvesting :** Leaves can be plucked from a mulberry plants which are planted six months earlier.

Structure of Honey bee family :

Honey bees are social insects belonging to the order Hymenoptera under the family apiae and genus Apis. They live in families together with several thousands of drones and workers. The green is the mother of the family. She is also the only true female. Her extreme specialisation makes her an egg laying machine. Workers, incomplete females perform all the domestic tasks like feeding the larvae and cleaning the hives. Drones, males of the bee species emerge in spring and die before winter sets in. Queens workers and drones cannot live for long if kept apart. Their interdependence is a key factor in apiculture.

What is Apiculture :

Apiculture provides rural people in developing countries with sources of income and nutrition. It is a sustainable form of agriculture which is beneficial to the environment on one hand and provides economic support on the other. The range, quality and potential of the products grow in line with the development of apiculture technology.

Bee species and races :

There are over 20,000 species of bees (Apoidea) in the world. Most of these are solitary bees where each female makes her own nest and lays eggs but does not live in it. A few bees are social, they live in a community known as a colony. Social bees make honey which is their food store. All the bees, capable of producing considerable amount of honey, belong to two sub families – Apinae (honey bee) and Meliponinae (stingless bees). Apinae has only one genus – Apis which includes six different species which are found in India.

1. *Apis dorsata*
2. *Apis mellifera*
3. *Apis cerana indica*

Life cycle and works distribution patterns of honey bee :

Bees usually complete their life cycle within six weeks. Within this short span, they have to perform a number of important tasks within the hives at different ages like cleaner, nurse, stores, manager, builder. guard and food gatherer. Most workers activities within the nest are social but what each bee does depend on the development of its various glandular systems. This is linked to age and to the needs of the colony.

During the first five days of life, it is essential that the worker bee feeds in order to develop her different glands to their full potential. The worker bee acts as a cleaner during this period and clean all the honeycomb cells to be used by egg-laying queen or for food storage. From, the five days to nine days, she has the job of nurse. Glands in her head secrete food which becomes part of the royal jelly that nurtures larvae, some of which may be destined to be queens. After nine day, the glands on the head becomes inactive while the glands in the abdomen starts producing wax. From 10^{th} to 16^{th} day, she is busy using wax to build comb. When the wax glands cease to secrete, the worker becomes a stores' manager. The 17^{th} to 19^{th} days are spent bringing pollen and nectors to the hive. During this period, they also ventilate the hives by flapping her wings. This allows the air to circulate, it also strengthens the muscles to work for taking flight. Before this, there is another job to perform – that of sentry. Around the entrance to every hive, there are guard bees whose duty is to keep out wasps, moths and other intruders. The rest of workers bees life is spent seeking food i.e. foraging. The bees suck up the nectar from the flowers and store it in their honey sacs and carry it back to the hive. There they regurgitate it and pass it to another bee. During these processes, enzymes are added to the nector and thereby change it into honey which is stored in the honey comb. Bees also produce propolis (this is not a food but a building material). It is a sort of bee glue and is used to seal cracks in the hive, to strengthen the comb and to mummify any intruder such as beetles, other insects etc. Propolis is plant resins collected from the buds of various plants and sometimes mixed with beewax. The bees carry it in their pollen baskets. It is very sticky and so the workers need the help of other bees to remove it when they return to the hive.

Communication and Control of honey-bee colony

Living in a large group, bees always need to communicate with one another. They do this in a number of ways like by producing various noises, secreting pheromones, by the presence and absence of queens, by the enlargement of hives vis-à-vis population increase etc. But, the most studied form of communication is the Bee dance. This is generally believed to be the way in which bees tell one another not only of the location of food but also the strength and the distance of the feeding place from the hive. This phenomenon will always be associated with the name of German Zoologists, Karl Von Frisch who was honoured with the Noble prize in the year 1973.

All the bees of a hive do not go out for search of food. There are certain workers generally called as "foragers or scout bees who perform this duty and on their information other workers move to the feeding place. The foragar after discovering a suitable source of food returns to the hive, loaded with nectores or pollen and inform other inmates about her find by performing the dance which is performed in two was –round dance and tail wagging dance (Waggle dance) Round dance coney the information about the source of food only (less than 100 meters) but the waggle dance tells the other bees that the nector is further away. The bee moves in a figure of eight and waggles her abdomen when she moves up the central line (Fig. 1 & Fig. 2).

Biofertilisers with special emphasis to Vermitechnology :

Biofertilizers are the nutrient availability system in which biological processes are involved. These biological systems are the essential part of life of several microbes found in soils and provide nutrient like nitrogen, phosphorus and several beneficial compounds for crop. Presence of these microbes makes soil alive and capable for sustainable support to the life of crop.

The biological soil fertility management is an ecological approach for sustainable agriculture and is mainly concerned with the the maintenance of yield, closely associated with desires to conserve natural resources, including a greater value accorded to maintenance of biodiversity (Spencer and Swift, 1992). According to Sanchez (1994) – Human beings however to rely on biological processes by adapting germplasm to adverse soil conditions, enhancing soil biological activity and optimizing nutrient cycling to minimize external inputs and maximize the efficiency of their use.

The term biofertilizers includes selective microorganisms like bacteria, fungi and algae which are capable of fixing atmospheric N or convert insoluble inorganic chemicals in the soil into forms available to plant and also other soil organic substances with high nutrient quality produced by the activities soil inhabiting fauna. Biofertilizers are cost effective, eco-firendly and renewable sources of plant nutrients to supplement chemical fertilizers.

Biofertilizers for sustainable agriculture :

Biofertilizers have for long witnessed shifting fortunes in agriculture. In developed countries during last three decades, a massive movement has been launched against the indicriminate use of pesticides and inorganic fertilizers in agriculture and also for the production of organic foods in order to avoid the problem of bio accumulation of toxic substances through biomagnification. But the large scale application of biofertilisers in developing countries has been hampered by several factors, including lack of trained personnel, absence of proper awareness programmes and availability of suitable industrial support. Another major problem, especially relevant to biofertilizers production and application is the virtual disconnection between research institutions and industry. A strong extension and training programme, actively supported by research and industry is the need of the hour.

Biofertilizers are inputs containing microorganisms or organics which enhance the growth of microorganisms and are capable of mobilizing nutritive elements from non-usable form to usable form through biological processes.

Groups of biofertilizers :

The following are the different categories of biofertilizers.

Free living	:	This group includes numerous species of blue algae and certain bacteria such as Azotobacter.
Symbiotic association	:	The bacteria, Rhizobium, live symbiotically on the roots of legumes. Azolla, a water fern, fixes atmospheric N in symbiotic association with blue green algae.

Different categories of Microbial biofertilizers

Bacterial Biofertilizers	:	Rhizobium, Azospirillus, Azotobacter, Phosphobacteria.
Fungal biofertilizers	:	My corrhiza.
Algal biofertilizers	:	Bleu green algae (BGA) and Azolla.
Actinomycetes bioferlizers	:	Frankia.

Mode of action of microbial biofertilizers :

Nitrogen is one of the chief and important constituents of protein and nucleic acid molecules that play the basic role in cell metabolism, growth, reproduction and transmission of heritable characters. Biological nitrogen fixation (BNF) is the reduction of atmospheric nitrogen to ammonia by microorganisms in the soil. It is a unique biological mechanism by means of which low-cost nitrogen production is ensured and also it enhances higher crop productivity.

Some soil microorganisms play an important role in improving soil fertility and crop productivity due to their capability of converting non-usable atmosphere nitrogen (80%) into usable form of nitrogen (ammoniacal), solubilize insoluble phosphate and decompose farm wastes resulting in the release of plant nutrients.

Characteristics of substances to become effective biofertilizers :

A number of products are now available that are generally referred to as soil and plant additives of non-traditional nature. These products include.

i) Microbial fertilizers and soil inoculants containing unique and beneficial strains of soil micro-organisms.

ii) Microbial activators that supposedly contain special chemical formulation for increasing the numbers and activity of beneficial microorganisms in soil.

iii) Several organic manures those create favourable soil physical and chemical conditions which result in increased growth and yield of crops.

Organic manures :

Farmyard Manure:

Good quality farm yad manure (F.Y.M.) is perhaps the most valuable and commonly used organic manure applied to a soil. It consists of a decomposed mixture of cattle dung, the liquid excreta, the bedding materials used in the stable and any remnants of straw and plant stacks fed to cattle. It contains 0.5% N, 0.2% P_2O_5 and 0.5 K_2O.

Composted Manure :

Composted organic manure is prepared from the compost from farmhouse and cattle shed wastes of all types composting is the process of reducing vegetables and animal refuse (rural or urban) to a quickly utilizable condition for improving and maintaining soil fertility. It is found that good organic manure similar in appearance and fertilizing value to cattle manure can be produced from waste materials of various kinds such as cereal straws, crop stubbles, cotton stalks, groundnut husk, farm weeds and grasses and other similar substances. These materials are rich in cellulose and other readily decomposable carbohydrates and have a carbon-nitrogen ratio of 40 or more to 1. The direct application of such undecomposed, low nitrogen organic matter as manure brings about a temporary deficiency of mineral nutrients (specially nitrates and ammonium compounds) in the soil by stimulating the growth of microorganisms which in turn compete with crop plants for available nitrogen, phosphorus and other elements. Hence, before using them as manure, it is necessary to compost or partially decompose them. This process lowers the carbon-nitrogen ratio to about 20 to 1.

Urban Compost :

In recent years, large scale composting of town refuse and night soil in properly constructed trenches away from human habitations has been taken up successfully by the municipal bodies of many large and small towns. Trenches, 1 to 1.2 m wide, 75 cm deep and of convenient length are filled with successive layers of night soil, town refuse and earth. In this process, the compost gets ready in about 2 months.

Super digested compost :

Application of super phosphate at 5% over the raw waste materials during composting improves the manurial value of compost. Application of this compost to acidic, calcareous and heavy soils increases the P availability.

Sheep and goat manure :

The droppings of sheep and goat provide a valuable manure. It has been estimated that by stocking 1000 sheeps in the agriculture field for a night will add about 2 tonnes of droppings the manure contains 3%N, 1% P_2O_5 and 2% K_2O.

Poultry manure :

The excretion of birds contain both solid and liquid parts and hence there is no urine loss. The decomposition rate of the poultry manure is very quick. The manure should not be exposed to sun since there is 50% loss of N within a month. The fresh droppings contain 75% moisture, 1.5%N, 1.2% P_2O_5 and 0.5% K_2O.

Sewage and studge :

Sewage has two components -- the solid portion called sludge and the liquid part called sewage water. Major portion of the suspended solids and effluents (99%) in the sewage is removed by settling. The sludge is latter collected separately, dried and used as manure. The sludge on an average contains 1.5-3.5 % N. 0.8-4% P_2O_5 and 0.3-0.6% K_2O.

Night soil poudrettes :

Night soil contains appreciable amount of N. It can be profitably converted into useful manure known as 'POUDRETTE'. Dehydration of night soil can be done as such or admixture of absorbing materials like soil, ash, charcol and sand dust. Among the materials, sand dust is the most effective one which can be very well used. Sand dust has high dehydrating capacity as well as the property of absorbing foul smell. About 40-50% of sand dust could be added with the night soil. By this way, it is possible to get a dry, acidic poudrette which may contain 2-3% N. 2-8% P_2O_5, and 4.01%. K_2O.

Oil Cakes :

After extraction of oil from the oilseeds, the residues are called as oil cakes. The non-edible oil cakes viz. Neem, Karanj, Mahua etc. are used as organic manures. Application of neem oil cakes serve dual functions like removal of pests and enhancement of fertility. Oil cakes usually contain high amount of N and small quantities of P and K, they have low C : N ratio (3-15) which helps in releasing the nutrients quickly.

Besides, crop residues, rice husk, tea-wastes, coir wastes, green manuring, poultry manure etc. are being used as organic manure.

Vermitechnology :

The technology which produce good quality organic manures by the use of suitable earthworm species from the waste material.

It has 3 important components :

i) **Vermiculture :** Through which steady supply of suitable earthworms species is ensured.

ii) **Vermicomposting :** Specially designed composting process of organic wastes where earthworms acts as accelator.

iii) **Vermi conservation :** Through the increase in the number of earthworms, it also ensures the higher production of earthworms and thereby their conservation.

Merits of Vermicompost :

i) Vermicompost contains higher NPK contents which is about 8 times greater than any other organic manure.

ii) C/N ratio in vermicompost remains in favourable condition (1:20) which is very much conducive for the plants to assimilate nutrients.

iii) Application of vermicompost creates a condition which enhances higher microbial growth in the soil and thereby lead to higher fertility.

iv) All micro-nutrients are present.

v) Duration of composting is less than 2 months.

vi) Termite resistant.

vii) Maintain soil texture and help water conservation by way of increasing water holding capacity.

viii) Locally available wastes are recycled.

ix) Vermiprotein may be utilised as feed in poultry and aquaculture.

Besides, earthworms can significantly influence soil structure and fertility in many ways – (i) they accelerate decomposition rate of organic matter in the soil and increase the simultaneous incorporation of soluble nutrients within the soil; (ii) they increase the number of water stable aggregates, improve the porosity, aeration, water infiltration and water holding capacity of soil, (iii) through their life cycle patterns and activities, they increase the microbial efficiencies and water holding capacity of soil, promote deeper root growth and assist in the incorporation of fertilisers.

Therefore, vermiculture and vermiconservation will faster earthworms density and diversity on the one hand and maintenance of agro-environment on the other.

Ingradients used for vermitechnology :

Three different types of ingradients will be required for vermitechnology

1) Suitable earthworm species
2) Waste materials including Organic wastes/bio waste
3) Suitable vermicomposting pits and other associated infrastructure.

Suitable Earthworm species :

The selection of suitable species is based on certain biological and ecological parameters. Technically, these have been referred by M.B. Bouche (1977) as habitat characteristics, distribution in soil and trophic functions. Based on these paramcters, we find that there are three types of earthworms which can be used in vermiculture.

(a) **Epiges :** The epigeic earthworms inhabit the litter heaps or any other degrading organic matter on soil surface. They are phytophagous and good bio-degradators and therefore suitable for vermicomposting. They have short life cycle with high reproduction and regeneration time.

(b) **Endoges :** The endogeic earthworms inhabit mineral soil horizons and feed more on soil than on organic matter, therefore they are mainly geoghagous. Life cycle is of intermediate duration but are potential in soil improvements due to high efficiency in energy utilization from poor soils. They can be used for soil reclaimation in the field.

(c) **Aneciques :** The anecics are large sized worms with pigmentation only at anterior and posterior ends. They live in highly complicated furrow systems. They surface out to feed on dead leaves which they normally drag into their burrows before feeding.

II. Waste Materials :

Waste materials for vermicomposting may be derived from several sources – mainly from Municipal Waste, and biowaste.

Municipal wastes are largely generated by urban human population and are some of the most problematic polluting and expensive to dispense with. In very developed cities in the world, the daily production of municipal sewage waste (MSW) per person varies from 2 kg to 4 kg. While in Bombay and Kolkata it is 600 gm. Bioconversion of this huge amount waste through vermicomposting will generate resource in one hand and abating of pollution on the other.

Biowaste arises from a variety of human, agricultural, horticultural and industrial sources and can be considered to form three general groups (i) waste of directly animal origin (faeces/manures), (ii) plant material (grass clippings, plant litters and vegetable pellings) and (iii) processed materials (food industries, market wastes, fisheries & animal husbandry sectors etc.). From the chemical standpoint, biowaste may be considered to be characterised by a high carbon content, the composition of biowaste from animal origin shows considerable variance. This depends on a number of factors including climate, body size, age, diet, daily intake and in the case of livestock, management regime, species or breed, while cultural and socio-economic influences affect the situation in humans.

Biowaste derived from plant material itself, is principally composed of cellulose, though with differing amount of other plants structural compounds including hemicelluloses and lignin.

Vermicomposting pits and other infrastructure :

Well designed vermicomposting pits (cemented/earthen) of different sizes and shapes endowed with water removing channels and ventilators for ensuring steady supply oxygen are to be constructed. In order to protect the ongoing decomposting materials in pits along with earthworms from predators, direct sunlight and rainfall, all the pits are to be roofed with straws/asbestos/cement in accordance wth the prevailing environmental condition.

Vermicomposting Process :

Different methods are evolved for the earthworms to feed on the organic wastes to convert them into manure.

In the composting pit, first programme is the preparation of bed. The bedding materials are generally hard/slow biodegradable i.e. agricultural stubbles, husk, sand dust, sugarcane thrash and much other. In the base of the culture tank this materials are used as a first layer, then this is to be covered with a thin layer of fine sand (3 cm thick). Over the sand layer, another layer of garden soil (3 cm thick) are used. After compleion of the preparation of bed, suitable earthworms are released and add the biodegradable waste material over the earthworms. Earthworms would feed on the soft material to begin with and release cast on the surface. The cast was brushed aside before adding fresh feed to earthworms. In the meantime, the material added at the base would soften and earthworms would feed on this bedding materials and convert the entire material into dark humus. During the harvesting period soil and some quantity of sands may be mixed with the compost. Therefore to avoid this problem, preparation of bed may be avoided. This may be ensured by directly using organic wastes with certain amount of cowdung and water.

Then, the pit is covered by hessian cloth. In this way the compostable wastes are predigested and generated heat. After 2-3 weeks, generated heat generally comes down and then earthworms are released depending upon the nature of waste materials. Within 45-60 days, 60-70% of wastes are converted into manure. During composting period moisture & temp. of pit should be maintained as (30-40%) and $(25\text{-}30)^0$C respectively.

Collection of Vermicompost :

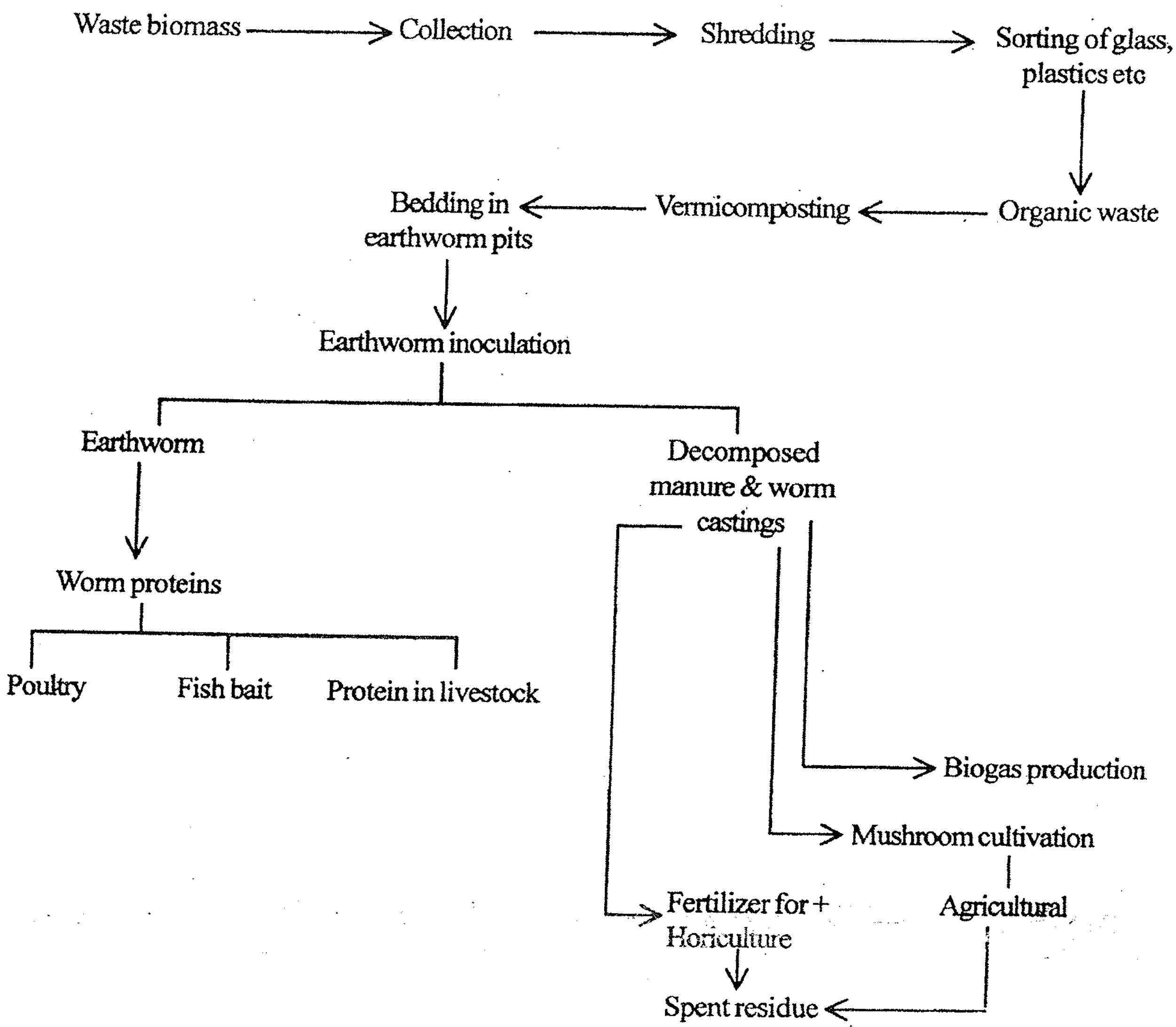
When vermicompost and vermicasting are ready for collection, top layers appear somewhat dark brown colour placed in the form of heap with granular texture. After that, water adding should be stoped for 2-3 days. Then total composting materials are to be in the pit. In this way due to loss of moisture, earthworms migrate vertically i.e. towards base of heaps. Therefore, apex of the heap may be easily separated where no earthworms are generally found. Through hand shorting method, the earthworms are separated from bottom of heap. Then total composting materials are seived by 2 mm galvanised mesh for removing cocoon & juvenile worms. Then this cocoon, juvenile worms are to be inoculated into the another pit. Collected vermicompost can be stocked in ground under shed. For commercialization, vermicompost should be packed in plastic bags.

Vermiculture :

Vermiculture means rearing of earthworms. Vermiculture in the first step of vermitechnology. Vermiculture can only be done on compostable or decomposable organic matter. Vermiculture & vermicomposting are two inter linked and inter dependent processes. Composting is the outcome of earthworm's activities. So both the process can be brought about simultaneously.

Step-wise work at start of vermiculture include : i) site selection, ii) availability of decomposable organic waste, iii) collection & study of know how on earthworms to be cultured, iv) Maintenance of seed culture for eventual large scale culture.

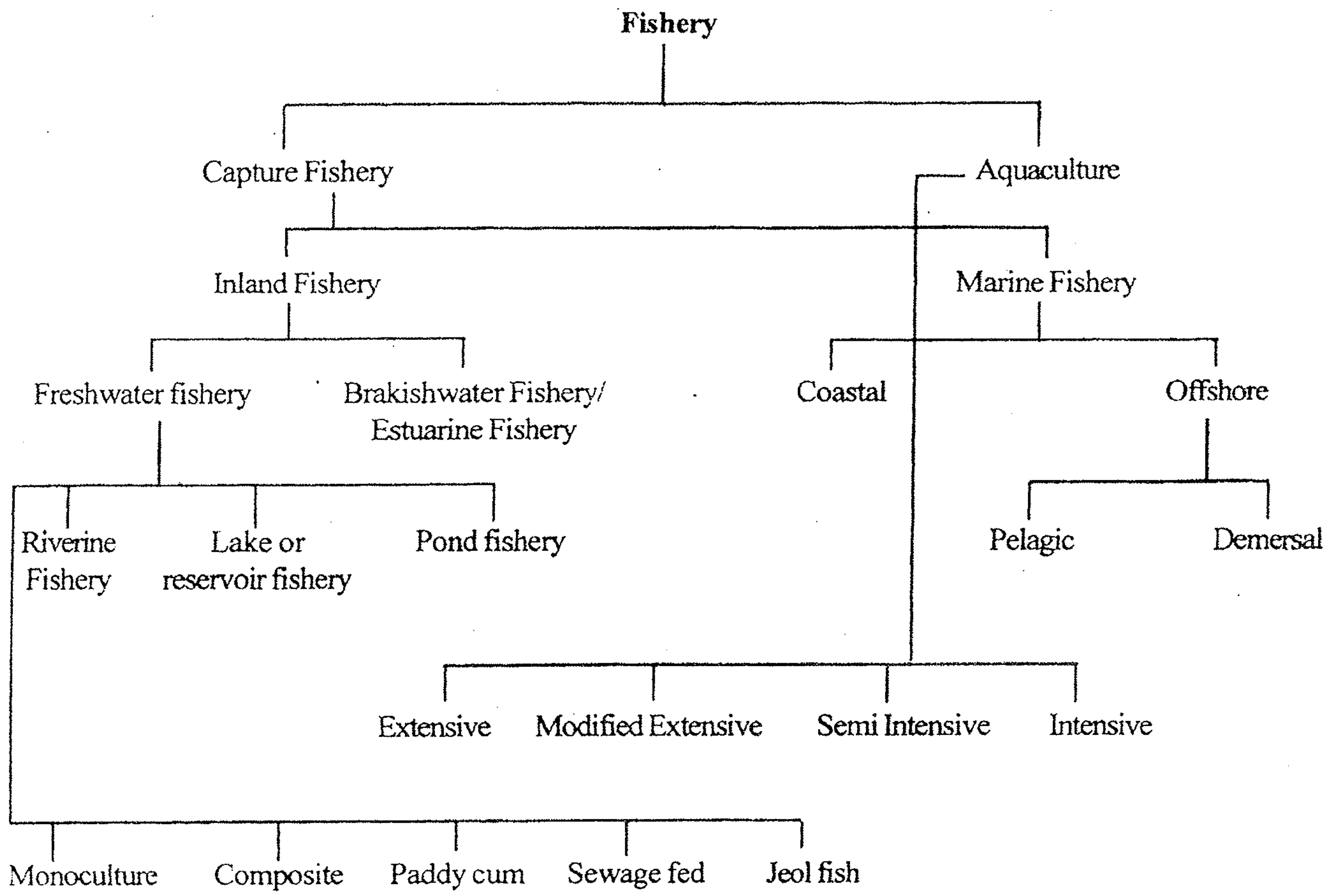
Recycling of organic wastes through earthworm cultivation



Topic – 5 : Concept of culture and capture fisheries; inland and marine fisheries of fin fishes and shell fishes-present status and prospect.

The subject fisheries deals with the capture culture and conservation of aquatic organisms for human consumption as food and their utilisation as essential commodity.

Classification of fisheries :



Commercially important Ichthyofauna :

Freshwater fishes :

i) Indian Major carps – Rohu, Catla, Mrigel, Kalbasu

ii) Indian Major Carps – Bata, Puti

iii) Exotic Major Carps – Grasscarp, Silvercarp

iv) Exotic Minor Carp – Tilapia, Javaputi

v) Jeol fishes – Anabus, Heteropneustes, Clarius, Channa

vi) Carnivorus fishes – Notopterus, Wallagu

Breakishwater/Estuarine fishes :

i) Harpodon neherius – Bombay duck

ii) Setipinna phasa – phasa

iii) Tenualosa ilisha – Ilish

iv) Polynemus – Topse
v) *Mrigal cephalus* – Parse
vi) *Lates calcarifer* – Bhatki.

Marine fishes :

1) Promfrets - a) Silver pomfret – *Pampus argenteus*
b) Chinese pomfret – *P. chinensis*
c) Black pomfret – *Parastromateus nigar*

2. Ribbon fishes – *Trichiurus lepturus*
3. Cat fish – *Arius maculatus*
4. Saradin – *Sardinella longiceps*
5. Anchovies – *Anchoviella commersonii*
6. Mackerel – *Rastrelliger kanagutra*
7. Tuna – *Thunnus obesus*

Fish Production (Metric Ton) in different countries of the world (FAO, 1998)

Countries	Marine capture fishery	Aquaculture	Total production
China	14,222,306	17,714,570	31,93,6876
Peru	9,515,048	6,912	9,521,960
Chili	6,692,653	217,903	6,910,556
Japan	5,964,090	829,354	6,793,444
America	5,000,799	393,331	5,394,130
India	3,491,998	1,768,422	5,260,420

Trend of pelagic fishery resources in India

There are about 250 species of fishes all over the world contributing to the pelagic fishery. A few species enjoy wide range of distribution, while a few like sardines, shads and bombay duck have rather restricted distribution. Until the mid-seventies, the share of the pelagic stocks in the over all production remained very high with a consistently increasing trend from 54% in 1950 to 71% in 1960 and thereafter at around 65% till the early seventies. The pelagic catches increased from 309,000 t in 1950 to the current 12,43,424 t in 1996 registering nearly a fourfold increase (Table 4).

Although the pelagic fish catches increased by 22%, during 1970-79, the trend in the overall production was mainly due to the demersal finfish and crustacean catches. The decade (1980-89) experienced a growth of 27% in the pelagic catches as well as in the overall production mainly due to the rapid motorization of traditional fishing crafts. Intensive motorization of the traditional fishing crafts resulted in a remarkable increase in the annual production especially of the total pelagics which increased from 769,000 t in 1985 to 1,313,000 t in 1989, registering a 71% increase.

The statewise average contributions to the pelagic fish production showed that Kerala ranked first among the maritime states of India contributing about 31% of the total pelagic fish catch, followed by Gujrat and Tamilnadu contributing 13.7% and 13% respectively. The contribution by other states were : Maharastra – 10.8%; Karnataka – 10%; Goa – 7.1%; Andhra Pradesh – 6.9%; West Bengal – 3.8%; Orissa – 1.4%; Andaman & Nicobar Islands – 1%; Pondichery – 0.8% and Lakshadweep – 0.5%. This shows that the southwest region comprising Goa, Karnataka and Kerala continued to be the highly productive area followed by northwest, southeast and northeast regions and other island's aquatic system.

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VIDYASAGAR UNIVERSITY

DIRECTORATE OF DISTANCE EDUCATION
MIDNAPORE - 721 102

M.Sc. in ZOOLOGY
Part-I
Group-B : Unit-I

Module No. – 9

Integrated Pest Management

Hazards of pesticides have led to the origin and evolution of different approach in suppressing pest population and reducing damage. 'Pest management' is relatively a new name for the philosophy and system of pest control that entomalogists have been using in the field of crop production.

The term 'pest' is simply defined as species detrimental to human being, whether it be an insect, disease orgnism, weed, rodent and other. 'Pesticides' are substances used to control pest; thus insecticides, fungicides, weedicides, rodenticides, etc. are all pesticides. 'Pest control', is a procedure employed to reduce pest population or prevent their detrimental effect 'Pest management' designates a philosophy and methodology of restricting pest population to subeconomic level. Integrated Pest Control interchangeably with Integrated Pest Management refers to an integration of control tactics into a strategy of pest control. Formerly it was applied by some only to the integration of biological and chemical control.

The FAO panel of experts on Integrated pest control defined "Intregrated Control" as "a pest management system that in the context of the associated environment and the population dynamics of the pest species, utilizes all suitable techniques and methods in as compatible a manner as possible and maintains the pest population at levels below those causing economic injury." (FAO, 1967).

Principles of pest management were enumerated by various workers as outlined briefly by Johansen (1978). Bottrell (1979) provided an expression that "Integrated Pest Management is the selection and implementation of pest control based on predicted economic, ecological and sociological consequences". In simple term pest management aims at expert utilization of existing mortality and suppressive factors in a (judicious) manner that enable the desired commodity to be produced in the largest sustainable quantity of highest quality at the least cost and with a minimum risk or disruption to the producer, consumer and the environment at and after the time of production. Obviously it does not remain single approach but becomes a multidisciplinary one.

Over the years a number of principles have gradually emerged for the application of the integrated pest control philosophy. They are described in outline form below in a logical order of their application in developing an Integrated Pest Management system. However, it must be remembered that these principles are closely integrated and must be applied in the context of the pertinent agroecosystem.

I. **Identify the status of pests :**

A. An organism should be called a pest until it is proven to be a pest. A particular species may be a pest in some situations and not in others or at certain times and not in others.

B. Identification of pest status should be coupled with the establishment of economic injury thresholds (see below).

C. Pests interact with one another and this interaction may compound or offset their effects on the crop plant. We should not assume their effects are additive.

D. Categories of pest

1. Key Pests are serious, perennially occurring persistent species that require control measures to be taken regularly because in the absence of control they frequently occur at above economic injury thresholds. Usually there are only a very few key pests (sometimes only one or two) in any agroecosystem. They key pests are the focal point of the pest management systems.

   Ex. Mango hopper, *Idioscopus clypealis.*

2. Occasional or secondary pests are relatively minor pests that rise to economically damaging levels only at certain times or in certain places. These occasional pests are especially suscepible to an integrated pest control approach aimed at preventing these occasional outbreaks. Prediction technology is especially useful for these 'part-time' pests.

   Ex. Paddy gall midge, *Orseolia oryzae.*

3. Potential pests cause no significant damage tinder the conditions currently prevailing in the agroecosystem. In attempts to manage key pests or occasional pests, care must be taken not to alter the conditions of the agroecosystem so that the potential pests cruet as severe pests.

   Ex. Brown plant hopper, *Mlaparvata lugens.*

4. Migrant pests are non-residents of the agroecosystems that enter periodically and which may cause severe economic damage, e.g. migratory locusts and army worm. The ecological approach to the control of such pests is still valid but must be applied in the perspective of a very large geographic area.
   Ex. Desert locust, *Scistocerca gregaria.*
5. Many other phytophagous forms may be present in the agroecosystem but are considered to be non-pests.

II. Definition of the management unit, i.e. the agroecosystem :

A. The limits of the agroecosystem are determined principally by the characteristics of the local cropping system and the characteristics of the pests (particularly their pattern of movement or vagility). The limits may circumscribe, for example, a tree, or an orchard, or a valley, or other large ecological unit.

B. The definition of the management unit is another way of approaching the definition of the target pest population.

C. To define the limits of an agroecosystem properly it requires an intimate knowledge of the interrelationship and mobility of the key pests in the agroecosystem.

III. Development the Pest Management Strategy :

A. The fundamental strategy of pest management is the coordinated use of multiple tactics in a single integrated system with the goal to hold pest numbers and damage to tolerable levels. It is a containment strategy rather than an eradiction strategy.

The fundamental tactics of integrated pest control are :

1. Utilization of indigenous natural control.
2. Management through cultural practices.
3. Use of inherent plant resistance and tolerance.
4. Selective use of chemical pesticides. How these tactics are utilized will depend on the specific agro-ecosystem and the nature of its key pests.

C. Any pest control procedure must only be applied when economically and sociologically justified. Strategies of pest Management :

1. Reducing level of original pest infestation.
2. Modifying the rate at which the. pest increases in the agro-ecosystem.

3. Reducing the influx of pest invaders into the agro-ecosystem.
4. Some combination of the above three. The exact combination will depend on the characteristics of the pest and the agro-ecosystem.

IV. Determination of Economic Thresholds :

A. The Economic Injury Threshold is that pest population level or of pest intensity that produces an increment reduction in crop value greater than the cost of implementing a pest management action. (The level of pest intensity may be measured by various indices of presence, e.g. number of pest individuals present per unit area.)

B. Often the economic injury thresholds are varied according to either phenological time or physiological state of the crop plants.

C. To establish an economic injury threshold some thing must be known of the following:

1. Methods of measuring plant response to pest injury or impact.
2. Methods of measuring directly or indirectly the pest abundance or intensity, i.e. sampling.
3. The crop loss from the anticipated level of pest intensity in terms of quantity and quality of the crop and its economic value.
4. A cost / benefit analysis of the proposed pest management action.

D. The establishment of an economic injury threshold is the most difficult research area facing the integrated pest management research worker.

E. *Economic Treatment Threshold* is a level at which action must be taken to prevent economic damage. It is a somewhat lower level of pest intensity than the injury level. At the economic treatment threshold, if a decision to take a pest management action is made, time is still sufficient, before the economic injury threshold will be reached, to permit the control actions to be carried out and for them to have their anticipated impact on the pest.

To establish an economic treatment threshold it requires some knowledge of

i. future patterns of pest intensity
ii. factors influencing the economic injury threshold and
iii. pest damage potential in the specific crop situation.

F. Not all pest control actions are based on direct response to levels of pest intensity.

For example :

1. Preventative or prophylactic actions which may be taken far in advance of the presence of the pest. They are
   a. aimed at lowering the mean level of the pest
   b. altering the pest population distribution or
   C. altering the basic structure of the crop management system.

But many others must be taken during the course of the growing season in response to seasonal development of pests in crop, or to the presence or absence of key elements in the management system, or changes in levels of pests.

The in-season response is usually a temporary, suppressive action, e.g. cultural practices or application of pesticides.

G. In some situations, it may be possible to raise the economic injury threshold through appropriate manipulations of the components of the agro-ecosystem. This may be just as effective in changing the status of pest or by reducing its mean population level.

H. The goal of an integrated pest control system is to manage and manipulate the agroecosystem so that the incidence of the pest always remains below the economic injury threshold.

V. **Development of reliable monitoring and predictive techniques :**

A. Develop sufficient understanding of the crop production system and associated agroecosystem to forecast with both short – and long – term prediction potential problems so that it is possible to undertake the necessary measures to prevent these events from occurring.

B. The development of a sound predictive technique may be based on one or a combination of the following :

1. An understanding of the crop phenology and related pest correlatives.
2. An understanding of the pest phenology.
3. Monitoring of pest incidence.
4. Monitoring of weather conditions.

VI. **Generation of Evolve descriptive and predictive models**

A. This is the ultimate goal in the more sophisticated pest management systems but is not an absolute requirement for the development of integrated pest control. Nevertheless, a sound understanding of the agroecosystem is always required for integrated pest control.

B. The usual steps in the system analysis approach may be described as follows :

1. Qualitative analysis of the structure and behaviour of the agroecosystem. This usually results in a flow diagram with the several components identified together with their interactions.
2. Formulation of mathematical model for the agroecosystem. This puts the flow diagram into mathematical terms.
3. Assessment of the adequacy of the model. The predictive capability is tested against the facts from the real agroecosystem. Gaps in information concerning the agroecosystem may be thus identified in this process.
4. Mathematical assessment and analysis of the behaviour of the agroecosystem together with refinement of the mathematical model.
5. Optimization of the agroecosystem management decisions. The models is utilized as a tool in reaching a decisions in the best procedure of obtaining the desired benefit at the lowest cost.

VII. Overcoming the Socio-Economic barriers for the establishment of integrated pest management system:

A. Overcome social, economic and political activities interfering with the development and establishment of integrated pest management.

B. Demonstrate that food crop production is everyone's business. Demonstrate that integrated pest management is a practical and sensible approach in dealing with pest problems.

C. Create a real awareness of the necessity for conserving the environment and resource of the biosphere. Plan a national utilization of the environment. Provide an environmental ethic.

poka (insect)". Incidence of the pest is usually noted from May to end of November, the peak of infestation

during October.

Life history :

Eggs are laid on the upper surface of the leaves. The incubation period ranges from 6-8 days. Nymphs after hatching feeds voraciously and gregariously until 4th instar. The nymphal period ranges from 20-30 days, passing through 5 instars.

Control:

1. Collection and destruction of adults and nymphs by hand nets.
2. Dusting of 10% BHC or 5% Malathion or 5% Dipterex during morning @ 10 kg/acre.
3. Removal of grasses in which the bug lives.

Select Books:

1. Anonymous 1985. Rice Research in India, ICAR, New Delhi.
2. Atwal, A.S. and Dhaliwal, G.s. 1998. Agricultural Pests of South Asia and their Management, Kalyani Publishers, New Delhi.

PESTS OF JUTE

Jute crop is subjected to attack from the seedling stage till stage of harvest by a large number of pests affecting the yield as well as the quality of fibre.

Below is given a list of pest classified according to their site of damage;

a. Foliage eater

1.	Jute semilooper	*Anomis sabulifera Guen* *Lepidoptera, Noctuidae*
2.	Bihar hairy caterpillar	*Diacrisia oblique Wlk* Lepidoptera, Arctiidae
3.	Indigo caterpillar	*Spodoptera exiqua Hbn.* *Lepidoptera, Noctuidae*

b. Stem damaging

1	Jute stem weevil	*Apion corchori* Marsh, *Coleoptera, Apionidae*
2.	Jute stem girdler	*Nupserha bicolor postbrunnea Dutt* *Coleoptera, Lamiidae*

Non-insect pests –

Leaf sucking

Yellow mite	*Polyphagotarsonemus latus*, Banks *Acarina Tarsonemidae*
Root damaging	*Meloidogyne incognita* (Kofoid & White) Chitwood *Tylenchida, Heteroderidae*

Of these only few are of major of importance and have been discussed below.

Jute semilooper - *Anomis sabulifera*

External characters :

Moth : Medium sized, dull brown or grey brown in colour with spots and wavy lines on fore wings, hind wings whitish.

Larva : Semi-looper assuming the semi-looping form because of the atrophy of the abdominal legs or prolegs arising from the 3rd and the 4th abdominal segments, body of the semi-looper is green in colour.

Nature & symptoms of damage :

The pest causes damage to both capsularies and olitorius jute and is considered to be the most important mid-season pest of jute. The caterpillars hide upon and cause damage to the top apical leaves and the growing apex of the stem. Susceptibility of leaves gradually decrease with increase in their age. Usually damage is restricted up to the 6th or the 7th leaf from the top. As a result of feeding of the growing maristem of the apex, the side branches come out. These side branches contribute very little towards the final yield. When the main stem rets properly, these thinner branches becomes over-tetted and the fibres are lost. Repeated feeding of top leaves in different waves of attack arrest the growth the affected plants and this is reflected in the yield.

Incidence starts when the crop is about 3ft in height usually from the month of June and continue till August. Three or four waves of attack are found in a jute season, of which the second often becomes very serious and destructive. In years of epidemic, loss of yield may extend up to 50 percent in extreme cases.

Life history

Eggs are laid singly on the top leaves at night. A single female can lay as many as 100 eggs. The Incubation period of egg is about 2 days. Larval period varies from 9 days to 15 days. Pupa formation usually takes place under dried leaves or crevices of soil. Pupal period is about 7 days. The pest generally hibernates in soil as the pupa during winter period. There maybe 3-4 generations in a year.

Control:

1. The pest can be controlled by application of Endosulfan @ 0.07%, carbaryl @ 0.1%, Dichlorvos 0.06% or Fenthion @ 0.07%.
2. Early showing suffer less infestation.
3. *Tricholiga sorbilans, Litomastris sp., Sigropaformosa* have been recorded as parasitic on the larva.

Bihar Hairy Caterpillar - *Diacrisia obliqua*

External characters :

Moth : Medium sized buff colour with black spots on fore wings abdomen creamson coloured with black marking on sides on the back.

Larva : Body covered with dense tuft of hairs, each tuft arising from a hump or tubercle.

Nature & symptoms of damage :

The caterpillars of the pest feed upon both olitorius and capsularis jute. The early instar caterpillars are gregarious in habit and feed upon the leaf tissues of older leaves from the undersurface leaving the upper epidermal layer and the midrib and the leaf veins intact and thus 'skeletonise' the leaves. Later on the caterpillars cease to remain gargarious and spread over the entire field.

Unlike the jute semi-looper, the caterpillars of D. *obliqua* cause damages to the older leaves but in absence of older leaves they may feed on younger leaves as is found under conditions of epidemic. Late instar caterpillars devour the entire leaves and bare stem may be left alone in severe infestation.

Presence of the pest in the field in the initial stage can be easily recognised by the skeletonised older leaves in the field.

The pest is considered to be the most important late season caterpillar pest of jute and cause damage to the old and mature leaves. The pest is usually more prevalent in high rain fall areas in the jute growing tract.

Life history

Eggs are laid by female in cluster on the lower surface of the leaves having approximately 200 eggs in each clusture. A single female lays as many as 1000 eggs. Incubation period of egg is about 6 days. Larval period covers about 3 weeks. The caterpillars are polyphagous in habit feeding on peas, cotton, ground nut, sunhemp, sunflower, bean etc. Pupal period is about 1 week. Pupation takes place under dried leaves or in cracks or crevices of soil within a cocoon into which body hairs of the caterpillars are incorporated.

Control :

1. Early instar caterpillar in gragerious state may be collected and killed by kerosinized water or by spraying with strong detergent soap solution.
2. The pest can be effectively controlled by using Endosulfan @ 0.08%.
3. *Apanteles obliqua* and *Eurytoma sp.* have been recorded as parasitic on the larva.

Jute stem weevil - *Apion corchori*

External characters :

Weevil Small in size, dull black in colour, elytra covers the abdomen completely, foms and vertex prolonged to form the rostrum or snout, antennae not geniculate.

Larva : Larva apodous, small in size, body tranversely wrinkled and curved.

Nature and symptoms of damage :

The pest causes damage to both the olitorius and capsul aril jute. Grubs feed on the stem tissues and make the local injury on the stem. As a result of the injury mucilagenous substances oozes out which binds the cut ends of the fibre bundles with the adjacent tissues which often resist separation at the time of retting and the hard mass often remain present on the fibre reeds as knots which are considered as defects in the fibre. Thus the pest is responsible for qualitative deterioration of jute fibre. The affected plants can be easily recognised by the drooping and withering of apical region, axillary buds or leaves. The stem at the region of attack is punctured, becomes swollen and discoloured. Damage on jute fibre can be recognised by the presence of knots which contain s a central hole. In case of incidence by the pest during the seedling stage of the crop, branching is induced. Immature pods are at times attacked resulting in damage to young seeds.

Life history

The adult female bores holes usually at the base of the petiole into which a single egg is laid and is covered afterwards by a gelatinous mass. Incubation period of egg is 3 days to 4 days. More than 500 eggs are laid by a single female. The larval life ranges from 8 days to 18 days. Longevity of adult may extend upto 7 months. The weevil passes winter in the adult stage.

Control :

1. Removal of the infested plants during the thinning operation which is an important agronomic practice in jute cultivation.
2. Self-sown jute plants should be destroyed so that the pest can not multiply on them.
3. Use of resistant var-JRO 321.
4. Application of 0.08% Endosulfun and 0.06% Methyl demeton are effective in controlling the pest controlling

Yellow mite - *Polyphagotarsonemus latus*

External characters :

Adult : Cephalothorax and abdomen fused together and appear to consist of a single segment. 4 pairs of legs present. Antennae, compound eye and wings absent. Simple eyes present. Metamorphosis present. Body translucent and yellowish in colour. In case of male posterior end of body narrow and tail like, containing a sucker apparatus ventral.

Nymph : Body whitish, 3 pairs of leg present.

Nature and symptoms of damage :

This is a non-insect pest of jute. Both the olitorious and the capsularis jute varieties are susceptible to damage. Apical leaves are attacked from the undersurface and tissue juices are sucked from below. As a result of such sucking from undersurface of leaves, curling and crimpling of leaves from above downwards occur. The affected leaves do not grown to their proper size and shape and become dull to deep green, sometime coppery brown and may drop prematurely leaving the apical region of the stem bare. The internode may not grow to their normal length. Early sown crop often become more liable for damage.

Life history :

Minute eggs are laid by the female on the undersurface of top apical young leaves and leafbuds usually along the margin of midrib and veins. Incubation period of egg ranges from 27-32 hours. Nymphal period lasts for 34 hours. Males are polygamous in habit. The pest has a large number of host plants like chillies, tea etc.

Control :

1. Clean cultivation with row cropping is effective for reducing the growth of mite population.
2. Use of resistant var - JRO 524,
3. Application of Dicofol @ 0.08% or Monocrotophos @ 0.07% become effective for control.

Select books :

1. Anonymous, 1964. Entomology in India, Entomological Society of India, IARI, New Delhi - 12 (India).
2. Nair, K. K., Ananthakrishnan, T. N. and David, B. V 1976. General and Applied Entomology, Tata McGraw - Hill Publishing Co. Ltd., New Delhi.

Pests of Cashew

Cashew is an export oriented crop, popularity grown in the district of Midnapore, West Bengal along with other parts of India. The high value crop is said to be infested by more than 50 different insect pests at different stage of growth and development. Of the various insect pest species recorded only few of them are more important owing to their extent of damage.

1. **Cashew stem and root borer** *Polcaederus ferrugineus L.*
Coleoptera : Cerambycidae

External characters :

Adult : Medium sezed dark longicorn beetle.

Larva : Dirty white, 60-80 mm. long, mouth parts well developed, thoracic legs reduced, no abdominal legs.

Nature & symptoms of damage :

The tiny dirty white grubs on hatching bore into the bark of the stem and feed on subeidermal layer including phloem tissues and grow finally into large grubs. The make irregular tunnels in the bark. Due to its feeding on pholen tissues the ascent of sap from roots to upper portion is arrested. Consequently the leaves become yellow and drop and in severe cases the tree dies.

The symptoms include the presence of holes plugged with excreta and reddish mass of chewed fibres on the collar region, exudation of gum, yellowing and defoliation of leaves, drying of twigs and final mortality of the tree in sequence.

Life history :

The adult beetle lays eggs in crevices of loose bark at the collar region or on exposed roots. The egg period is about 15 days. On descending to root zone for pupation, the larva also feeds on roots. The grub stage lasts for 6-7 months. It pupates at the root zone in a calcareous bean-shaped cocoon. The life cycle is completed in 9-10 months.

Control :

1. Use of hooked wire to kill the grub.
2. Painting the bark with dilute suspension of BHC (0.2%) or coaltar.
3. Injection with kerosin, petrol, CS, napthalene followed by mud plugging.
4. Spraying with Endosulfan @ 0.06% or Chlorpyniphos @ 0.1% or Carbaryl @ 0.1%.

2. **Cashew mosquito bug** *Helopeltis antonii* Sign.
Hemiptera, Miridae

External characters :

Adult : Blackish brown bug, about 8 mm long, head black, thorax red, prothorax characterized by pin like knobbed process arising vertically.

Larva Freshly hatched spidery in appearance, ant like, orange coloured, about 3 mm long.

Nature & symptoms of damages :

Both adults and nymphs suck sap from tender shoots, leaves, floral branches, panicles, tender apples and nuts. Due to sucking on the leaves necroitic patches develop, on shoot elongate streaks and brownish patches develop on wither side of feeding puncture due to exudation of gummy substance and on immature nuts and apples characteristic scabby spots develop. The infestation results in crinkling or distortion and drying of leaves, death of shoots etc, resulting inflorescence blight leading to scorched appearance of the tree. The peak of incidence is during blossoming period in January and the pest remain active up to May.

Life history

Eggs are laid singly inserted into the soft tissues of tender shoots, nuts, floral branches etc. Eggs hatch out in about 7 days. The nymphal stage is completed in 10 days with fibre instars. The total life cycle is completed in about 3 weeks.

Control :

Two full cover sprays (covering the leaves, inflorescences etc.) with Monocrotophos or Carbaryl or Endosulfan @ 0.5 kg. a.i. / ha with the help of high volume power sprayer, first at the initiation of flower bud and second after three weeks of its first application, are effective in controlling he bug and to have good fruit setting.

Leaf miner, *Acrocercops syngramma* M
Lepidoptera, Gracillariidae

External characters :

Moth : Silvery grey with fringed wing, small sized.

Larva : Pale white turning to reddish brown when fully grown, body dorsoventrally flattened, 4-6 mm long, tapering posteriorly.

Nature & symptoms of damages :

Caterpillars mine into the leaves and cause blisters on leaves due to swelling up of epidermal layers. As the infested leaves mature the damage is manifested as big holes due to drying and crumpling of the mined areas. The damage results in the reduction of the photosynthetic areas leading to reduced growth and yield of the crop.

Control :

Application of Endosulfan or Carbaryl or Dischlorvos or Chlopyriphos at the dosages mentioned earlier synchronising with the time of emergence of new flushes.

Leaf and blossom webber, *Macalla moncusalis Wlk.*
Lepidopters, Pyralidae

External characters :

Moth : Dark brown.

Larva : Freshly hatched larva pale white then turn reddish brown with yellow lateral longitudinal bands and pinkish dorsal, lines.

Nature & symptoms of damages :

The caterpillars on emergence webs the terminal leaves and inflorescences and feeds on them. As a result the flowers do not open and the tender apples and nuts as webbed drop prematurely. It appears on the new flush in June-July and January-March.

Life history :

The female moth lays eggs on tender twigs, tender leaves or panicle stalks. The incubation period lasts for 4 to 7 days. The larval period is 16-29 days. It pupates within the webs in. a silken cocoon and pupal period lasts for 9-14 days. The total life cycle is completed is 29-43 days.

Control :

Disturb the webs mechanically and spray with Carbaryl or Malathion @ 0.1% / Endosulfan @ 0.06%.

Select Book :

1. Anonymous, 1964. Entomology in India,
Entomological Soceity of India,
IARI, New Delhi - 12 (India).

Pests of Betelvine

Betelvine is attacked by various species of insect and unfortunately, in this the leaf is more vulnerable to the attack of the pests than any other part of the plant. The most obnoxious enemy is Aleyrodid fly, next in order being the phid *(Aphis gossypii),* scale insect *(Lepidosaphes sp.),* termite *(Odontotermes sp.)* etc.

Black fly –	*Aleurocanthus rugosa* Singh
White fly –	*Dialeurodes pallida* Singh
	Hemiptera, Aleyrodidae

External characters

Black fly *(A. rugosa)*

Adult fly : About 1 mm long, bright black, abdomen reddish, eyes red, antenna 7 segmented, wings with . black patches.

Nymph : Elliptical, size 0.35 mm" pale yellowish white, 3 pairs of munute legs.

White fly *(D. paffida):*

Adult fly : about 1 mm long, dull white, thorax ash colour.

Life history :

Minute eggs are laid in the form of a spiral in case of black fly *(A. rugosa)* while in case of white fly *(D. pallida) it* is scattered on the under surface of the apical tender leaves. The eggs are entangled with short stalks inserted into plant tissues. Incubation period of egg varies from 9-11 days. Nymphal stage lasts for about one week. Adults live for 4-5 days. Several overlapping generations are there. Adults are crowded near the growing apex preferring undersurface of apical tender leaves. They are very agile and have a peculiar habit of frequently raising their wings while feeding.

Nature & symptoms of damages :

Nymphs and adults of both the species of insects cause damage the betel leaves by sucking cell sap. The nymphs just after hatching crawl first and then settle at a suitable place on the same leaf. Due to the constant draining of cell sap the vigour of the plant becomes affected resulting stunting of growth, curling of leaves, discolouration of leaves, development of the brown scars at the point of feeding. The physical injury as caused makes the path way for the entry of pathogens. Besides sucking they also excrete honey dew on the dorsal surface of the leaf which leads to the development of sooty mould. The blackening ugly fungal growth interferring the photosynthetic activity of the plant quite adversely. The damage thus caused results significant qualitative loss by reducing taste, texture and market value of the high value cash crop.

Control :

1. Avoiding dense growth.
2. Use of controlled irrigation and balanced fertilizer.
3. Use of organic fertilizer like neem cake.
4. Spraying of 2% neem oil mixed with 0.5% teepol.

Selected Book :

1. Nair, M. R. G. K., 1975. Insects and mites of Crops in India, ICAR, New Delhi.

Pests of stored grain and their control

There are more than 50 different species of pests that attack and cause damage to the grains under the condition of storage. Of these, few are however, important. The important species mostly belong to insect orders, coleoptera and Lepidoptera.

Below is given a list of major pests of stored grains.

1.	Rice weevil	*Sitophilus oryzae* L.	Coleoptera, Curculionidae
2.	Grain weevil	*Sitophilus granarius* L.	do
3.	Lesser grain borer	*Rhizopertha dominica F*	Coleoptera, Bostrychidae
4.	Red rust flour beetle	*Tribolium castaneum* Herbst.	Coleoptera, Tenebrionidae
5.	Confused flour beetle	*T confusum* duval.	do
6.	Khafra beetle	*Trogoderma granarium*	Coleoptera Dermestidae
7.	Pulse beetle	Everts. *Callosobruchus*	Coleoptera, Bostrychidae
8.	Angoumois grain moth	*chinensis L. Sitotroga*	Lepidoptera Gelechiidae
9.	Rice moth or Rice meal worm	*cerealetta Oliv. Corcyra cephalonica* Staint.	Lepidoptera Gelechiidae

Rice weevil - *Sitophilus oryzae*

External characters :

Adult : Tiny weevil with its head produced to a curve shout or rostrum, body dark brown or almost black in colour having light reddish or yellowish spots on the elytra, antennae geniculate.

Larva : Apodus, white with yellow brown head, and strong madibles.

Nature & symptoms of damage :

Grains of paddy and all the cereals such as wheat, maize, barley etc. and their products are severely damaged by the pests. In fact, it is the most common pest that is met in a godown. The pest was first reported from rice as early as 1763 and hence it is referred as rice weevil. It is particularly common in warm countries but it is widely distributed all over the world. According to some authors, India is the native place of the pest. Adults and the grubs feed upon the grains leaving the skin only. Damaged grains become useless for human consumption or for use as seed. Adults are, however, scanty feeders and make shallow pits. Grubs are most destructive and completely hollow the grins. As a rule one grub is found in one grain but there may be 2 or 3 depending on the size of the karnel. Grains break in cases of heavy damage. The peak period of damage is between August to November. Nearly 50% of damage in godown can be attributed to this pest.

Life history :

Eggs are laid by the female in small holes which are sealed by mucilaginous material. A single female can lay about 150 to 300 eggs. Incubation period is about 4 days in summer but may be extended to 6 to 9 days in winter.

The grubs bore into the karnels of the grains feeding on the starchy content and hollowing them out. Larval fife varies from 19 to 30 days with 4 maultings. Pupation occurs inside the grains and the pupal period ranges from 3 to 6 days. Usually 5 to 6 generations are met with. Longivity of adults varies from 7 to 5 months. It has been estimated that a pair of weevils may give rise to 1 million individuals in about 3 months.

Angoumois grain moth - *Sitotroga cerealella*

External characters :

Moth : Small, delicate with yellowish brown forewings, hind wing light grey with long fringe of hairs.

Larva : White with yellowish brown head, measuring 5 to 7 mm long.

Nature & Symptoms of damage :

The pest was first reported from the Angoumois province of France in 173 6 and hence the name "Angoumois moth". The pest is found distributed all over the World and is a very destructive pest of unmilled or unhusked grains and is considered to be second in importance to *Sitophilus oryzae*.

It causes severe damage especially in areas of temparate climate. All types of grains including summer and winter cereals are attacked. The infestation is restricted to top layer only. Larva bores into the grain and eats out a cavity.

Life history :

Eggs are laid singlet' or in groups by the female in the depressions, holes of the grains or cracks and crevices of floor or walls. The fecundity is about 40 eggs (maximum 389). Incubation period of egg is about one week. The larvae after hatching get entrance of the grain through abrations or cracks in the seed coat and feed upon the karnels till pupation. Larval life varies from 2 to 3 weeks. Pupal period is about one week. The pest has usually 3 to 4 broods in a year but there may be as many as 8 broods in a year.

Rich moth or Rich meal work – *Corcyra cephalonica*

External characters :

Moth : Slightly larger than *Sitotroga cerebella,* body greyish brown, proboscis present.

Larva : Creamy white in colour, head prominent, prothoracic shield distinct.

Nature & symptoms of damage :

The pest causes serious damage to rice and other cereals and legumes. It has also been noted on oil cakes, cocoa, biscuits, chocolates, "suji", "atta", dried fruits and vegetables as well as on animal products. The larva damages the grains by feeding on them. They bore into the grains. The larvae wave dense mass of silky fibres with the grains, frass etc. which is typical of species. Often the grains are covered with waves and are formed into a large mass.

Life history :

Female lays eggs indiscriminately on the surface of bags walls, grains etc. A single female lays 90 to 200 eggs. Incubation period is about 5 days. The larva after hatching waves and binds the grains and the frass etc. together into a dense mass. Larval period occupies about 4 weeks. Pupal period is about 10 days. Life cycle is completed in about 6 weeks.

Lesser grains borer – *Rhizopertha dominica*

External characters :

Adult : Beetle small, cylindrical, dark brown or black in colour, head hypognathous, antenna short with a club, body covered with sunken dots.

Larva : Brownish white with a curved abdomen, legs will developed, body covered with small fine hairs.

Nature & symptoms of damage :

It is a major pest of nearly all cereals such as paddy, wheat, maize etc. The term 'Lesser' in the popular name of the pest refers to its small size, not to its importance. The larva on hatching feeds first on debris of the grain then bores the grains to feed into grains. Adults feed upon the grains. It prefers damaged grains.

Life history :

Eggs are laid by the females usually near the soft of the embryo in the grains. A single female lays 300-500 eggs. Incubation period of egg is 5 to 6 days in summer but may extend 10 days in winter. Average larval life is about 42 days. Pupal period ranges from 5 to 8 days. There may be 4 to 5 generations in a year.

Khapra beetle - *Trogoderma granarium*

External characters :

Adult : Beetle shout, oval in shape, brown marking on the body, antenna short, and clavate.

Larva : White in colour, body covered with short and long reddish brown fine hairs arranged in tufts.

Nature and symptoms of damage :

The pest is nearly cosmopolitan in distribution. Damage to the grains are done by the larvae only. Due to feeding caused by the larva the damaged grains become grains become the powdery mass. Infestation by khapra beetle is characterized by the presence of large number of larvae and their cast-off skins.

Life history :

About 125 eggs are laid by a single female, singly or in clusters of 2 to 4. Incubation period varies from 5-16 days. Larval period lasts for about 50 days. Pupal period ranges from 6 to 17 days. Longivity of adult varies from 10 to 32 days.

Red rust flour beetle - *Tribolium castaneum*

External characters:

Adult : Reddish brown, little flattened, pro-thorax rectangular wider than long, legs short.

Larva : Yellowish white, cylindrical, distinctly segmented.

Nature and symptoms of damage :

The pest is much less serious than *Sitophilus oryzae* and *Rhizopertha dominica.* Sound grains are seldom damaged by the adults and the larvae. But they may attack grains which are already damaged by other pest or broken grains or may damage the soft embryo end of the grains. This is a serious pest of' atta', 'moida', 'suji' etc. and they are common in flour mills and stores.

Life history :

Eggs are laid singly in flour and similar grinded products or on broken grains. A single female may lay as many as 450 eggs. Incubation period varies from 5 to 12 days. Larval and pupal period range from 27 to 29 and 6 to 9 days respectively. Life cycle is completed in about 6 weeks.

Pulse beetle - *Callosohrucus chinensis*

External characters :

Adult : Choacolate brown in colour and oval in shape, head small, antenna long, prothorax large.

Larva White, fleshy, wrinkled, curved.

Nature and symptoms of damage :

It is a serious pest of all kinds of pulses. It causes damage to cowpes, gram, 'mung', 'kesbari', 'Arhar', 'pea', 'soyaben' etc. In the field eggs maybe laid on green pods. Maximum damage to the pulse grains is done under the storage conditions. The grubs feed upon grains and cause serious loss. Heavily damaged grains show one or more neat circular holes on them.

Life history :

Eggs are laid single by the adult female, which is firmly glued to the surface of the seed coat. The egg hatches in about 5 days. The larval life covers 2-3 weeks. Pupation occurs inside the grain. Pupal period ranges from 4-7 days. There may be several overlapping generations in a year.

Control of Pests of Stored Grains

The following measures are recommended for control :

Prophylactic or preventive measures :

i) Hygiene and sanitation in the store should be properly maintained. All dirts, rubbishes are removed, cracks and crevices are sealed, holes are closed and cemented and room may be white washed.

ii) Stacking of the grain bags should be done with provision of dunnage materials.

iii) The godown and the gunny bags should be disinfested with Malathion 50 Ec in the ratio of 1 : 100 applied @ 3 liters/ 100 m2.

Curative measures :

i) Physical control :

Drying of grains usually in the sun is effective to obtain the moisture content of the grains below 10% as the condition is not condusive for normal activity and development of insect pest species. Super heating (5 5-60°C for 10-20 rains) by infra red heater can be employed to control the insects.

Use of 'Entoletor' a mechanical device to produce centrifugal force can be used to do away with insect infestation. Various inert dusts like alumina, silica etc. prevent the entry of insects into grains by causing physical injuries, which results desiccation and death of insects by abrasive action on the insect cuticle. Irradiation with gamma rays is also effective causing mortality and sterility in insects.

ii) Mechanical control :

Screening or sieving out of broken or damaged grains is an effective measure to reduce pest infestation.

iii) Ecological control :

The development of insects in storage may be prevented by creating unfavourable conditions including temperature, moisture control of the grains and the availability of oxygen. Temperature above 42°C and below 15°C retards reproduction and the development of insects and also prolonged exposure to temperature above 45°C and below 10°C may kill the insects. It is reported that all the immature stages of *S. oryzae, R. dominica* and stages of *S. cerealella* are killed when exposed to temperature of 80°, 70° and 60°C for about 4, 6 and 8 minutes, respectively, Grains heated to 50°C is lethal to many insects but the grains loose viability at such temperature.

Grains stored around 60% moisture content escape the attack of most insects, however khapra beetle can develop even below this moisture content.

Reduction of oxygen availability to a critical limit stops the multiplication of insects species. This can be achieved by purging nitrogen or addition of CO_2.

iv) Chemical control :

The most usual method of the control is by surface application and or fumigation of different poisonous pesticides as and when the pests are visible.

Surface sprays with Malathion 50 EC in the ratio of 1 : 100 @ 3 litres/100M^2 or Deltame thrin 2.5% WP @ 3 mg a.i./m^2 has been found effective.

Spraying of alleys between two grain stocks with Dichlorvos (DDVP) @ 0.05% is effective in preventing the 'cross infestation'.

For rapid destruction of all stages of insect species in a stored commodity fumigation with following quantities of various chemicals should be carried out under experts supervision and caution.

Aluminium phosphide 9g/tonne

Ethylene dibromide + carbon tetrachloride ....200 g/m^3

(3 parts + 1 parts)

Ethylene dibromide .... 80 g/ m^3

Carbondisulphide + carbontetrachloride .... 200 g/ m^3

(I part + 4 parts)

Select Book :

1. Anonymous, 1964. Entomology in India, Entomological Society of India, IARI, New Delhi - 12 (India).
2. Khare, B. P., 1993. Stored Grain Pests and their Management Kalyani Publishers, New Delhi.

Questions :1.

1. Define Integrated Pest Management, Discuss briefly the principles and Strategies of IPM.
2. Right an account on the plants' evolutionary reactions to insect attack and insects' evolutionary response to defensive mechanisms.
3. Write short accounts on insect pollinator – plant interaction and insect vector-plant host in interaction.
4. Enumerate the important insect pest species infesting paddy with respect to site of infestation.

Describe briefly nature and symptoms of damage, life history and control of any two internal feeders one each of lepidoptera and hemiptera.

5. Describe briefly of the nature and symptoms of damage, life history and control of any two insect species infesting either foliage or reproductive parts of paddy plants.
6. Name the important insect species infesting Jute / Mango. Give brief accounts on the nature and symptoms of damage, life history and control of any two important insect pest species infesting jute / Mango.
7. Give brief accounts of the damage and biology of insect pests infesting stored grains. Suggest suitable measures for their control.
8. Give brief accounts of the following (any three)
   a) White and black fly of beetlevine.
   b) Cashew stem and root borer.
   c) Cashew mosquito bug.
   d) Jute yellow mite.

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ZOOLOGY

Part – I, Paper – I, Unit - II, Group-B

(Group B)

Module No. 10

PRINCIPLES OF TAXONOMY AS APPLIED TO THE SYSTEMATICS AND CLASSIFICATION OF ANIMAL KINGDOM

INTRODUCTION :

Taxonomy is an ever-changing, controversial and exciting field of biology. The last 30 years has been a period of unprecedented activity in the field of taxonomy. This is documented by the founding of new journals and societies with a significant increase in the number of publications related to the methods ana principles of taxonomy. Taxonomy is such a subject which is much operational as well as it requires great deal of conceptual and theoretical knowledge. The problems of taxonomy are different in every group of animals and disagreements are there about every taxonomic procedure.

Taxonomy and systematics encroach either directly or indirectly on many other areas of science including fields as diverse as agriculture, horticulture, medicine, pharmacology, anthropology, archeology and petrology as well as the traditional areas of botany, zoology and microbiology. Within each of these, they provide names for organisms and a framework within which these are classified.

OBJECTIVES OF TAXONOMY :

1. The task of taxonomy is to find uniqueness of species and higher taxa.
2. Taxonomy estimates the diversity fauna.
3. The contribution of taxonomy to the applied sciences such as medicine, public health, agriculture, conservation, management of natural resources needs special mention. It has provided important solution of some perplexing problems.
4. Taxonomy has made significant contributions to the understanding of many evolutionary phenomena such as natural selection.
5. It supplies classifications which are of important explanatory value in most branch of biology.
6. It provides all kinds of information needed for a construction of the phylogeny of life.

MICROTAXONOMY AND MACROTAXONOMY:

Two branches of taxonomy can be recognized –

Microtaxonomy – It is the taxonomy at the species level.

Macrotaxonomy – It is the taxonomy of higher taxa i.e. the rank higher than the species.

DEFINITION OF TAXONOMY :

There is no one definition either of taxonomy or of systematics. Many workers have used these two terms more or less synonymously. Hawksworth and Bisby (1988) suggested a very useful distinction between the two terms. **Taxonomy includes a range of different areas from the description and naming of new taxa (=nomenclature), the arrangement of organisms into a convenient classificatory system (=classification) and the construction of identification systems for particular groups of organisms.** The definition can be contracted as Mayr and Ashlock (1991) expressed : **Taxonomy is the theory and practice of classifying organisms.**

Systematics may be considered as a rather broader topic of which taxonomy is only a part. Thus it includes traditional taxonomy with the addition of theoretical and practical aspects of evolution, genetics and speciation. It is also the study of the evolutionary relationships between organisms. This aspect of systematics is usually referred to as phylogenetics. Emphasizing all these aspects, Simpson (1961) defined the term "**Systematics is the scientific study of the kinds and diversity of organisms and of any and all relationships among them**". Systematics deals with populations, species and higher taxa.

The terms taxonomy and systematics are defined above. This leaves the term classification, which partly overlaps with taxonomy. Most commonly it designates the product of the activity of the taxonomist. Simpson (1961) defined the term "**Zoological classification is the ordering of animals into groups (or sets) on the basis of their relationship**".

STAGES IN TAXONOMY :

There are three stages of taxonomy. These are referred to as alpha (analytical phase), beta (synthetic phase) and gamma (biological phase) taxonomy.

Alpha taxonomy :- The level of taxonomy concerned with the characterisation and naming of species.

Beta taxonomy :- The level of taxonomy concerned with the arrangement of species into a natural system of lower and higher taxa.

Gamma taxonomy :- The level of taxonomy dealing with various biological aspects of taxa, ranging from the study of intraspecific populations to studies of speciation and evolutionary rates and trends.

TAXONOMIC CHARACTERS :

In taxonomic practice, it is actually more productive to look for differences between taxa.

A taxonomic character is any attribute by which a member of a taxon differs or may differ from a member of another taxon.

Any difference between two individuals is a character, but not all characters are useful for taxonomic purposes. It is the most important skill of a systematist to find out the most useful characters of specific value. This requires not only a good theoretical knowledge but experience as well.

Ashlock (1985) introduced a new term the *signifier*, instead of character, to denote a feature that varies from one organism to another. For example, the feather would be the signifier and "feather white" and "feather black" would be the character.

Almost any attribute of an organism may be useful as a taxonomic character if it differs from the equivalent feature in members of another taxon.

Taxonomic characters may be morphological, physiological, molecular, behavioural, ecological and geographic in nature. The detail subdivisions of these characters are –

1. Morphological characters
   - a) general external morphology
   - b) special structures (e.g. genitalia)
   - c) internal morphology (anatomy)
   - d) embryology
   - e) karyology and other cytological differences
2. Physiological characters
   - a) metabolic factors
   - b) body secretions

c) genic sterility factors

3. Molecular characters

a) immunological distance

b) electrophoretic difference

c) amino acid sequences of proteins

d) DNA hybridization

e) DNA and RNA sequences

f) Restriction endonuclease analyses

g) Other molecular differences

4. Behavioural character

a) courtship and other ethological isolating mechanisms

b) other behaviour patterns.

5. Ecological characters

a) habitats and hosts

b) food

c) seasonal variations

d) parasites

e) host reactions

6. Geographic characters

a) general biogeographic distribution patterns

b) sympatric-allopatric relationship of populations

SPECIALITY OF TAXONOMIC CHARACTERS :

A taxonomic character is any attribute which is related to any feature of the dead or living organism that is amenable to comparison.

1. taxonomic characters that are conservative (i.e. that evolve slowly) are most useful in the recognition of higher taxa; those that change most rapidly or concern isolating mechanisms are most useful in the lower taxa.
2. Taxonomic characters that are subject to parallelism, especially those involving loss or reduction, should be used only with great caution.
3. Taxonomic characters are expressions of the biology of their carriers. An understanding of this biology is a prerequisite for the proper evaluation of these characters.
4. The same phenotypic character may vary in value and constancy from taxon to taxon and even within a single phyletic series. The weight to be given to such a character depends largely on its constancy in the given group.

The entire zoological classification is based on the proper evaluation (=weighting) of taxonomic characters.

THE WEIGHTING OF CHARACTERS:

Experienced taxonomists have always insisted that characters differ in the contribution they make to the soundness of a classification. Owing to their crucial importance the weighting criteria must be discussed.

(i) A priori and A posteriori weighting :-

The Aristotelians and their successors often assigned a priori weights to certain characters. **The weighting of taxonomic characters on the basis of preconceived criteria (e.g. their physiological importance) is known as a priori weighting**. Neither function, conspicuousness, nor any other known aspect of a character gives it a priori a greater weight than other characters have. A few arbitrarily chosen a priori characters leads inevitably to a classification that is not "natural" i.e. that has a low predictive value.

After eliminating useless and redundant characters, an attempt is always made to assess the relative merits of each character. From such a posteriori weighting good classification results. Weighting is now defined as a method for determining the phyletic information content of a character. **A posteriori weighting is the weighting of taxonomic characters on the basis of their proved contribution to the establishment of sound classification.** Tooth structure in mammals, wing venation and structure of the genitalia among insects and the structure of bony palate among birds are taxonomic characters that are fairly constant within groups and therefore given high weight.

ASPECTS OF MICROTAXONOMY :

The first and most basic task of the taxonomist to discriminate species. But this is the most controversial issue that how species should be discriminated. There are difficulties in the recognition of species at several levels. There are semantic confusions regarding the concepts underlying the terms phenon, taxon and category. Two levels of discontinuity are of special importance to the taxonomist : individuals and reproductively isolated populations. Taxonomists must adopt criteria that permit them to distinguish these two levels and must learn how to apply these criteria properly. But some insoluble problems are there regarding incipient species, that is, populations that have some of the properties of species but lack others.

Phenon – This is the convenient term for the different forms or phenotypes that may occur within a single population. Camp and Gilly (1943) introduced the term phenon. **A phenon (pl. Phena) is a sample of phenotypically similar specimens in a population.**

Taxon – The words snakes, beetles, song birds and vertebrates refer to groups of organisms. Such concrete objects of zoological classification are taxa. A taxon is defined by Simpson (1961) as "**a group of real organisms recognized as a formal unit at any level of a hierarchic classification**". The term taxon always refers to concrete zoological objects. Thus the species is not a taxon but a category.

Category – A category designates rank or level in a hierarchic classification. Terms such as species, genus, family and order designate categories. A category is thus an abstract term, a class name, while the taxa placed in categories are concrete zoological objects. A taxonomic category is a "**rank in a hierarchy of levels to which taxa are assigned such as subspecies, species and genus. It is a class whose members are all taxa assigned a given rank.** The categories fall naturally into three groups :

1. The species category
2. Infra specific categories
3. The higher categories

ASPECTS OF MACROTAXONOMY :

The ordering of species in a rational and practical classification is the second great task of taxonomy. It is the subject matter of macrotaxonomy.

Three schools of macrotaxonomy – Active interest in the problems of macrotaxonomy did not develop until the 1950s and 1960s. It has produced controversies, which are still unresolved.

(a) **Phenetic methods** – Degree of overall similarity, as displayed by a large number of characters, is the overriding criterion of relationship for phenetic methods. Because pheneticists and their methods frequently deal with individuals or populations as well as with species and higher taxa, they often refer to operational taxonomic units (OTUs) as a convenient cover-all term. It is now widely accepted that the output of phenetic method does not reflect evolutionary relationships accurately, such diagrams are best referred to as phenograms and these should not be confused with cladograms which represent hypotheses about phylogeny. Sokal and Sneath (1963) provide an extensive discussion for believing the phenetic clustering techniques.

(b) **Cladistic methods** : In 1950 Willi Hennig published a book in which he articulated a set of principles that led to a revolution in taxonomic thinking. He emphasized that phylogenetic reconstruction can only be based on shared derived features (=synapomorphies), while ancestral features (=plesiomorphies) should be ignored. Furthermore, every taxon should be "monophyletic", consisting of the stem species and all its descendants, including all "ex-groups". When a dendrogram (=tree diagram) depicts a phylogenetic hypothesis on the basis of synapomorphies, it is known as cladogram. A cladogram only indicates the branching pattern of the evolutionary history.

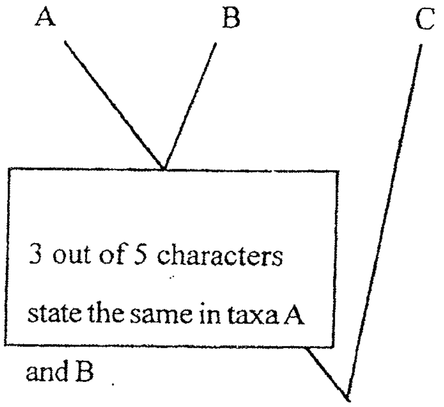
Data Matrix

Character

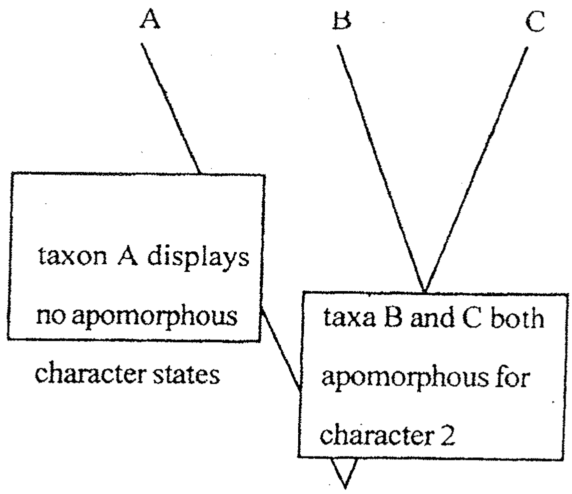
		1	2	3	4	5
	A	0	0	0	0	0
taxa	B	1	1	0	0	0
	C	0	1	1	1	1

tree constructed on the basis of maximum phenetic similarity : shared 0's and 1's treated equally

tree constructed by cladistic analysis, character states coded as 0 believed to be plesiomorphous.



Phenogram



Cladogram

A simple data matrix with five characters and three taxa is used to demonstrate how a tree constructed on the basis of overall phenetic similarity (=a phenogram). It is different from one based on cladistic principles (=cladogram) which makes use of the polarity of character states.

(c) **Evolutionary methods** – Simpson (1961) and others prefer evolutionary classification because it commonly needs information which is still largely phylogenetic but practically impossible to include in a tree diagram. It shows reality, arbitrariness and the likes : monophyly, polyphyly, different kinds and degrees of affinity involved in phylogeny and relative antiquity of taxa. It is based on the evolutionary relationships of organisms, not just their phylogeny. This method considers information from all possible data derived from different branches of biology. The whole concept of the evolutionary method is based on Darwinism. A biologist, thus, understands that he is classifying populations, not individuals or phena.

THE ACTIVITIES OF THE TAXONOMIST :

Compared to the extraordinary activity on the species level, there has been very little conceptual agreement on the level of the higher categories. The activities of the taxonomist at both micro and macro taxonomy level can be recognized by four steps (Mayr, 1969) :

A. Preparatory activities.

1. The sorting of individuals into phena and these into populations.

B. Genuine classification

2. The assigning of populations to species.

3. The grouping of species into higher taxa.

   a. Determination of relationship

   b. Formal delimitation of taxa.

4. The ranking of taxa in a hierarchy of categories.

BASIC RULES OF ZOOLOGICAL NOMENCLATURE

INTRODUCTION : The term nomenclature comes from the latin words 'nomen' (=name) and 'clare' (to call) and means literally to call by name. It is the role of nomenclature to provide labels for taxa at all levels in order to facilitate communication among the biologists. There are three important requisites of any system of scientific nomenclature – uniqueness, universality and stability.

THE INTERNATIONAL CODE :

The valid rules of zoological nomenclature are contained in an authoritative document entitled the "International code of zoological nomenclature". Its recent version was adopted by the 15th International Congress of Zoology (London, 1958).

HISTORICAL BACKGROUND :

1737	-	Linnaeus first mentioned a set of rules of nomenclature in 'Critica botanica'.
1751	-	Linnaeus wrote 'Philosophia botanica' to mention more rules of nomenclature.
1758	-	Linnaeus applied binomial nomenclature system to animals for the first time in the 10th edition of his 'Systema naturae'.
1843	-	'Stricklandian Code' was adopted in Britain.
1877	-	'Dall's Code' was made in U.S.A.
1889	-	Prof. Blanchard presented a set of rules in the First International Congress of Zoology held in Paris.
1892	-	Second Congress in Moscow in 1892 accepted the set of rules.
1910	-	The International Commission of Zoological Nomenclature was formed.
1958	-	XV International Congress of Zoology accepted by voting as "The International Code of Zoological Nomenclature".

1997 Fourth edition of the code was published.

TEXT OF THE INTERNATIONAL CODE OF ZOOLOGICAL NOMENCLATURE :

The third edition of the code (1985) includes 88 Articles grouped in 18 chapters. Each article may contain a single paragraph or may be divided into sections and subsections. The articles are composed of mandatory rules to which in some cases Recommendations are attached. There are also Appendices related to articles. The terms used in the text are clearly defined in the Glossary.

RELATIONS BETWEEN THE ZOOLOGICAL CONGRESS AND THE INTERNATIONAL COMMISSION ON ZOOLOGICAL NOMENCLATURE :

The relations between the Zoological Congress and the International Commission on Zoological Nomenclature are frequently misunderstood. The Congress is a legislative body and all provisions of the code as well as the constitution of Commission are adopted by vote of the Congress. The Commission is a judicial body elected by the Congress as provided in the Constitution and By-laws of the Commission.

BINOMIAL AND BINOMINAL NOMENCLATURE :

The system of nomenclature first standardized by Linnaeus is known as binomial nomenclature. The system of nomenclature adopted by the International Congress of Zoology, by which the scientific name of an animal is designated by both a generic and specific name is known as binominal nomenclature.

ESSENTIALS OF THE CODE OF ZOOLOGICAL NOMENCLATURE :

1. **General Consideration** – (Article 1, 2, 3, 4, 5) – Zoological nomenclature is the system of scientific names applied to taxonomic units of animals (taxon known to occur in nature, whether living or extinct). Zoological nomenclature is independent of botanical nomenclature. The scientific designation of animals is uninominal above species group, binominal for species and trinominal for subspecies. The scientific names of animals must be words which are either Latin or Latinized. Starting point of Zoological nomenclature is 1st January, 1758 (10th Edition of Systema naturae).

2. **Family and Subfamily names** – (Article 35, 36, 37) – The name of a family is formed by adding the ending 'idae' (e.g. – Hominidae), the name of a subfamily by adding *oidea* (e.g. Hesperoidea).

3. **Generic and Subgeneric Names** – (Article 42, 43, 44) – A generic name must consists of a single word, simple or compound, written with capital initial letter, and employed as a nominative singular. E.g. *Canis, Neoceratodus* etc.

The genus is divided into subgenera and where it is desired to cite the names of a subgenus, this name is to be placed in parentheses between the generic and specific names and it is not counted as one of the words in the binominal name of a species or trinominal name of a subspecies.

e.g. – *Mystus (Mystus) vittatus*

Sources of generic names – Following kinds of words can be used as basis for generic names (some are not now acceptable, some recommended against in 1961 code).

1. Simple ancient Gk. Nouns transliterated into Latin, either –

   a) Retaining the Gk ending

      Eg. *Lepas (Lepas)*

   b) With latinized endings (*Syrphus* from Gk. *Syrphos*)

2. Derivation from Gk nouns modified by suffixes that change the meaning and transliterated into Latin gaster + *odes* to form *Gastrodes*.

3. Compound of Gk nouns.

   Schistos + soma = Schistosoma.

4. Latinized compound GK words

   Gk *Spanios* + Gk teknon = *Spanotecnus*

5. Simple Latine nouns

   L. Canis (Canis)

6. Mythological names

   Ver[illegible] verrucosa

7. Patronymic name :

   Pojetia runnegari

Proposal of Generic Names :

i) By a specified author.

ii) Before 1953, by an anonymous writer / writers.

iii) By a reviser raising subgeneric taxon to generic rank.

Citation of Authors of Generic and Subgeneric Names :

The authors of generic name is –

a) The person(s) who was (were) responsible for the name in the 1st publication in which it is acceptably published. The author name should bear the publication date. Its citation is optional, but citation should be made at least once.

Philobrya Carpenter, 1872.

The date of publication of a name, if cited, follows the name of the author with a comma interposed (Art. 22).

The author's name is put in parentheses when the species is transferred from one genus to the other retaining its original author and date. *Hemilca bipars* (Walker, 1862).

If the date of publication is determined only from outside evidence it is to be enclosed in square brackets.

4. **Specific and subspecific names** – (Article – 45, 46, 47). The specific and subspecific names are to be written with a small initial letter. Patronymic names were written with the first letter capitalized after two ICZ (1889, 1892) but 1948 Congress at Paris prescribed the uniform use of small initial letter for such names.

e.g. *Felis marmorata.*

Rhizostoma cuvieri

If it is desired to cite the subspecific name such name is written immediately following the specific name without interposition of any mark of punctuation.

e.g. *Rana esculenta marmorata.*

5. **Formation, Derivation and Orthography of Zoological names** – The original orthography of a name is to be preserved unless an error of transcription, a *lapsus calami* or a typographical error is evident.

In forming names derived from the languages in which the Latin alphabet is used, the exact original spelling including diacritic marks, apostrophe etc. were earlier retained but now they are not to be used in zoological names and these marks are to be deleted from originally published names (Art. – 27). Only the exception is the German "umlaut" sign which is deleted from a vowel by inserting the letter 'e'.

miilleri becomes *muelleri.*

d'urvillei becomes *durvillei.*

If a species group name is formed from a personal name of a man it should end in 'i'

e.g. *Botia dayi.*

If it is formed from a personal name of a woman it should end in "ae".

e.g. *Macrobrachium rosae*

Suffix "ensis" designates a geographical name –

e.g. *Macrobrachium assamensis.*

6. **Authorship** – The author of a scientific name is that person who first publishes the name in connection with an indication, a definition or a description (Art. 50).

If it is desired to cite the author's name, this should follow the scientific name without interposition of any mark of punctuation, if other citations are desirable (date etc.), these follow the author's name, but separated from it by a comma or parentheses.

Cancer pagurus Linnaeus, 1758.

The name of a subsequent user of a scientific name if cited is to be separated from it in some distinctive manner.

Cancer pagurus Linuaeus *sensu* Latreille.

If the scientific name of a taxon was published anonymously but its author is known and his name should be enclosed in square bracket (Recom – 51A).

If a species group taxon was described in a given genus and later transferred to another the name of the author of species group name is to be enclosed in parentheses. (Art. 51D).

Taenia diminuta Rudolphi now becomes

Hymenolepis diminuta (Rudolphi)

7. **The Law of Priority** – (Art – 23) – The valid name of a genus or species can only be that name under which it was first designated on the condition –

   a) That this name (prior to Jan 1, 1931) was properly published and accompanied by an indication or a definition or a description.

   b) That the author has applied the principles of binominal nomenclature.

   c) But no generic name nor specific name published after December 31, 1930 shall have any status of availability under the rules, unless and until is published either –

      1) With a summary of characters differentiating the taxon.

      2) With a definite bibliographic reference.

      3) In the case of a generic name with the definite unambiguous designation of the type species.

      4) After 1930, a new name published anonymously is not available.

Exception : Momen oblitum – A name remained unused as a senior synonym for more than 50 years is to be considered as a forgotten name and thus facilitating the use of later described or junior synonym.

8. **Rejection of names** :

   a) A generic or specific name once published cannot be rejected, even by its author because of inappropriateness –

      e.g. names like *polyodon, albus, sinensis* etc. when once published are not to be rejected because of a claim that they indicate characters or distribution in contradictory to those possessed by the animals in question.

   b) A name is not to be rejected because of *tautonemy,* that is, because the specific and subspecific names are identical with the generic names –

      e.g. *Trutta trutta; Bison bison; Apus apus apus.*

   c) A generic name is to be rejected as a *homonym* when it has previously been used for some other genus of animals.

e.g. *Trichina* Owen, 1835, nematode is rejected as a homonym of *Trichina* Meigen 1830, insect.

Taenia ovilla Rivolta, 1878 was rejected as a homonym of *Taenia ovilla* Gmelin, 1790.

d) It often happens that two or more different taxonomists independently publish two or more competing names for a given taxon. This is known as synonyms and the names are referred to as synonyms. Here the senior synonym will be the valid name.

e.g. *Astacus marinus* Fabricius, 1775 is a junior synonym of *Cancer gammarus* Linaeus, 1758.

TYPE CONCEPT : HOLOTYPE, PARATYPE, SYNTYPE ETC.

INTRODUCTION :

The very word 'type' embodies an idea generally held in the 18th and early 19th centuries, derived from the ancient Greeks, that a species is definable by a fixed pattern (or essence), which in another sense is its 'type' (=archetype). A nomenclatural type is simply something to which a name is attached by purely legalistic convention.

DEFINITION OF TYPE :

Simpson (1961) - " The type for the name of a species is an individual specimen and the rule is that regardless of any other contents of the taxon a name belongs to the species in which its type specimen is placed."

Mayr (1969) - "A zoological object which serves as the base for the name of a taxon".

Jeffrey (1989) - "An element on which the descriptive matter fulfilling the conditions of availability or valid publication for a name is based or is considered to have been based and which by its taxonomic position decides the application of the name".

MAIN FUNCTIONS OF TYPE :

1. Serves as the sole or principal basis for the description and definition of taxa.
2. Serve as a standard of comparison, approximation during identification of another specimen.
3. Serves as a vehicle attached to a name.

RELATIONSHIP OF THE TYPE TO THE TAXON :

The type affords the standard of reference that determines the application of a scientific name. Nucleus of a taxon and foundation of its name, the type is objective and does not change.

Types of family-group taxa – The type of each taxon of the family-group is that nominal genus upon which the family group name is based.

Type of genus-group taxa – The type of each nominal genus is a nominal species known as the "type-species".

Type of species-group taxa – The type of each taxon of the species group is a single specimen, either the only original specimen or one designated from the type-series (holotype, lectotype) or a neotype.

VALUE OF TYPES :

Holotypes, syntypes, lectotypes and neotypes are to be regarded as the property of science by all zoologists and by persons responsible for their safe keeping.

Recommendation 72A has spelt the institutional custody of type specimen. A zoologist who designates a holotype or lectotype should deposit it in a museum or other institution where it will be safely preserved and will be accessible for purposes of research. Deposit of neotypes in a museum etc. is mandatory.

DEFINITION OF PRINCIPAL TYPES :

1. **Holotype** – If a nominal species is based on a single specimen, that specimen is the holotype. Article 73 and Recommendations 73A, 73B, 73C are related to holotype.

   Recom. 73A states that a zoologist when describing a new species should clearly designate a single specimen as its holotype.

   Recom. 73C states that a holotype must be supplied with the following data –

   1. Size of the specimen.
   2. Locality, date and other relevant data.
   3. Sex.
   4. Developmental stage and form.
   5. Name of the host species if it is a parasite

6. Name of the collector
7. Collection or register number assigned to it
8. Altitude in meters for terrestrial species.
9. Depth of meters for marine species
10. In case of fossil species, its geological age, stratigraphic position etc. to be mentioned.

Importance of holotype –

1. It is required for comparison during identification of new taxa.
2. It is the official standard of reference for a species.
3. It acts as catalogue of specimens found in a locality.
4. As a holotype bears the name of the collector, author, date etc. these have some historical importance.
5. A later reviser may find the original describer's type to compare his record of collection.

2. **Syntype** - If a nominal species has no holotype, all the specimens of the type series are syntypes, of equal value in nomenclature.

3. **Lectotype**- If a nominal species has no holotype, any zoologist may designate one of the syntypes as the lectotype.

The first published designation of a lectotype fixes the status of the specimen, but if it is proved that the designated specimen is not a syntype, the designation is invalid.

4. **Neotypes**- A specimen designated or selected as a neotype subsequently to serve as the type of a name when all the original type specimens are destroyed or missing or believed to be so.

Neotypes ought to be designated only in connection with revisory work, and then only in exceptional circumstancs, when a neotype is necessary in the interest of stability of nomenclature as stated in the Article 75a.

Exercise

1. **Write nots on : (5 marks each)**

1. Define the terms taxonimy and systematics.
2. Write four important objectives of taxonomy.
3. Distinguish between microtaxonomy and macrotaxonomy.
4. What are the three stages of taxonomy?
5. What is meant by taxonomic characters?
6. What do you mean by weighting of characters?
7. What are a phenon and a taxon?
8. What is a taxonomic category?
9. What is phenetic method of macrotaxonomy?
10. What is cladistic method of taxonomy?
11. What is evolutionary method of macrotaxonomy?
12. What are the important steps of activities of taxonomists?
13. What is meant by the ICZN? Write the contents of it.
14. What do you mean by the International commission on Zoological Nomenclature?
15. How family, subfamily, generic and subgeneric names are written?
16. When the author's neme is written within parentheses and within square brackets?
17. What do you mean by patronymic name?
18. Who can claim the authorsing of a scientific name?
19. What is a holotype? Write the significance of holotype.
20. What is homohymy? Give Example.
21. What is a neotype?
22. Define the term type and state its main functions.
23. What is synonyms give example.

24. What is law of priority?

25. What is nomen oblitum?

2. How do you refer and explain the following situations -

   (a) If two different taxa of the same rank (subspecies and above) are given the identical names.

   (b) The species 'X' which has been described from India in 1903 is now found taxonomically same to species 'Y' described from Malasia in 1947.

   (c) If holotype and paratype are destroyed or missing.

   (d) Two new species under a genus have been described recently but having insufficient description.

   (e) A genus which was described in 1902 with a single species is still without any further species under it.

   (f) The species A under the genus 'X' and species B under the genus 'Y' although districtly different but have been given same name.

3. What is taxonomy? What are the objectives of taxonomy? What are microtaxonomy and macrotaxonomy? What is your concept on taxonomic characters. 2 + 3 + 2 +3

4. Write what you know about three schools of macrotaxonomy. 10

5. What do you mean by the terms binomial and binominal system of nomenclature. Write what you know about the Law of Priority and Rejection of names. 2 + 4 + 4

6. Define the term "type". What are the main functions of type? Give definition of principal types used commonly in taxonomic activities. 2 + 2 + 6

Suggested books :

1. Theory and Practice of Animal Taxonomy (4th ed) - V.C. Kapoor. (1998). Oxford & IBH Pub. Co. Pvt. Ltd. N. Delhi.
2. Principles and Techniques of contemporary Taxonomy (1st ed) - D.L.J. Quicke (1993) Blackie Academic & Professional. London.
3. Biological Nomenclautre (3rd ed) - C. Jeffrey (1989). Edward Arnold.
4. Principles of Systematic Zoology (2nd ed) - E. Mayr and P.D. Ashlock (1992). Mc Graw Hill, New York.
5. Principles of systematic zoology (TMH ed) - E. Mayr (1969). Tata Mc Graw - Hill Pub. Comp. Ltd.
6. Taxonomy, a Text and Reference Book - R.E. Blackwelder (1967). John Wiley & Sons, New York.
7. Taxonomic Analysis in Biology. - L. A. Abbott, F.A. Bisby and D.J. Rogers (1985) Columbia University Press, New York.
8. Biological Identification - R.J. Pankhurst (1978). Edward Arnold, London.
9. Principles of Animal Taxonomy - G.G. Simpson (1961). Columbia University Press, New York.
10. Classification - A beginner's guide ... - S. Jones and A. Grhy (1983). British Museum (Natural History) Pub. Lond.
11. Methods and Principles of Systematic Zoology - E. Mayr, L. Gorton and R.L. Usinger (1953) Mc Graw-Hill Book Comp. Inc., New York.
12. Main topics in Animal Taxonomy - R.P. Sethi (1982), Rajhans Prakashan Mandir, Meerut.

VIDYASAGAR UNIVERSITY

DIRECTORATE OF DISTANCE EDUCATION
MIDNAPORE - 721 102

M.Sc. in ZOOLOGY

Part-I

Paper –I, Group – B, Unit – II

Module No. – 11

Syllabus :

Modern Taxonomy :

α, β, γ taxonomy;

Biochemical Taxomomy;

Cytotaxonomy;

Numerical taxonomy;

INTRODUCTION :

The most impressive aspect of the world of life is its diversity and the unqueness of its components. No two individuals in sexually reproducing populations are the same, nor are any two populations, species or higher taxa. Whenever we look in nature, we find uniqueness i.e., diversity. To short all this and determine its nature is the task of Taxonomy.

The world taxonomy is derived from the Greek Words *taxis* (= arrangement) and *nomos* (=law). It was first coined by A.P. de Candolle, a professor of Montpellier University in France, in his Botany treaties in 1813, as a French world 'Taxonomine'. Later in 1819, he spelled it as 'Taxeonomie'. The Greek Scholars criticised this spelling and they provided the term 'Taxinomie'. Under these circumstances some taxonomist used the term 'Taxomomy'. But the present day taxonomists prefer the already established term 'Taxonomy' as it is use now for over 160 years.

What is taxonomy :

Taxonomy is actually the part of systematics and the study of the principles and practices of classification. Mayr (1969) provided a good definition "Taxonomy is the theory and practices of classifying organisms."

In simple terms, taxonomy is concerned with describing and naming the many kinds of organisms that exist today, those that have been extinct for many, even million of years and also those that are becoming extinct.

The History of Taxonomy :

Diversity has interested humans ever since the begining of our species. However, the development of a scientific theory of classification is a remarkably recent phenomenon. Simpson (1961) gives a valuable survey of the history of taxonomy and the development of its concepts. Mayr (1982) describes in considerable detail the various periods in this development.

i) Several early Greek Scholars, notably Hippocrates (460-377 B.C.) enumerated types of animals, but there is no indication of a useful classification.

ii) There is no doubt than ARistotle (384-322 B.C.) was the father of biological classification. He not only studied morphology but also paid much attention to embryalogy, habits and ecology.

iii) The knowledge of animal kingdom increased more rapidly with the wrirings of William Turner (1508-1568), pierre Belon (1517-1564) and Guillaume Rondelet (1507-1566) on different animals.

iv) Animal taxonomy made little conceptual progress in the seventeenth and eighteenth centureies, although the work of Willughby (1635-1672) on birds and that the Reaumur (1683-1757) on insect revealed a remarkable advanced in knowledge.

v) Natural history in the eighteenth century was dominated by two great figures – Buffon (1707-1788) and Linnaeus (1707-1778). Linnaeus, sometimes called the father of taxonomy.

vi) Due to development of cytology, genetics modern taxonomist advanced the taxonomic work.

Stages of Taxonomy :

It is now well known that taxonomy of a given group passes through several stages. These stages are referred to as –

Alpha Taxonomy (α-Taxonomy) i.e., Analytical phase.

Beta Taxonomy (β-Taxonomy) i.e., Synthetic phase.

Gamma Taxonomy (γ-Taxonomy) i.e., Biological phase.

- **α–Taxonomy :**

  Alpha taxonomy is the level of taxonomy concerned with the characterization and naming of species (Mayr, 1969).

- **β–Taxonomy :**

  Beta taxonomy is the taxonomic level concerned with the arrangement of species into a natural system of lower and higher taxa (Mayr, 1969).

- **γ–Taxonomy :**

  Gamma taxonomy is the taxonomic level which deals with various biological aspects of taxa, ranging from the study of intraspecific populations of the studies of specification and of evolutionary rates and trends (Mayr, 1969).

Note : Actual practice is ratehr difficult to dessociate these α, β & γ taxonomy because these are overlap and intergrade. There are only few groups of animals (some vartibrates, especially the birds and a few insect orders like Lepidoptea) where the taxonomy has reached up to gamma level otherwise in almost majority of the groups the works are still at alpha and beta level.

Aims and Tasks of a Taxonomist :

The primary aim of a taxonomist must be the construction of classes of living about which scientifically useful indicative generalizations can be made. Many workers (Blackwelder and Boyolen, 1952; Michener, 1963; Ehrlich, 1964; Blackwelder, 1967; Simpson, 1961; Mayr, 1969 & Darlington,

1969) have enumerated various aims and tasks of taxonomist. These are summarized as follows:-

i) To catalogue the diversity of life on earth and to preserve large samples, both of extent and extinct organisms, drawn from the diversity in various sorts of collection.

ii) To differentiate the various kinds of organisms and to point out their characteristics (both qualitatively and quantitatively) through descriptions, keys, illustrations etc.

iii) To provide names for each kind of organism, so that all concerned can know what they are talking about and so that information can be recorded, stored and retrieved when needed.

iv) To develop a set of principles in regard to the choice and relative importance of characters with the ultimate aim of arranging species in hierarchy of higher categories.

v) To estimate genetic and phylogenetic relationships among organisms.

vi) To contribute towards the understanding of evolutionary process.

vii) To integrate the data from all fields of biology, like behaviour, genetics, psysiology etc. and to detect and then summarise significant patterns possibly with the help of modern electronic computers.

viii) To document and preserve specimens to provide a useful reservor of data.

ix) To help in clarifying the place of systematics or taxonomy in general biology by revising their aims and priorities.

Role of taxonomy in Biology :

The multiple role in taxonomy in biology can be summarized as follows:

1. It is the only science that provides a viviol picture of the existing organic diversity of the earth.

2. If provides most of the information needed for a reconstruction of the phylogeny of life.

3. It reveals numerous interesting evolutionary phenomena and thus marks them available for casual study by other branches of biology.

4. It supplies, almost exclusively, the information needed for entire branches of biology (e.g.

biogeography).

5. It supplies classifications which are of greatest heuristic and explanatory valuc in most branches in biology e.g. evolutionary biochemistry, immunology, ecology, genetics ethology and historical geology. A sound classification is the indispensible basis of much biological research. Classifications are particularly important applied biology, for instance, agriculture, public health and environmental biology, because the correct identification of an important agricultural insect pest, disease vector, or major component of an ecosystem depends on the availability of a sound classiciation.

6. In the hands of its foremost exponents systematics makes important conceptual contributions (such as population thinking) that would not otherwise be easily accessible to experimental biologists. Thus it contributes significantly to a broadering of biology and to a better balance within biological science as a whole.

Importance of Taxonomy in applied biology :

Taxonomy has played quite a wider role in the important field of applied biology. The applied biologists, too, are heavily relying on it for laying accurate and foolproof experiments and getting quick useful result. A wrong identification may upset the entire control strategy. The useful role of systematics in specific areas of applied biology are discussed under following heads –

i) **Agriculture and Forestry :**

Presently we are faced with the acute problems of saving our crops and trees from the attack of various kinds of pests. It is essential to know the correct names of such pests before their proper control or eradiction. Every species has its own niche in nature and differe from its related species in food preference, breeding seasons, tolerance to various stimuli, resistance to predators, competitors, pathogens etc., and all these are essential for an applied worker before applying control measures. All this information can be easily obtained by screening the literature if the identity of the pest is known. it is also sometimes very important to have local observation of the destruction of the crop. On getting correct identity of the pest species, it becomes easier to collect information about its habits which is vital for its effective control.

ii) Biological control :

As the use of insecticides is declining and replaced by specific methods of biological control, the use of accurate identification of the pest and its natural enemies is becoming increasingly important. Natural enemies of pests can often be introduced for biological control to the enormous advantage of agriculture, forestry etc. When successful, the biological control is much more economical than chemical control because its need not be repeated and has no injurious side effect. The systematics are presently greately involved in designing and implementing the biological control programmes of pests and disease most effectively. Since it is now well known that knowledge of an organism's relationship with other permit us to develop means of control more easily, total dependance on correct identification of both the parasite and host.

iii) Public Health :

Taxonomy plays great role in public health programmes. There are a number of disease which are spread by many arthropods which are disease specific. So our control strategy should be planned in such a way that only the target species is attacked. This is possible only on getting the correct identification of that species. For example, some species of Anopheles mosquitoes are responsible for transmiting malaria and others not. The control measures were then applied only on the target species and in this way a lot of money & manpower were saved. Thus, currect identification ensures a maximum of effective control at minimum cost.

iv) Wild life management :

Presently great attention is being paid to conserve and propagated wild life. Many programmes have been initiated all over the world to teach the people the importance of fauna and flora for human welfare. The indiscriminate killing of animals and felling tree have already resulted in great disturbance in the natural environment. Taxonomists help the environmental protection protectors to identity all such animals which are endangered by man's activities.

v) National Defence :

Information concerning disease vectors and parasites is an obvious application of systematics to national defence. During world war II, Japanese paper baloons carrying fire bombs containing large number of shells of micro organisms. In this cases, both in making the bombs and their destruction, the correct identification of the organisms has been the first step. Moreover, the identification of potential disease vectors is vital to the health of both military and civilian populations all over the world.

vi) Environmental problems :

Systematics have also played a useful role in trackling the various environmental problems. Pollutants such as certain chemical pesticides may persist in the environment or even concentrate in certain plants or animals. Tracing the movement of these pollutants to determine their effects requires identification of the species within the food chain. It is also now cleat that a biological approach, to be successful, requires a thorough understanding of the taxonomic relationship between pest species and component species of the ecosystem. The identification of species present in a particular location provides a rapid and inexpensive monitoring system for detecting pollution.

vii) Soil Fertility :

Many animals play an important role in increasing the fertility of the soil. The soil is tunnelled in such a way that it becomes more areated and is also enriched by their secretions and dead body. It is necessary to know such animals for their proper management in agriculture.

viii) Mineral prospecting :

Sedimentary rocks can be dated only by their enclosed fauna and flora. The palaeoutologists play a major role in the identification of the fauna and flora and thus give clear picture of the correct sequence of geological events.

ix) Quarantine :

Many new pests and diseases of plants, animals and human beings have already entered many countries. Their spread from one country to other is through transportation of various crop, ornamental plants, and mainly through the agency of human beings. Respective Governments have established quarantine laboratories at aerodromes, ports etc. to check such occurrences. Taxonomist play a vital role here in providing correct and prompt identification of the pest or disease.

x) In Commerce :

Products like honey, silk, lac and dyes are provided by insects. Besides, there are many other animals which are directly eaten as food or provide us other useful commercial products. Taxonomists can play an important role in increasing and improving the quality of these products manipulating the useful species. The introduction of any useful species is possible only through correct identification.

NEWER TRENDS IN TAXONOMY :

The aim of modern taxonomy is not only to describe identity and arrange organisms in convenient categories but also to understand their evolutionary histries & mechanisms. Earlier approaches were mainly bases exclusively of observed characters without going into the question of intraspecific differences. Many of the species are, therefore, known by single or a few specimens. Presently great attention is paid to the sub-groupings of the species, like subspecies and populations. The old morphological species is now called a biological one which also includes ecological, genetical, biochemical and other characters. All these new approaches have contributed a lot in explaining the true structure of the species and its evolutionary position. But since most of the new approaches require specific methods. All these current approaches in taxonomy is used as –

1. Morphological approach.
2. Embryological approach.
3. Ecological approach.
4. Behavioural approach.
5. Cytological approach.
6. Biochemical approach.
7. Numerical approach.
8. Differential approach / Differentoal Systematics.

BIOCHEMICAL TAXONOMY

The use of biochemical characters is taxonomy was first initiated by de Candoll in 1813 to differentiate closely related species of plants. It is now a well known fact that the metabolism of an organism is a complex of chemical change and all morphology, behaviour and ecology of an organisms must depends on its metabolism. The animal contains a large number of complex compounds like hormones, enzymes and other proteins with peptides, nucleic acids, amino acids and sugars. The Biochemical taxonomic techniques are probably less subject to direct environmental influences and thus are more likely to reflect genetic divergence than many of the classic morphological analysis.

The principal work of a biochemical taxonomist concerns the comparison and contrasting of compounds of the same class and performing the same function in different animal species, with regard to their properties as well as to their distribution in different organs of the body. Thus, the species can be differentiated on the basis of the amino acid sequences in proteins of an organism and on difference between these as found in different species. Crick (1958) called it "Protein Taxonomy". It is also believed that the change in the enzyme structure can also help in the discovery of new species. Lahin (1964) calls it Molecular Taxonomy (=nucleotide sequences of poly nucleotides). Turner (1966) prefferred to divide it into two – Micromolecular and Macromolecular taxonomy.

(a) Micromolecular Taxonomy :

It plays stress upon the distribution and biosynthetic interrelationship of small molecular weight compounds such as free amino acids, alkacids, terpenes, flavonoides etc. commonly referred to as secondary compounds. The approach is especially useful in resolving systematic problems where hybridization has been a factor.

(b) Macromolecular Taxonomy :

This type of taxonomy concerned with the polymeric molecules like DNA, RNA, polysaccharides and proteins. This approach is useful in resolving some of more intractable systematic problems especially those involving relationships among higher categories.

Example :

There are many good examples where biochemical characters have been found extremely useful in solving taxonomic problems.

i) Basu and Chatterjee (1969) demonstrated polygenetic relationship among various orders ...is of the quantitative analysis of ascorbic acid (Fig. 1)

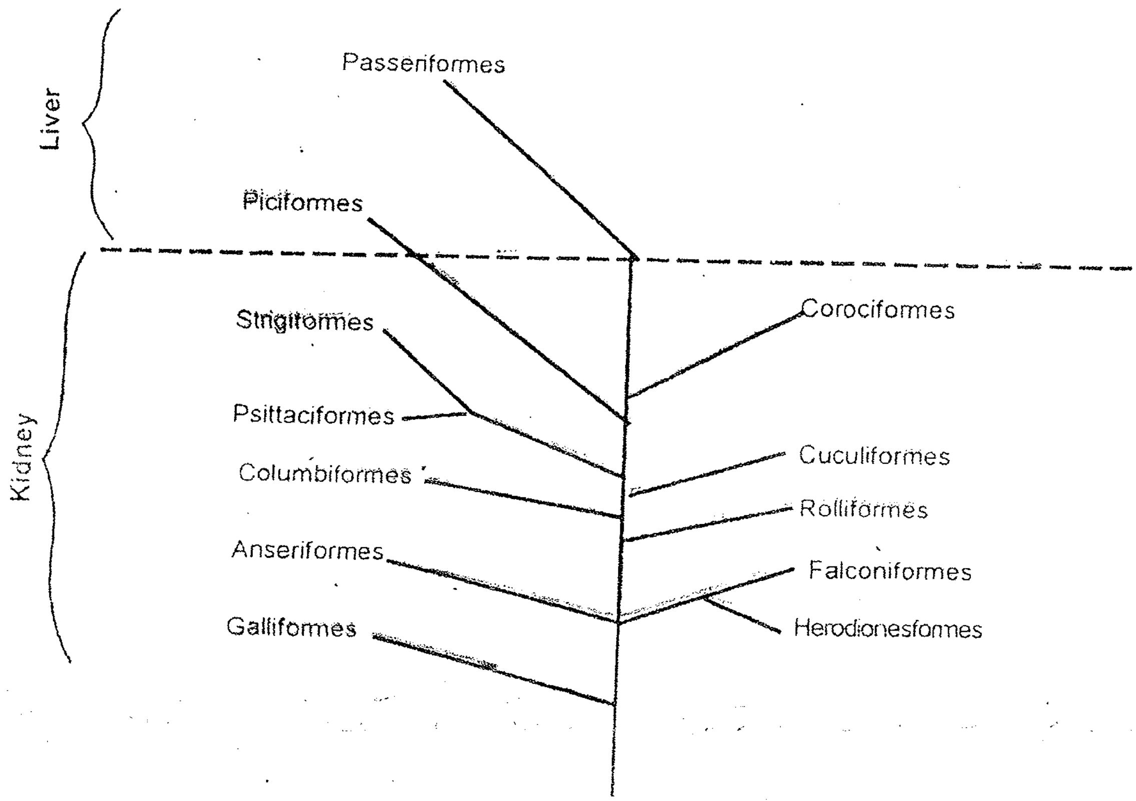


Fig. 1 : Probable Phylogenetic presentation in birds based on the sites of synthesis of L-ascorbic acid. In few both kidney and liver, in some only liver and majority incapable.

In some birds it is produced in the kidney but in other some in the live. In some, in both liver and kidney and in others, in neither. Accordingly they clarified that the ancestral enzyme systems involved occurred first in kidney, were later somehow transferred to the liver, and finally, in some of the more evolved passerine birds, completely lost.

ii) Brend *et. al.* (1972) established the phylogeny of a group of fireants using biochemical characters of the highly unique fireant venoms.

iii) Walbank and Waterhouse (1970) correlated the phylogenetic affinites of certain genera as Australian Cockroaches after analysis their defence secretions.

Difficulties :

Biochemical approach is definitely helpful involving many taxonomic problems, but this is not useful in many cases. Moreover, such studies are possible only in the existing organisms and therefore it is difficult to trace the course of evolutionary history. It can not lead to definite judgements with regard to the phylogency of any organism where fossil records are inadequate are lacking. Most of the biochemical taxonomic works are based on qualitative and quantitave differences in single chemical constituents of whole organisms or one of their tissue. Like morphological characters, chemical characters are also variable. A proper understanding of the taxonomic relationship of organisms required comparison of a number of biochemical charactrs in combination with one another to reveal the diversity on biological patterns rather than on a single biochemical character.

Since proteins and nucleic acids provide a reliable, though indirect, estimate of the digree of genetic homology among animals (Wilson and Kaplan, 1964), comparison of various characteristics of these chemical constituents as such are more suitable than other constituents for understanding their taxonomic relationships. The distribution of free amino acids in different organs of insects is of greater taxonomc value than their mere presence or absence or concentration in whole animals or in of their tissues (Schachar *et. al.*, 1966). Brown (1967) did not find the distribution of metabolic amino acid 3-hydroxyl-L-kyneurenine, a wing pigment, as a useful taxonomy character in nymphalid butterflies. However, in mammals the classification of species, based on amino acid sequences of the peptides, agrees in general with the accepted one based on morphological data (Blomback and Blomback, 1968).

KINDS OF CHEMICAL APPROACHES :

Biochemical taxonomy studies in different ways like immunological, chromatographic, electrophoresis, Infra-red-spectropholometry and histochemical aspect. All these are concerned with elucidating the chemical composition of the tissues and the serum of the blood which carries the necessary chemicals to feed the cells both in the development and reproduction.

a) Immunological aspect :

This approach is based on the precipitation reaction preferred for the study of soluble antigens, such as those contained in animal cera or tissue extracts from plants of animals. It was first discovered by Radolph - Krauss (1897) in respect of micro organisms. Nuttal (1901) was the first to extend its use in animal systematics. Boyden (1943, 58, 63) further elaborated its use in animal systematics with refined techniques. Its application is based on the fact that "the proteins of one organism will react more strongly with antibodies to the proteins of a closely related organism than to those of one more distantly related". An antigen when injected into an animal, will stimulate that animal to generate compounds and the antibodies will react with a high degree of specificity to the material that was injected. The animals with the antibodies are considered to be immunised and the process of immunisation is detected by the formation of a precipitate, the precipition, when the soluble antigen is mixed with its immune serum in optimal proportions. It is also possible to determine whether an antigen is unique to a certain genus, species within the genus, or even to a particular strain within a species or it shows cross reaction.

Although this practice has been in use for over half a century, it has not yet benefited us as much as was expected. Irwin's work (1974) on the blood group genes for the specific classification of pigeons has been remarkable and has now been extensively applied to the study of primates. Some of the important achievements made possible through these studies in taxonomy have been discussed in proceedings of the 'Kansas Symposium' (ed. Hpwkes, 1968) and in "Biochemical and Immunological Taxonomy of Animals" (ed. Wright, 1974).

b) Chromatographic aspect :

It is a technique by which the constituent of complex mixture can be separated and subsequently identified. It depends on the "different rates at which the compounds in a double mixture move along a porous medium, i.e., a piece of chromatographic. Paper chromatography has been widely used for compairing the chemical composition of closely related species, especially with regard to amino acids and peptides through ninhydrin treatment. The material to be analysed is prepared through two general approaches. Either pieces of tissues or small whole animals are squashed directly on the filter paper. A minimum of 21 amino acids have been detected in homogenised adult mosquitoes. But one should be very cautions in using total homogenates, often hydrolysed as these show differences due to age, sex and physiological state.

Buzzati – Traverso and Rechnitzer (1953) were first to apply this practice to animal systematics. They studied the amino acids of muscle protein in different species of fish and found these characters extremely useful in segregating them.

Kirk *et al.* (1954) distinguished seven species of land snails by their fluorescent patterns. Florkin and Jeuniaxu (1964) discovered that the primitive hemimetabolous insects have low concentration free amino acids in their haemolymph as compared to high concentration in holometabolous insects.

Dechateau and Florkin (1958), Wyatt (1961), Chen (1966), Ball and Clark (1953), Throckmorton (1962), Micks *et. al.* (1966), Saxena (1965), Harlow *et al.* (1969) and Stephen (1974) are other workers who have shown the importance of these studies in animal systematics.

At present modern chromatographic technique like SDS-PAGE, Gas liquid chromatography used for better taxonomic studies.

c) Electrophoresis :

This is another technique involving a similar movement of dissolved substances through a fixed medium, but here the movement is brought about by electrical potential differences. It is based on the fact that the "Components of mixtures carry electric charges varying amounts and so will move at different rates in salt solution through which a current is passed.

Such techniques were first used by Tiselius (1937) to distinguish multiple fractions of serum proteins migrating through solution under the influence of an electric current. Now these are various types of electrophoretic methods to study the molecular composition of complex proteins.

In paper electrophoresis the mixture to be analysed in poured on a strip of paper. The paper, due to its high molecular absorptive qualities, variable pore size and high elctro-endosomatic buffer flow, was first replaced bu agar get, then starch and more recenty by acrylamide gel. The use of polyacrylamide gels for the separation of proteins as a substitute for starch gel was first reported by Davis and Ornstein (1959) and Raymond & Weintraub (1959).

The electrophoretis investigations of amino acids have shown that the insulin from oxen, horses and sheep are different. The ACTH of pigs is different from that of oxen. The vesopressin of oxen contains arginine but that the pigs lysine. Such biochemical studies are of great helps of solving the phylogenetic problems. Which otherwise do not receive enough support from taxonomy. Sibley (1960) analysed the egg white protein of 359 species of non-passerine birds by paper electrophoresis. Wright (1974) made a breakthrough in molluscan taxonomy when he seperated some species of the genus *Bulinus* through electrophoretic analysis of their egg protein.

In another biochemical approach to taxonomy a single complex molecule, like haemoglobin of one species is selected and its amino acid composition is compared with that of closely related or more distantly related species (Sande and Karcher, 1960). Manwell and Baker (1963) reviewed much of the systematic literature in this field and themselves discovered a sibling species of seacucumber using these techniques.

(d) Infared Spectrophotometry :

It is based on the principle of absorption of infrared light by biochemical materials. The patterens thus formed depend upon their chemical composition and bring to light many featurs of taxonomic importance. Micks and Benedict (1953) for the time applied this technique in the identification of mosquitoes. It is hoped that this technique if applied extensively to other animal groups can yield useful taxonomic information (Fig.-2).

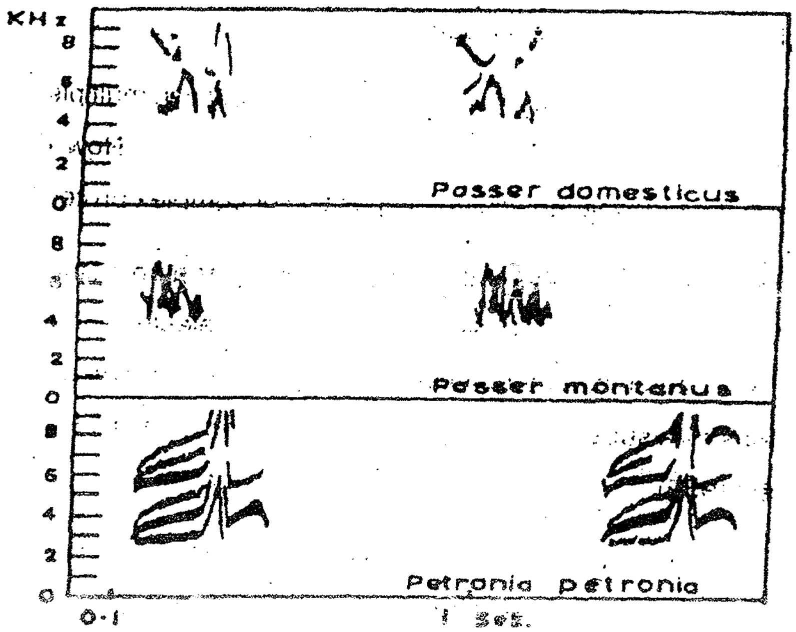


Fig.2 : Sound spectrograms of three species of birds (After Thieleke, 1964)

(e) Histochemical studies :

When the same kind of tissue from different animal species may exhibit approximately the same functions, histochemical differences between them may be observed which could be of taxonomic value. This can also help in the recognition of intraspecific groupings. The histochemical approaches involve distinctive microtechniques and specific staining reactions. The mode of fixation of material of such studies is of great importance as there should be no chemical alternation from what exist in life. These techniques have been employed in the quantitative and semi quantitative analysis of proteins, free amino acids, enzymes, carbohydrates, liquids and nucleic acids including metal ions.

Various dyes for staining are used for better perception these characteristics. The use of cryostat microtomes and electron microscopes have made such studies more meaningful. This approach when combined with other characteristics, can be also be great help in inferring taxonomic relationships amongst vatious animal groups (Fig.-3, 4, 5, 6, 7, 8).

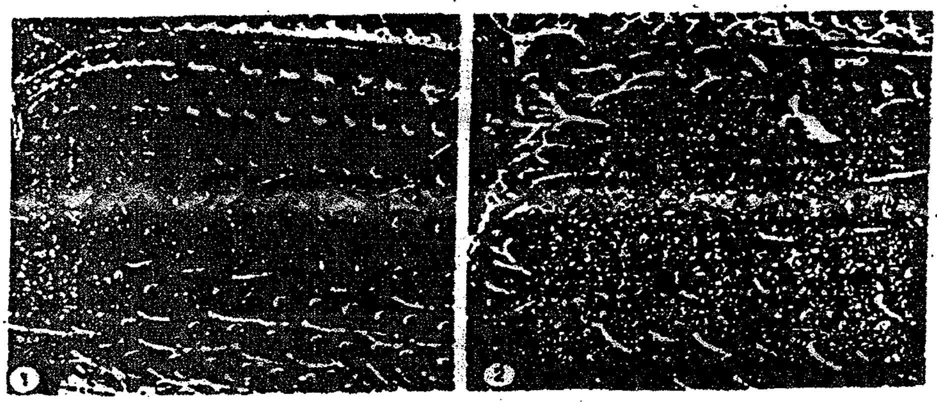


Fig. - 3 : Seanning elctron micrographs of dorso-lateral view of elytra (after Lanier *et. al.*, 1972)

Fig. I. *Ips calligraphus calligraphus;* Fig. 2. *I.c. ponderosac.*

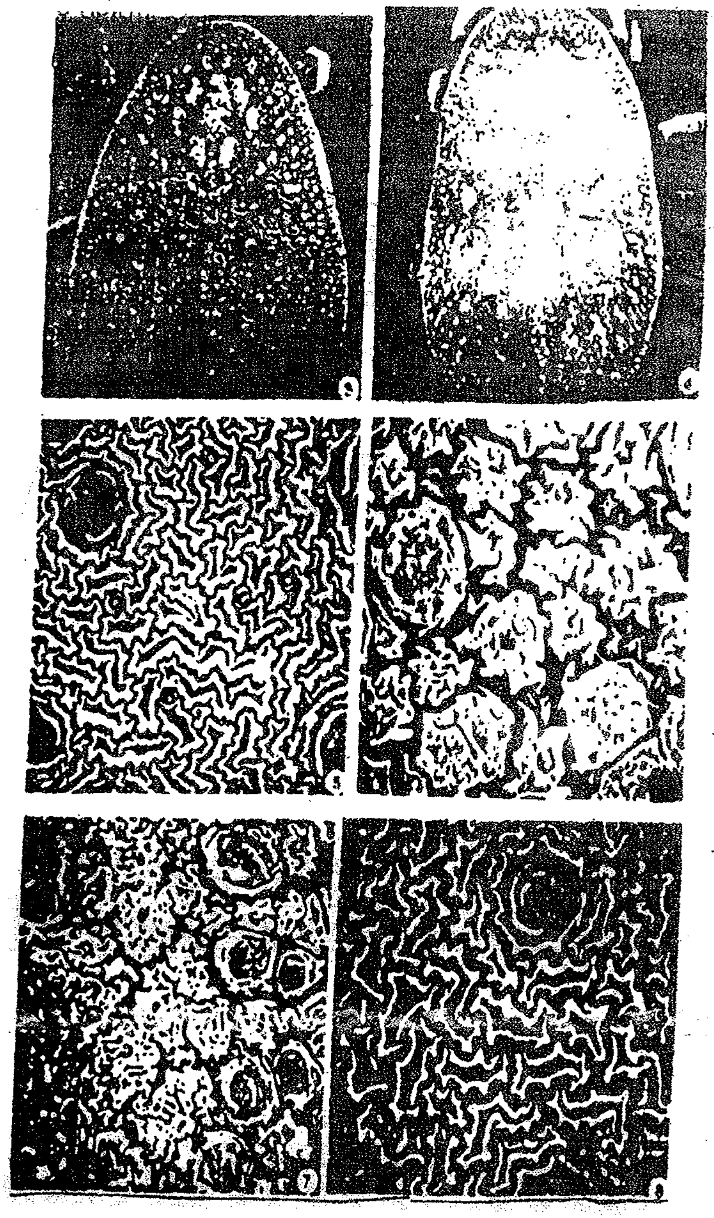


Fig. 4 : Scaning electron micrographs of some specres of Argas (Argas), all , figs 3-21 (after Krzyszotof et.*al.*, 1979 and Kerirans et. al., 1979) Dorsal views 3. *polonicus* (x 13); 4. *vulgaris* (x 26) postero-dorsal integument — 5. *moreli* (x 161); 6. *monachus* (x 158); 7. *dul* (x 158); 8. *neghmei* (x 182).

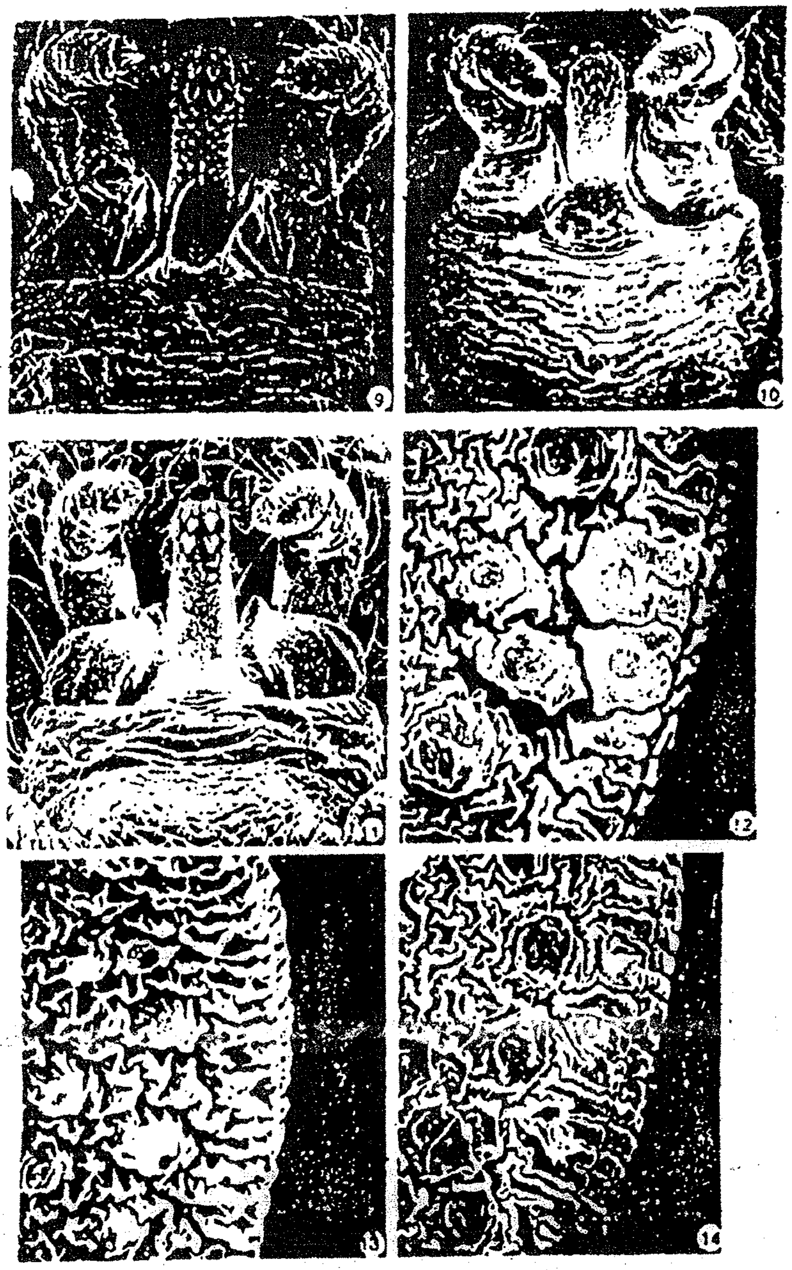


Fig. 5 : Captitulum vmtral view — 9. *polonicus* (x 221). 10. *vulgaris* (x 182). 11. *moreli* (x 121), one posthypostomal seta missing); peripheral striated area — 12. *neghmei* (x 162), 13. *daleri* (x 162) 14. *moreli* (x 161).

CYTOTAXONOMY

The aim of cytotaxonomy is not only to describe identity and arrange organisms in convenient categories but also to understand their evolutionary history and mechanisms. This approach have contributed a lot of explaining the true structure of the species. Different techniques used for biochemical studies by the different way.

a) The Genetic Complement :

It comprises the genome (the DNA in the nucleus) and plasmon (the DNA in cytoplasmic organelles). DNA is the essential material of heridity. It is believed that if the DNA composition of all species is known, their evolutionary course would become quite apparent. It is believed that the amount of DNA per chromosome set is constant for each species. But it is still not certain whether the ratio of the DNA content of the chromosome are attributible to variation in the size of heterochromatic segments or they are associated with differences in the metaphase thickness. Even today it is not known that a given amount of DNA and proteins is stimulated at mitosis to become distributed into a particular member of chromosomes (Fig.-9).

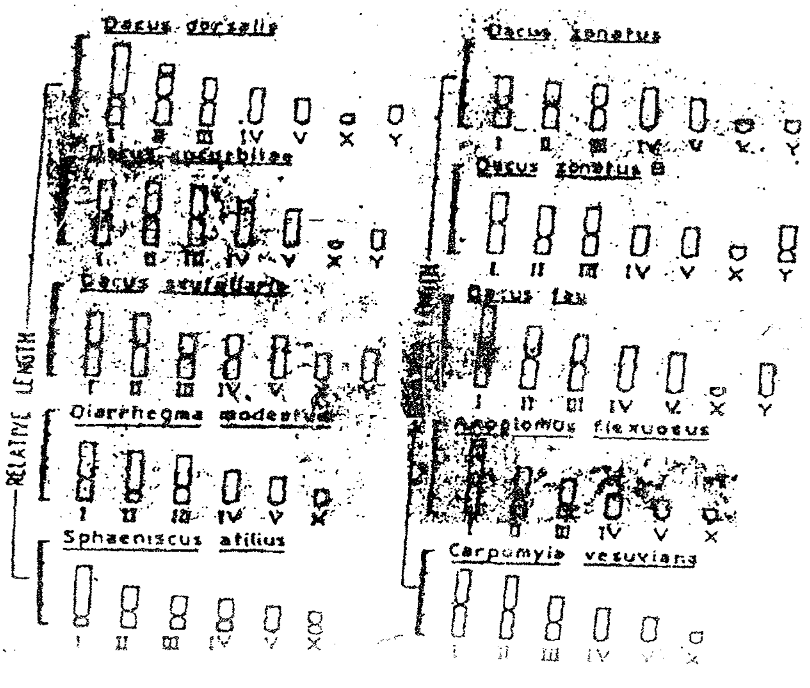


Fig. 9 : Diagrammatic presentation of the idiograms of some fruit fly species.

b) DNA Hybridisation :

The discovery that 'hybridisation' between single stranded DNA components from different origins can occur (Schildkrant *et. al.*, 1961) provides a physico-chemical means for assessing genetic relatedness among species (Murmer *et. al.*, 1963). In such studies the DNA is extracted from an organism and made to hybridise *in vitro* with the cell lines of other organisms. The DNA matching techniques hold much promise in solving complex taxonomic problems. The taxonomic implications of these have been well reviewed by Hoyer *et. al.*, 1964). The incomplete fossil record in many animal grounds may pose problems in solving the evolutionary or phylogenetic problems through these studies.

c) Karyological Studies :

Chromosomal cytology has been manipulated more extensively by plant taxonomists rather than animal taxonomists. The karyotype, characterised by chromosomic number, size and morphology, is a definite and constant character of each speices. The numberm shape and banding of chromosomes can be determined by using various disecting and staining techniques. Chromosomal taxonomy can be quite useful both in determining the phylogenetic relationships of the taxa as well as in the segregation of sibling or cryptic specoes (Fig.-10, 11, 12).

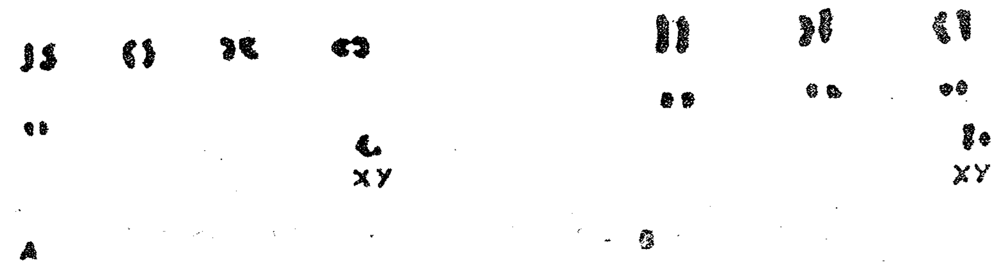


Fig. 10 : Male karyotypes — A. *Labidura riparia*; B. *Labidura bengalenis*.

The improves techniques evolved during the past 30 years have made chromosome work much less laborious. Now it is also possible to work with the different groups like mammals, birds and insect like lepidoptera. There are now more reliable karyotypes for about 1000 species of mammals, several bundrds species of fishes, amphebians, reptiles and birds. A number of species complexes have been broken up, especially in mammals and urodels. The dipterous flies, particularly with gaint or polytene chromosomes and orthopterans are the most suitable groups for chromosomal studies. Patterson and Stone (1952) differentiated 16 species of the genus *Drosophilla* on the basis of number and shape of chromosomes. Kiauta (1968) was able to demonstrate the phylogenetic relationship among the various famileis of the order Trichoptera on the basis of number of chromosomes. Mittal *et. al.* (1974) were able to separate two synonymised species of the earwing genus *Labidura* on the basis of number & morphology of their chromosomes. Grewal (1982) separated some important fruit fly species on the basis of the shape and number of chromosomes. He also discovered another population of *Dacus zonatus* on the basis of their characteristics.

Polyploidy is not common in animals except among wholly parthenogenetic forms. But the variation in the number of chromosomes occurs in many ways. One of the way for reduction in the number of chromosomes is through chromosomal fusion. In some groups the chromosome pattern has remained substantially constant through long evolutionary stages, while in others it has undergone distinct changes even in closely related species. For example among is fairly constant while in Lepidoptera, Trichoptera, Scorpions and fishes, it has shown marked variations. The closely species may show considerable rearrangement and many species are polymorphic for the very chromosomal differences that in other cases differentiate closely related species. Conversely welldefined and reproductively isolated species may completey agree structurally in their chromosomes and differ only in their gene contents.

Thus, karyomorphology can be taken as the only answer to solve all systematic problems. It can be used in selective cases. However, the value of the karyological data can be better utilised if combined with the highest possible taxonomic elements for the diagonosis of species.

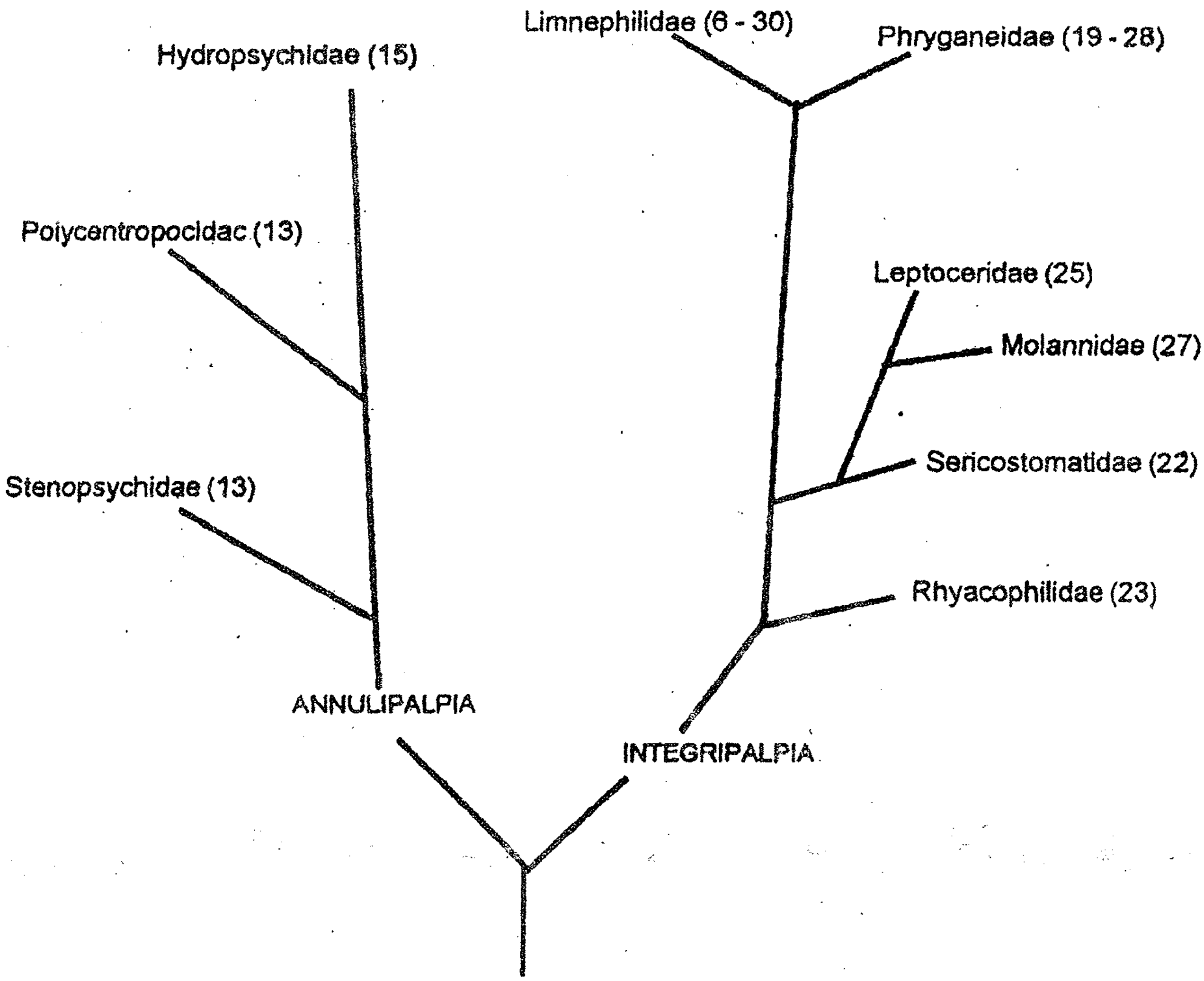


Fig : 13 : Chromosome number plotted aganist the phylogency of Trichopteran families (from Klauta, 1968).

NUMERICAL TAXONOMY

It is the numerical evolution of the affinity or similarily between taxonomic units and the ordering of these units into taxa on the basis of their affinities. Numerical methods were classified into phenetic & cladistic ones and vice versa, it is more informative to distinguish between distance methods, in which the similarly or distance of taxa from each other is determined, and character-data methods, in which dendrograms are constructed that consist of texa share derived characters. Some molecular methods produce only distance data. More prominant examples come from DNA-DNA hybridization and micro complement fixation. One can also convert charactor data into distance data by calculating measures of distance between taxa on the basis of the character data. Farris (1972) developed a cladistic algorithm based on the toxon by taxon matrix of phenetic differences. Such an approach is particularly sutiable for data sets such as those derived from immunological comparison and DNA-hybridization.

In contrast to distance methods, character-based methods of phylogeny inference use data about the status in taxa as a strting point. Hennig and his earlier followers constructed their cladograms by hand, but now many computer programmes are available to aid the experienced taxonomist.

Numerically it is actually based on the principles of Adanson (1727-1806). This concept is based on the use of maximum number of characters and that, too, all are given equal weight. In general the larger the number of taxonomic characters, the better will be the result. The characters may not be necessarily derived only from external or internal morphology but may now include any attributes of the other taxonomic unit like biochemical, behavioural, cytological, ecological, developmental etc.

Distinct taxa can be constructed due to the diverse character correlation in the various groups under study (Sneath and Sokal, 1962). But still there are differences of opinion regarding the number of characters used in this approach. Sokal and Sneath (1963) prefer the use of at least 60 characters; Moss (1967) 135 - 146 characters, while steyskal (1968) at least 1000 characters, especially in insects.

Majority of the work in numerical taxonomy is concerned with the classification in the group-recognition sense. These workers have greatly supported their studies and claim too much in solving the problems of biological classification. Bossert (1969), Pankhurst (1975) and Morse (1971) made use of computerised methods in divising dichotomous keys for the identification of various taxa. Dr. J.A. Peters of the United States National Museum, Washington had already devised a computer programme for the identification of the genera of central and South Americal Snakes (Ross, 1974). A large array of computer programs are now available. They all have certain advantage & disadvantage. There are a packages for phylogenetic analysis. The most widely distributed ones are – PHYLIP (Phylogeny Inference pakcage), PAUP (Phylogeny Inference package), PAUP (Phylogenetic Analysis using persomony), HENNING - 86 etc.

Simpson (1961) feels that the approach of compairing characters in common including ninuteness of resemblance and multiplicity of similarities is very useful in all taxonomy because the conclusions based on the affinities become stronger and stronger when more and more characters are used.

Blackwelder (1967) and many others also doubt the usefulness of numerical methods. The approach is exposed to the great risk of reach in unsound classification, because in giving equal weight to all characters it does not allow for mosaic evolution, special adaptations, convergence, parallelism, development and genetic homeostasis in addition to evolutionary, genetic and developmental phenomena that disturb the expected close relation between phenetic similarity and phylogeny (Mayr, 1969).

Moreover, the use of complex mathematical and statistical methods by numerical taxonomists has further gone against its due recognition because of great difficulties faced by the biological taxonomists to follow them. Moss and Hendrickson (1973) and Schlee (1975) have discussed in detail the merits and demerits of numerical taxonomy.

No taxonomist has the time to test one numerical method after the other in order to see which one produces the best, or most meaningful, phylogeny. However, in a remarkably large number of recent taxonomist revisions, the authors actually used a variety of distance and character - based methods to determine which would produces a phylogenetic hypothesis that best reflected the numerical parren of that group. In the course of this testing & compairing of methods, it has already become apparent that certain methods are inferior. It is hoped that eventually the number of proven methods will be narrowed to a few (Felsenstein, 1988b).

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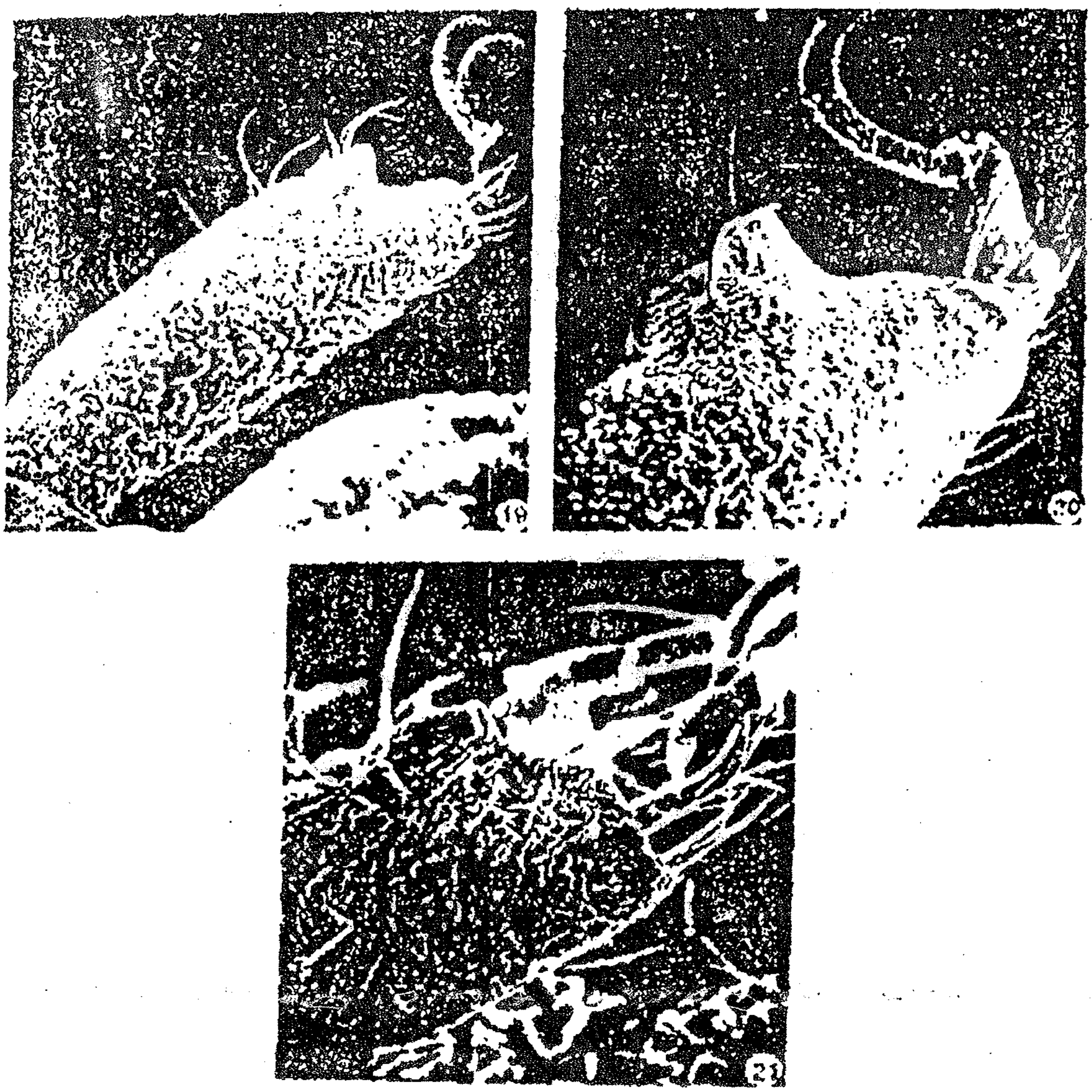

Fig. 6 : Tarsus I, apical external view — 19. *polonicus* (x 156); 2. *magnus* (x 302); 21. *dalei* (x302)

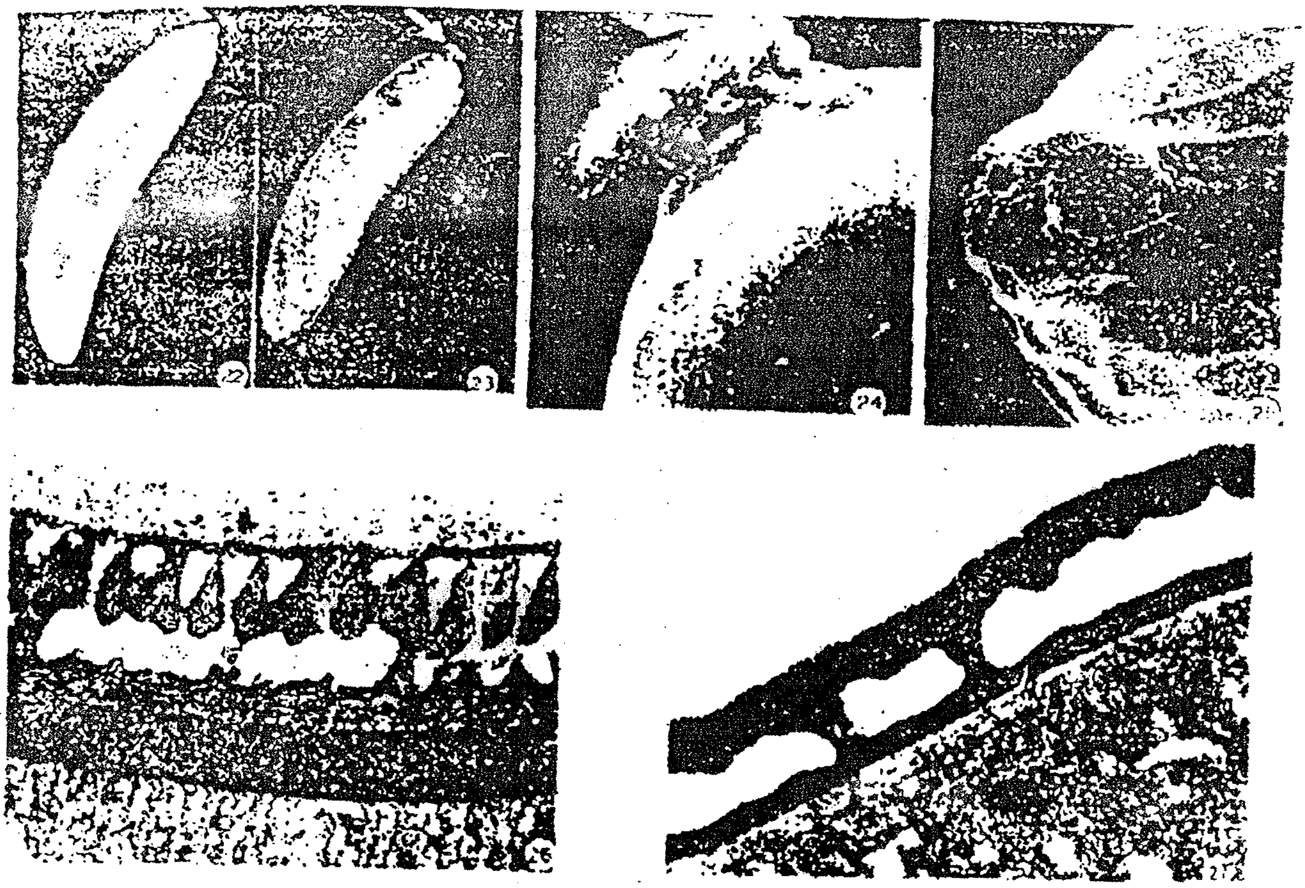

Fig. 7 : Whole eggs (Scaning electron micrograph) Fig. 22. *Ceratatus capitata*; Fig. 23. *Dacus oleae*. Anterior pole of eggs (shown with arrow) (SEM), Fig. 24. *Dacus oleae*; Fig. 25. *Certitis capatitis*. Thin sections through main body of the egg (Transmission electron micrographs), Fig. 26. *Ceratitis capitata*. Fig. 27. *Dacus oleae*.

Fig. 11 : Differences in the number and shape of chromosomes i some species of fruit files (Diptera, Tephritidae), courtesy Dr. J.S. Grewal — A. Main *Bactrocera zonata*, B. a. population of *zonata*. C.B. *dorsalis*, D. B. *cucurbitae*, E. B. *scutellaris*, G. *Diarrhegma modesta*, H. *Anoplomus flexuosus*, I. *Sphaeniscus* *atilus* and J. *Carpomyia vesuviana*

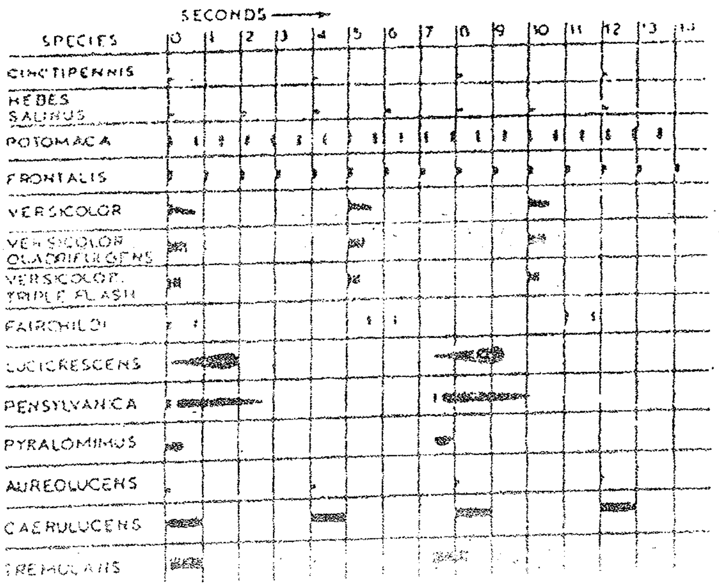

Fig. 12 : Pattern of light flashes in some species of fireflies of the geneus *Phetrats* (modified from Barber 1951).

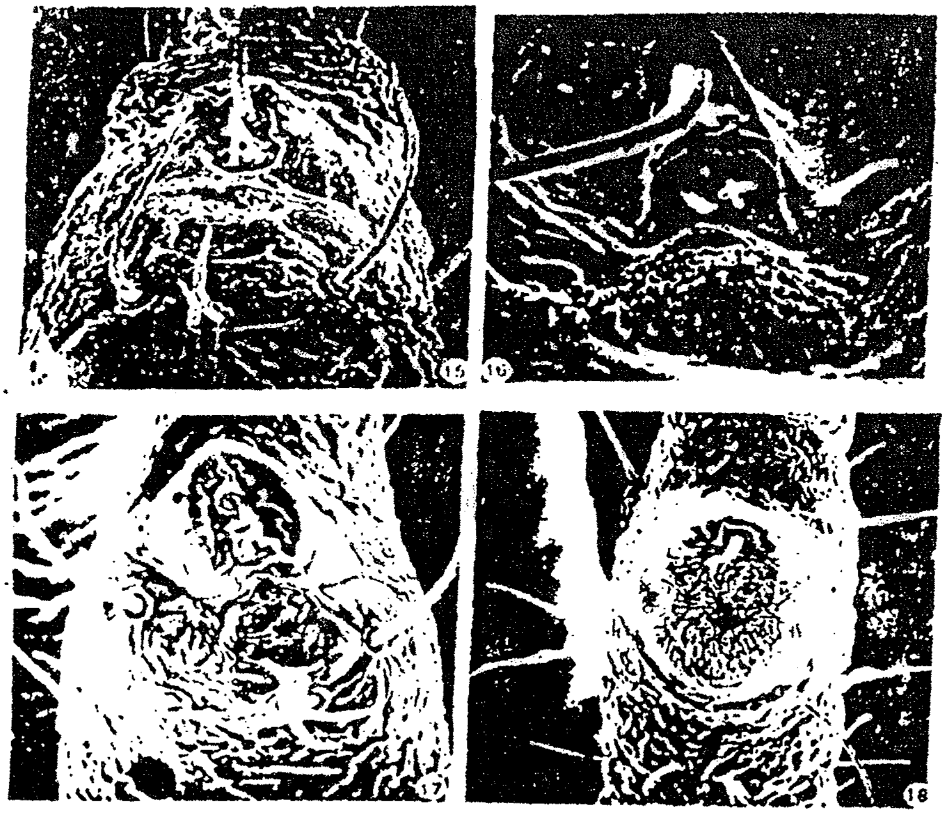

Fig. 8 : Haller's organ area — 15. *polonicus* (x 480); 16. *vulgaris* (x 182); 17. *delei* (x 208); 18. *cucumerinus* (x 208).

VIDYASAGAR UNIVERSITY

DIRECTORATE OF DISTANCE EDUCATION
MIDNAPORE - 721 102

M.Sc. in ZOOLOGY

Part – I

Paper – I, Unit - II, Group-B

Module No. 12

Syllabus :

1. Species Concept
2. Sibling Species
3. Allopatric Speciation
4. Sympatrie Speciation

The basis unit or building stone in biological classification is the species. Species in time, as segments of phylogeny, raise special problems of subdivision of unbroken successions of species & treatment of branching lineages. The concept of species seems so absurdly simple that it always comes as something of a shock to a beginning taxonomist to learn how voluminous & seemingly endless the debate about the species problem has been. In Zoology there in now fair agreement on the species concept, although heterodox views are still vigorously defended. For recent summaries see Mayr (1957a, 1963) & Simpson (1961).

The species problem has been made to appear more difficult than it is by a confusion of the concepts underlying the terms phenon, taxon & category. To be able to undertake the ranking of taxa, the taxonomist must have a clear conception of the category species.

The objective of a scientifically sound concept of the species category is to fasilitate the assembling of phena into meaningful taxa on the species level.

Taxonomic literature reports innumerable species concepts by their philosophical basis, all these concepts fall into the following major groups.

Typological species concept

According to this concept the observed diversity of the univers reflects the existence of a limited number of underlying "universals" or types (eidos of plato). Individuals do not stand in any special relation to each other, being merely expressions of the same type. Variation is the result of imperfect manifestations of the idea implicit in each species. This species concept, going back to the philosophies of plato & Aristotle, was the species concept of Linnaeus & his followers (Cain, 1958). Since his philosophical tradition is sometimes referred to as essentialism, the typological definition is also sometimes called the essentialist species definition.

Two practical reasons exit for rejection of the typological species concept which are as follows:

1) Individuals are frequently found in nature that are clearly conspecific with other individuals inspite of striking differences in structure owing to sexual dimorphism, age differences, polymosphism & other forms of individual variation. Although often described originally as different species they are deprived of their species status, regardless of the degree of morphological differences as soon as are found to be members of the same breeding population.

2) Sibling species differ hardly at all monphologically, yet are good biological species.

Its own adherents abandon the typological species concept whenever they discover that they have named as a separate species something that is nothing but a conspecific phenon. At present the typological species concept is still defended by some writers adhering to thomistic philosophy.

Nominatistic species concept

The nominalists (Occem & his followers) deny the existence of real universals. For them only individuals exist, while species are man made abstraitions. Bessey (1908) expressed this viewpoint particularly well : "Nature produces individuals & nothing more ..... species have no actual existence in nature. They are mental concepts & nothing more .... species have been invented in order that we may refer to great members of individuals collectively."

Any naturalist, whether a primitive native or a trained population geneticist, knows that this is simply not true. Species of animals are not human contracts, nor are they types in the sense of Plato & Aristotle, but they are something for which there is no equivalent in the realm of inanimate objects.

The Biological species concept

An entirely new species concept began to emerge after about 1750. It is angured by statements made by Buffon, Marrem, Voigt, Walsh (1864) & many other naturalists & taxonomist of the nineteenth Century. K. Jordon (1905), however, was the first who clearly formulated the concept in all of its consequences. It combines elements of the typological & nominalistic concepts by stating that species have independent reality & are typified by the Statistics of populations of individuals. It differe from both by stressing the populational aspect & genetic cohesion of the species & by pointing out that it receive its reality from the historically evolved, shared information content of its gene pool.

As a result, the members of a species form three units -

a) A reproductive Community :

It holds that individuals of a species of animals recognise each other as potential mates & seek each other for the purpose of reproduction in all organisms.

b) An elological unit :

The species is also an ecological unit which, regardless of the individuals composing it interacts as a unit with other species with which it shares the environment.

c) A genetic unit :

The species finally is a genetic unit consisting of a large, intercommunicating gene pool, whereas the individual is merely a temporary vessel holding a small portion of the contents of the gene pool for a short period of time.

These three properties raise the species above the typological interpretation of a "class of objects" (Mayr, 1963). The species definition which results from this theoretical species concept is:

"species are groups of actually or potentially interbreeding natural populations which are reproductively isolated from other such groups." (Mayr, 1969).

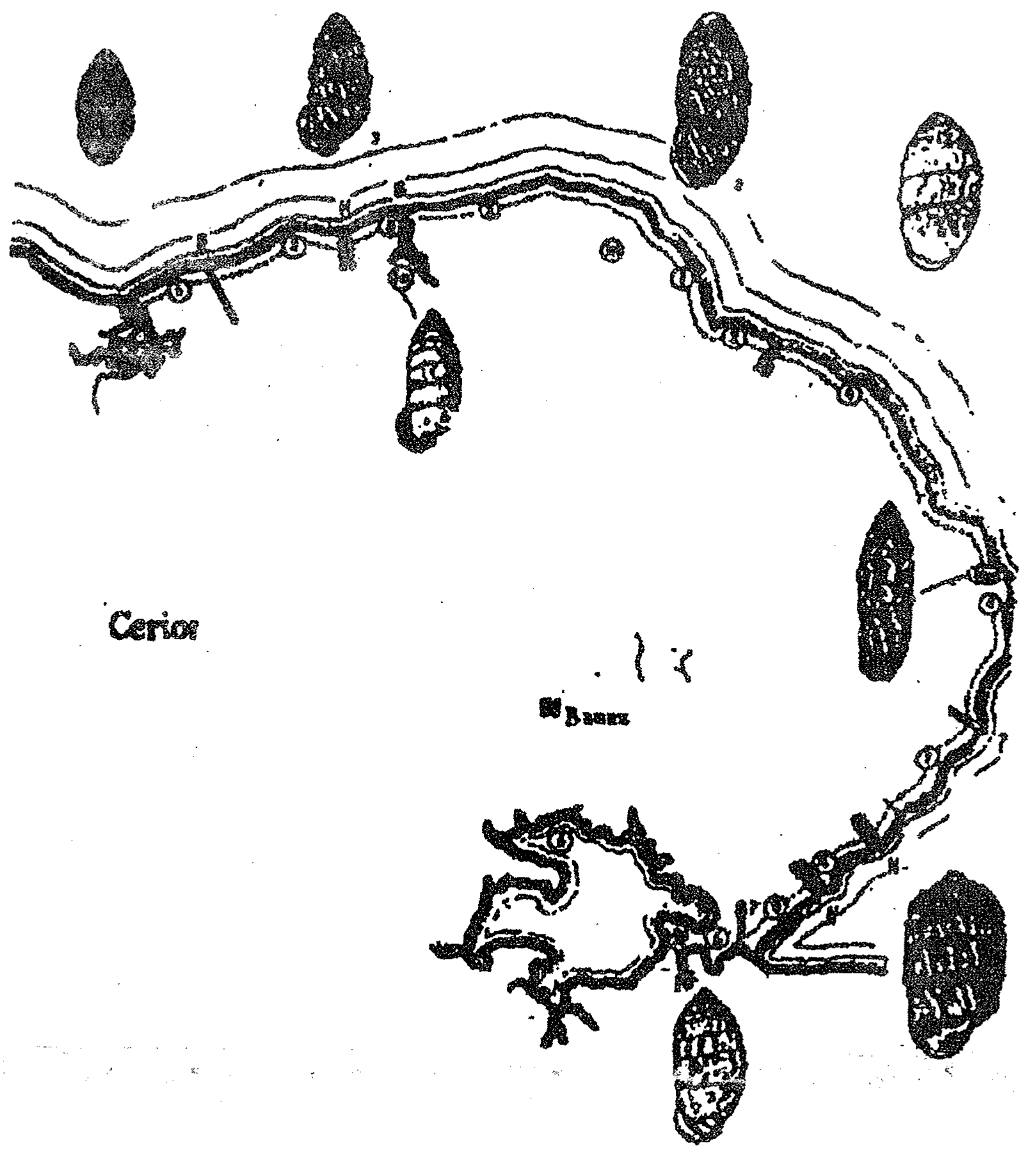

Fig. I : Irregular distribution of populations of the halophilous land snail Cerion in estern Cuba. Numbers refer to different races of species. Where two populations come in contact (with the exception of lipida) they hybridize (H), regardless of difference. In other cases contact is prevented by a barrier (B). In isolated population (from Mayr, 1963).

Difficulties in the biological species concepts :

The fact that difficulties sometimes arise when biological species concept is applied to natural taxa does not mean that the concept such is in valid. However the difficulties are discussed below:

1) Insufficient Information :

Individual variation in all of its form often raises doubt as to whether a certain morpho type is a separate species or only a phenon within the variable population. Sexual dimorphism, age differences, polymorphism & other such types of variation can be unmarked as individual variation through a study of life histories & through population analysis.

2) Uniparental reproduction :

In many organisms systems of reproduction are found that are not based on the principle of obligatory recombination of genetic material between individuals self fertilization, perthenogenesis, pseudogamy & vegatitive reproduction are some of these forms of uniparental reproduction.

Species recognition among a sexual organisms based not merely on analogy but also on the fact that each of the morphological entities, separated by a gap from other similar entities, seems to occupy an ecological niche of its owns it plays its own evolutionary role.

3) Evolutionary intermediacy :

The species as manifested by a reproductive gap between populations, exists in full classifcal distinctness only is a local fauna. As soon as the dimensions of space & time are added, the stage is set for incipient speciation populations will be found under these circumstances which are in the process of becoming separate species & have acquired some but not yet all of the attributes of distinct species. In particular, the acquisition of morphological distinctness is not always closely corelated with the acquisition of reproductive isolation.

i) Acquisition of reproductive isolation without equivalent morphological change. Reproductively isolated species without morphological difference are called sibling species.

ii) Acquisition of strong morphological difference without reproductive isolation.

4) Semi species :

Geographical isolation occationally have an intermediate status between sub-species & species. On the basis of some criteria, they would be considered species; on the basis of others they would not. It is usually more convenient for the taxonomist to attach such doubtfull population to the species which they are most nearly allied.

Circular overlap & other borderline cases are other instances of evolutionary intermediacy that will have to be devides from case to case on the basis of convenience & degree of evolutionary intermediacy.

Evolutionary species concept

It is the fact of evolution that has made genetical species separate & that keeps them from always being sharply, clearly separated. It is also aided that the genetical definition of species has evolutionary significance. Still it is striking that the definition does not actually involve any evolutionary criterion or say any thing about evolution. To relate the genetical species directly to the evolutionary processes Simpson (1951) defined species as an evolutionary species is a lineage (an ancestral desendent sequence of population) evolving separately from others & with its own uvitary evolutionary role & tendencies.

This definition not only is consistant with the genetical definition but also helps to clarify it & remove some of its limitations. It also justifies why genetical species has evolutionary significance, removes some of the conceptual difficulties remaining in the purely genetical concept helps to solve why disjunct populations should be placed in one species if they retain the same evolutionary role.

The one important difficulty in the evolutionary concept of the species in the definition & recognition of roles. But the roles can not be directly observed in a series of dead specimens, recent or fossil, in a museum, valid & sufficient evidence of separation & unity in roles can however be obtained from observation on such specimen; morphological resemblances & difference are related to roles if they are adoptive in nature.

Conclusion

These four species concepts considerably overlap each other; for some organisms are definition is more suitable than another & for same the definitions will coincide. It becomes even more difficult to estimate the populations of species in the living world on in specied groups of organisms to which any two, three, or all four species definitions apply. In any case the biological distinctness in primary & the morphological difference secondary (Mayr 1957).

It is still not settled as to which species concept should be accepted & it can not be devided until a way is found to correlate the species composed of populations supposedly phylogenically related. Presently the Zoologist can deal with them separately, but yet cannot arrive at a final single concept by combining them. The confusion still persists & if it not settled early it would not be surprising when Zoological taxonomy may again be forced to surrender & abandon a well established term, the species, as has already happened with the well established term, the genotype.

SIBLING SPECIES

Biological species are reproductively isolated gene pools. When two populations become geographically isolated. They diverge in their isolation genetically & may eventually acquire isolating mechanisms. As a by product of the genetic divergenic during this process, species normally also acquire morphological differences suitable for diagnostic purposes. A few species fail to acquire conspecuous morphological differences during the process of speciation. Such very similar, cryptic species are called sibling species. All the available evidence indicates that minuteness of monphological difference is the only aspect in which they differe from ordinary species. They are merely those species that are near the invisible end of the specturm of morphological species differences. They grade imerceptibly into species that are morphologically more & more distinct from one another. Once discovered, throughly studied, sibling species are usually found to have previously overlooked morphological differences.

Mayr (1963) has shown have wide spread in the animal kingdom sibling species are Most of them were discovered not during routine toxonomic analysis but during the study of species that are medically (e.g. *Anopheles*), genetically (e.g. *Drosophila, Paramecium*), cytologically, agriculturally, or other wise of special importance. It is therefore impossible to indicate what percentage of species are sibling species.

The discovery of sibling species is possible because they may differe in various attributes even when they are extremely similar in the marphological characteristics normally employed in taxonomic analysis. Mayr (1963) has listed a number of characteristics that facilitate the recognition of sibling species. Precise measurements sometimes display bimodal characteristics & the two modes can be correlated with additional characters. Very often there are differences in the number or structure of the chromosomes, a fact which has led to the recognition of sibling species in *Drosophlia, Sciara,* Chironomus & other dipterans & other insects. Various aspects of behaviour have perhaps led to the discovery of more sibling species than any other characteristic. Sibling species are able to occupy different niches in the same community without appreciable differentiation in those mosphological characters that are used by taxmonomists in their classification. Every case of sympatry among sibling species is a case where no sympatric character divergence, in the sense of Darwin, has accurred in taxonimically useful morphological characters.

Definition :

Morphologically similar or identical population that are reproductively isolated is called sibling species (Mary, 1942).

According to Dobzhansky sibling species are reproductively isolated Mendelian populations, the members of which show few or no easily visible differences in the bodyly structures.

Well studied group of sibling species :

The characteristics of sibling species are best revealed by discribing in detail some of the better knwon cases. In the genus *Drosophila* most of the species complexes contain groups of sibling species (Patterson & Stone, 1952).

The kinds of differences that may exist between two sibling species are typied by the extensively studied pair *Drosophila pseudobscura* Florova & D. *persimilis* Dobzhansky & Epoling.

From the most beginning the member of differences has increased steadily & when it was discovered that the two races consist to the rank of full species (Dobzhansky & Epling, 1944). It first it was though that the two species were identical in morphology; but later it was found different. The differences are tabulated below:-

	Characters	D. *Pseudobscura*	*D. persimilis*
1)	Structure of Y-chromosome	J. Shaped	V.Shaped
2)	Index of wing meanirements	45.7 – 62.8	68.8 – 76.2
3)	Shape of male genitalia	Clear cut difference in shape	
4)	Egg laying capacity	At 35"C lag more eggs	At 14"C lay more eggs more eggs.

Other invertebrates :

The most celebrated case of sibling species is that of the malaria mosquito complex in Europe. It was proved that the malaria mosquito of Europe was actually a group of 6 sibling species (Genus-*Anophelis*).

In molluses, sibling species are common 4 sibling species of the genus *Patella* are currently recognised in Europe & species seem to be well defined in most localities.

In protozoa, the instance of sibling species was found to occur in *Euplotes*, *Peramoecium*.

In vertebrates :

In mammals, sibling species are common in the order Rodent. In Birds, stressmann (1948) recorded 12 differences between two species of Nightingales (*Luscinia* megarhyncha & *L. lunivia*) of which only 3 are morphological.

In Reptiles, sibling species occur in snakes & lizard. In Amphibia, they are wide spread among toads. *Rana brevipoda* differs from *R. nigromaculata* in ecology & general behaviours.

In fishes, sibling species seems to be wide & particularly studied groups are in the genera of *Salmonids* etc.

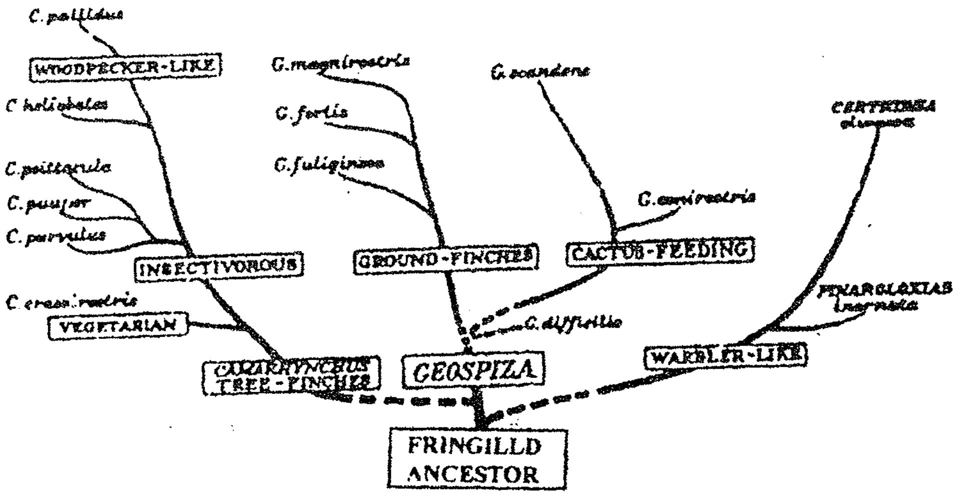

Fig - 2 : Adaptive radiation of Darwin's finches (Geospizinae) on the Galapagos Islands into a number of different niches (from Lack, 1947)

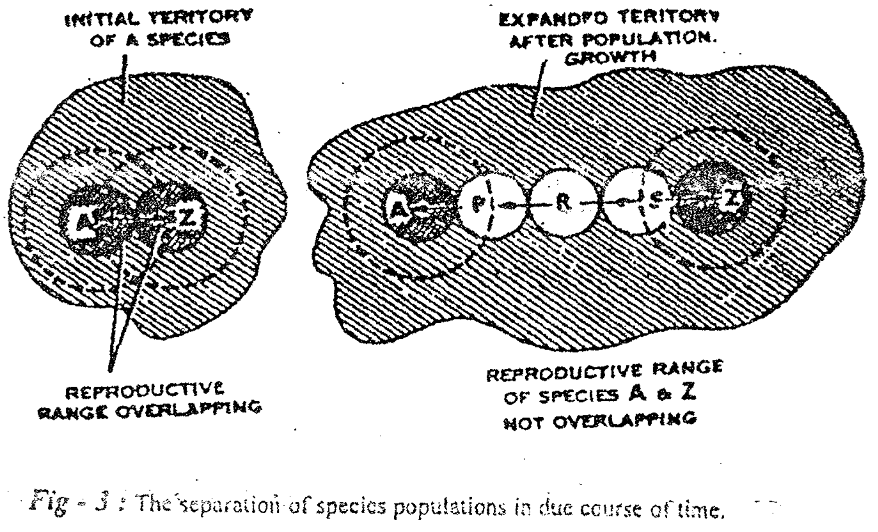

Fig - 3 : The separation of species populations in due course of time.

The recognition of sibling species :

Because of super ficial morphological similarity, sibling species may be identified by following ways :-

(1) Biometric differences.

(2) Breeding tests.

(3) Habitats.

(4) vocalization.

(5) Next preference.

(6) Pathogencity.

(7) Cytology.

(8) Biochemical analysis.

ALLOPATRIC SPECIATION

Allpatric speciation or geographic speciation means the acquisition of isolating mechanisms by a population during a period of geographic isolation. This type of speciation is perhaps the principal method of speciation in animals.

Historical :

Many naturalists of the late 18th & early 19th century were state the importance of geographic factors in speciation. They were aware of both factors of geographic speciation is climatic variation & isolation, but failed to units these two factors. Climatic variation was emphasised by Buffon, Pallas, Van Bear etc. The statement of Leopold Von Buch was remarkably very near to the modern approach of gepgraphic speciation when he wrote a description of fauna & flora of canary islands (1825). Von Buch's theory deeply impressed Darwin as evidenced from his not books. Bates (1863), Wagner (1968) & particularly Gulock (1887) in his studies of the *Achatinella* snails on the Haiwaiian Island emphasized the extreems important of segregation of populations as role of speciation.

Evidence for geographic speciation :

There are three sets of phenomena that give us information on this question :

(a) Levels of speciation.

(b) Geogrraphic variation of species characters.

(c) Border line cases & distribution patterns.

(a) Levels of speciation :

Numerous species groups analysed by recent authors showed the populations that represent every stage of divergence upto recently completed speciation (Huxley, 1942; Mayr, 1942; Dobzhansky, 1951; R.R. Miller, 1948). Distance related species f the genue *Drosophila* do not cross, even sub species & strains show no interest to mate. This shows that species differences evolve through allopatric strains, sub species to species. Another well known case is the Platy fished of central America (Xiphophorus sp.P studied by Gorilen & authors.

i) *X. cocuhianus* – Northern most, restricted to single river system.

ii) *X. variatus* – South river system of three states.

iii) *X. muculatus* – Southern most river system.

(b) Geographic variation of species characters :

In geographic speciation, following two sets characters are subject to geographic variation as morphological characters.

1) Ecological properties : Every wide spread species formed to differ in ecology to lesser or greater extent e.g.

(i) *Turdus Poliocephalus* Solomon Island 6000 ft.

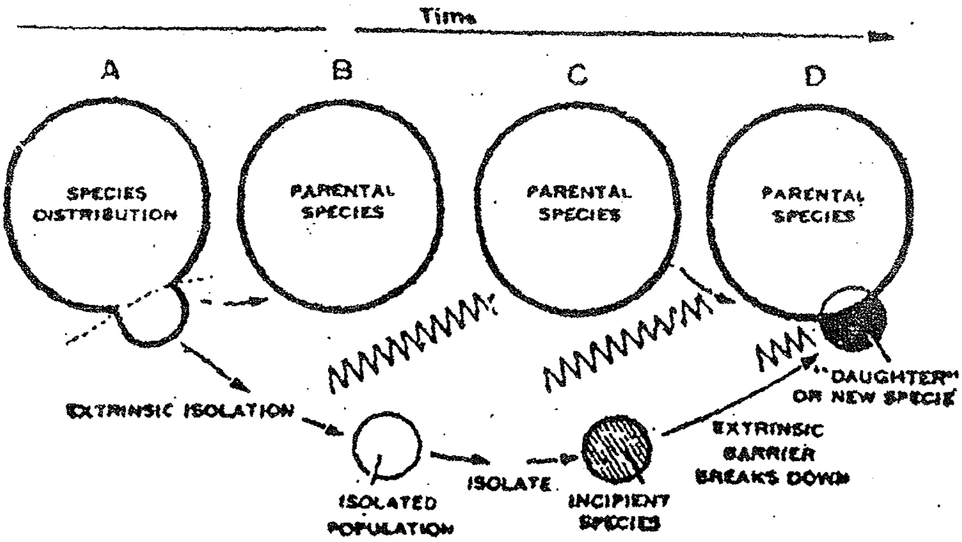

Fig - 4 : Reproductive isolation establish

Species. **Place** **Ecology**

2) Isolating mechanism :

(i) Sterility barrier

We have the best evidence is well studied genus *Drosophila*. In *D.Pallidipennis* no sexual ioslation between a subspecies from Vera Crus, Mexico & one from Suopolo, Brazil & males & females court at random. Chromosome pairing in salivary gland chromosomes of hybrid larvae is neerly prefect; yet the F. males are steril.

(ii) Ethological barrier

According to Goetz & Schmidt (1942), the male honey bee (*Apismellifera*) has special scut organ which varies geographically & which may be important for courtship. Geographic variation of song; an important isolating mechanism in birds.

(iii) Structural barrier

Though it is not considered as an important isolating mechanism e.g. Genetal anceste of insects may very considerably as has been shown by Vendesplank (1948) in tsetse flies which may cause death of the female if mating occurs between different sub species.

(c) Border live cases & distribution patterns

The geographic ioslate is key unit in the process of geographic speciation. Isolates may show every stage of speciation. New species may be allopatric from which they diverged, may overlap as sympatric species. The majority of isolates are 'border live' cases i.e. they have some but not all attributes of species with isolating mechanism more or less incompletely developed.

(i) Peripheral isolates :

These isolates ae situated along the periphery of the species & most polytypic species has such peripheral isolate. e.g. Spongled Drogo (*Dicrurus hottentotters*) has almost a dozen of peripheral subspecies which are considered as full species by Mayr 1948. Every island or isoland groups situated infront of a continent – like Britain, Ceylon, Japan etc. has given rise to peripheral isolates.

(ii) Super species :

Allopatric populations are often os distinct that there is little doubt about their having reacted species level. Rench (1929) proposed for such groups of allopotric species the German term Artenkris for which the termed super species coined by Mayr (1931).

(iii) Semi species :

The allopatric species of which a super species is composed have been designated by Mayr (1940) as semispecies.

(iv) Secondary contact zones & Incomplete speciation :

When a geographical isolate reestablishes contract with the parental species before isolating mechanism & have been perfected & a hybrid zone will develop.

(v) Partial overlap :

The invasion of the geographic range of parental or sister species by a newly formed species. Species of *Crocodilus acutus* new widely overlaps, with the ranges of rhombifer & morelei with which premmably formerly allopatric.

(vi) Multiple invasion :

Multiple invasions occur when the same stock colonizes an isolated district several times, producing several species in it. Each separate invision produces a population cut off from present stock. When isolation persists is per sufficient length of time, the product of the same stock may behave as good species e.g. Darwin finches speciated freely in the Galapots Island by multiple invasions.

(vii) Circular overlaps or ring species :

The clearest evidence of geographical speciation is afforded by ring species in which the terminal links have become sympatric without interbreeding. These cases, incidently, are also a perfect demonstration of 'speciation by distance'. Nine cases were described by Mayr (1942).

Conclusion

Three important quesions now arise :

(1) How do isolated populations diverge from each other?

(2) When they meet, how do they maintain their species distinctness?

(3) How can they invade each other ranges & co-exist ecologically?

Production of divergenic may be due to

(a) Random incidence of mutations.

(b) Genetic Drift.

(c) Natural selection.

Ernst Mayr said, ..."Immerable aspects of the geographic variation of species of distributional patterns & of the ranking of the lawer taxonomic categories give evidence for the wide spread occurence of geographic speciation."

Evidences of Sympatric speciation

Morphological distinctness is no dubt really makes the species.but it is argued that such forms acquire their ecological difference while still sympatric & become morphologically distinct species subsequently.

Following complex phenomena can be cited as evidence for such sympatric speciation.

1) **Incipient sympatric species**

e.g. Variety.

2) **Biological races**

a) morphs (members of same gene pool showing different preferences):-

e.g. one races of leaf hopper (Cicaduliva rp.) transmict streak disease at maize while other races does not.

b) clones (sexual reproduction is permanently or temporarily abandaned parthenogenetically reproducing strains differ in biological characteristic) :-

e.g. In pea Aphid strains of various virulence may be isolated from same local populations (on pea plants).

c) Host race (Where temporary strains may develop on species host plants).

e.g. *Phytophaga destrictor* individuals which gave rise to strains that damaged previously resistant varieties of wheat.

3) **Sibling species** (the good species that are separable only with difficulty on morphological differences).

e.g. *Drosophila, Anophilis* etc.

Reputed cases of sympatric speciation

One of the strangest arguments used in favour of sympatric speciation is the existence of certain situations in nature which supposedly can be explained by sympatric speciation but which can not be explained on the basis of geographic speciation. There are 5 kinds of phenomena that form the basis of this argument.

1) **The occurence of sibling species :**

It is argued that sympatric sibling species could not have originated in any other way except through sympatric speciation. This is claimed particularly in those cases in which the sibling species were listed as biological races until this reproductive isolation was discovered (e.g. *Drosophila*).

2) **Speciation in monophagons species groups :**

It many groups of insects there are genera with many species, each of which appears to be limited to a single host (e.g. microlepidoptera, beetles etc.). It is plausible that the greater number of congeneris species is due to vastly increased number of available niches & the reduction of competetion.

3) **Speciation in parasites :**

Two types of distribution of parasites can be noted.

a) Different closely related parasites in or on different body parts of the same host.

b) Co-existence of several related species, on different host in same geographical area.

For instance, South American monkeys have 4 species of lice, all derived from human louse (Pediculus) which is wide spread among America, India. The population on each host is a spatial isolate.

4) **Special Swarms :**

Considerable member of this situated occurs when a closely related species Swarms which are confixed to narrowly circumscribed area & no close relious occuring elsewhere. They occur particularly ancient fresh water lakes such as Lake Baikal & also recent takes like Lake Lakas in Philippives or other takes in Tanganylika & Nyasa in Africa. Lake Lakas in Philippines originated recently by damming up of valley by a Lava flow. A Swarm of 18 closely related species of Cyprinids has evolved in this lake & they are seems to derive from Barlons binotatus a malayan fish.

5) **Instantaneous splitting of fossil lineage :**

Paleontologist have described a number of cases in which supposed by a single likeage has suddenly split into two clearly species (e.g. *Planorbis multiformis*). Many other think it is not the case of sudden sympatric speciation but to immigration from elsewhere. Some proposed models for sympatric speciation :

Among the various models of sympatric speciation proposed in recent decades. The following four deserve particular attention.

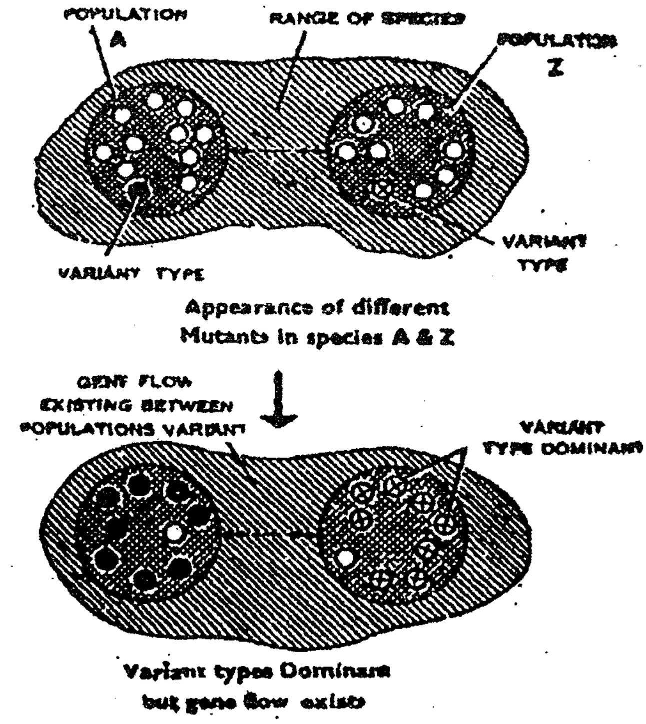

Fig : 7 Diagram to show how differnt populations of species may develop into different subspecies by the selective spreading of variants.

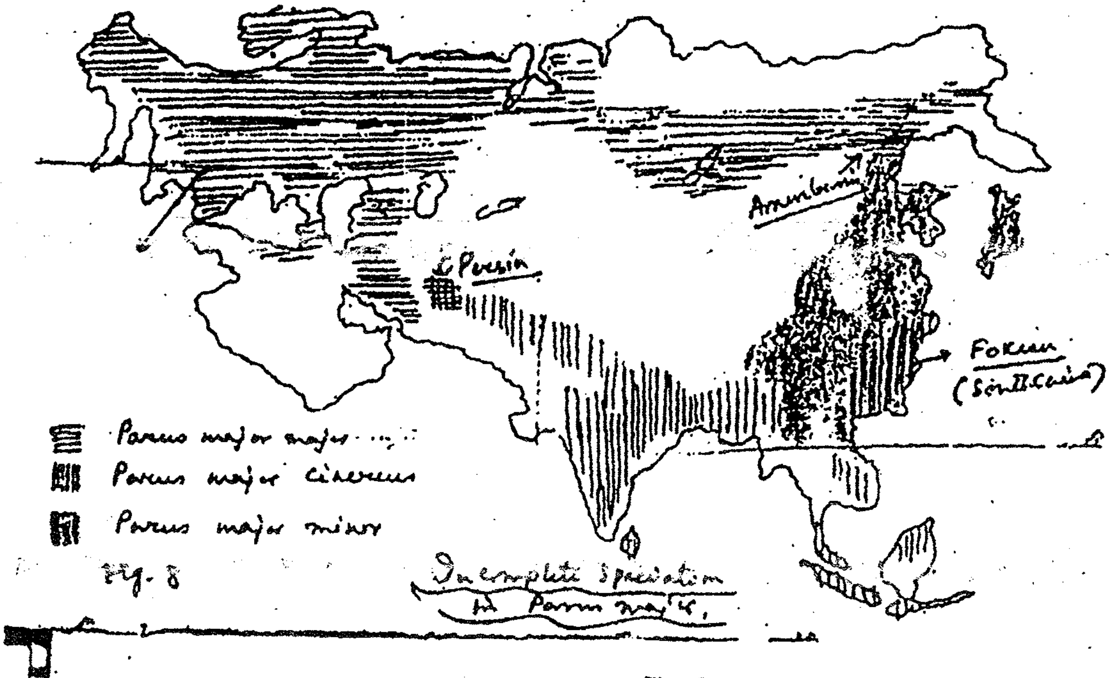

Fig : 8

(a) Speciation by disruptive selection :

Mimatic polymorphism, perhaps the most frequent & best analysed product of disruptive selection. Supporters of this type of speciation are Mathus (1956). Thoday & Boam (1959) etc. Thoday & Gibson (1962) have shown disruptive selection may lead to incipient speciation under laboratory condition. When high & low bristle number was arrived on in a population of Drosophilia melanogasfer complete homogamy was seen upon 12 generation. After that high bristle number males tended to mate with high number females & to reserve.

b) Speciation by Cytoplasmic Sterility :

Laven (1959) discovered a cytoplasmic factor in culex pipiens that remlts in normal fertility when O+O+ 'B' strain 'A' are crossed with ōō of strain 'B', but strility of o+o+ 'B' when crossed with ōō of strain 'A'. He postrulated that cytoplamic strility factor is responsible for this case.

c) Speciation by a mutation changing Host specificity :

Cytoplasmic speciation by a shift a new hot species make the following genetic assemptions–

AA Aa	aa	
These animals	This animal	
have host	have host	a = recessive mutation.
specificity on	specificity	
Plan – I	On Plant – II.	

If 'A' X As' by recombination 'aa' forms which have difficulties to find the plant–II. Then there will be a little mixing between 'Aa' or 'AA' to 'aa' & a gradual accumulation of genetic differences take place. Ultimately acquisition of reproductive isolations forms by this way.

d) Speciation by seasonal isolation :

It has been postrulated by various authors that a species with a very long breeding season might be sumpatrically split into two. Let their be a species which breeding season lasts to spring. Let an event take place, like a killing off by climate or newly invading competetor that leads to the extinction of the mid season breeders. As a result, only two sets of breeders remain.

i) early season breeders.

ii) late season breeders.

Both kinds are hence forth reproductively isolated & can accumulate genetic differences (e.g. field cricket).

Conclusion

According to Mayr "The hypotehsis is neither necessary nor supported by irregulable facts". No doubt the essential component of speciation is the genetic repatterwing of populations & it only takes place when populations are temporarily protected from disturbing gene flone of a lies genes.

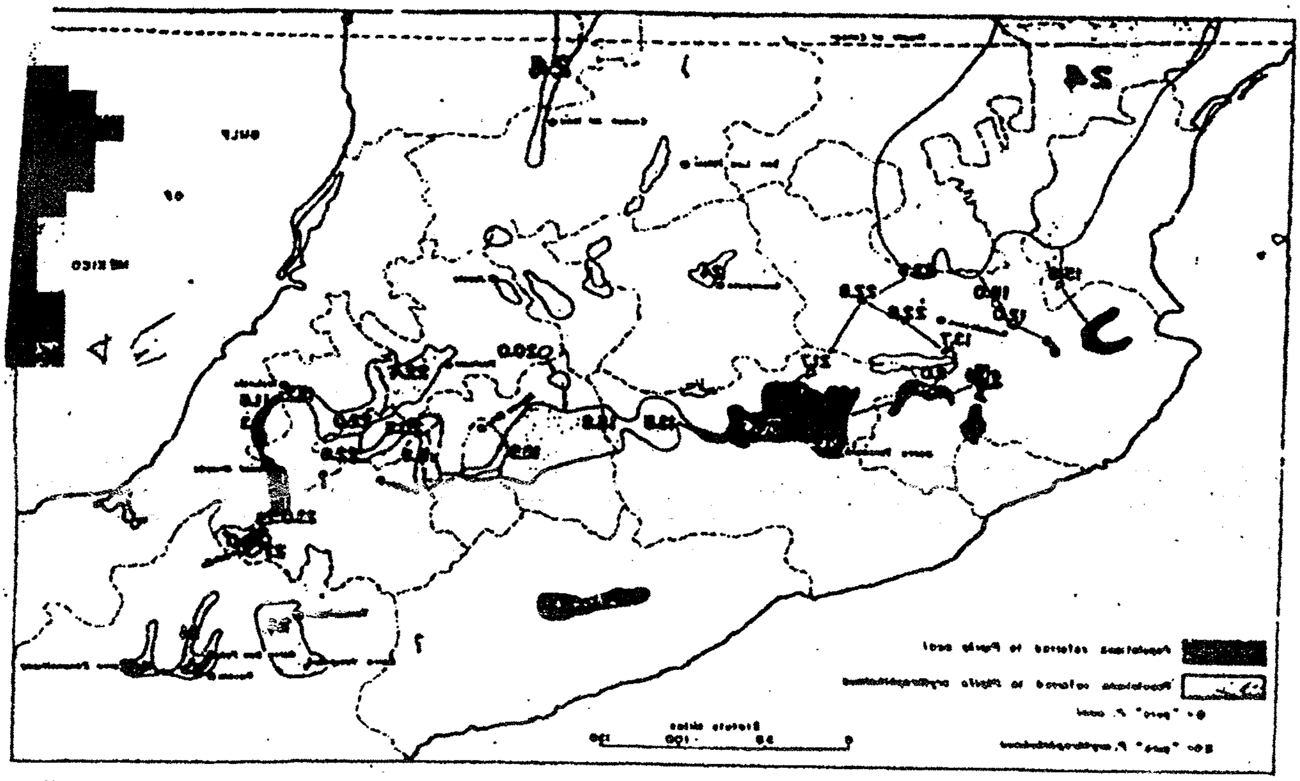

Fig. 9 : Sympatry and hybridization of two species of towhees (pipilo) in Mexico. Pure erythrophihalmus (24) in the north and outheast, pure and (0) in the South and southeast. The numbers (from 0-24) designate the mean character indices of various hybrid populations (from Sibery, 1954)

Further Reading :

1) Principles of systematic Zoology

By Erust Mayr.

2) Principles of Animal Taxonomy

By G.G. Simpson.

3) Theory & Practices of Animal Taxonomy

By V.C. Kapoor.

4) The new systematics

By W.T. Arkell & J.A. Moythomas.

5) The Taxonomic aspect of the species

By C.E. Bessey.

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"Learner's Feed-back"

After going through the Modules / Units please answer the following questionnaire. Cut the portion and send the same to the Directorate.

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