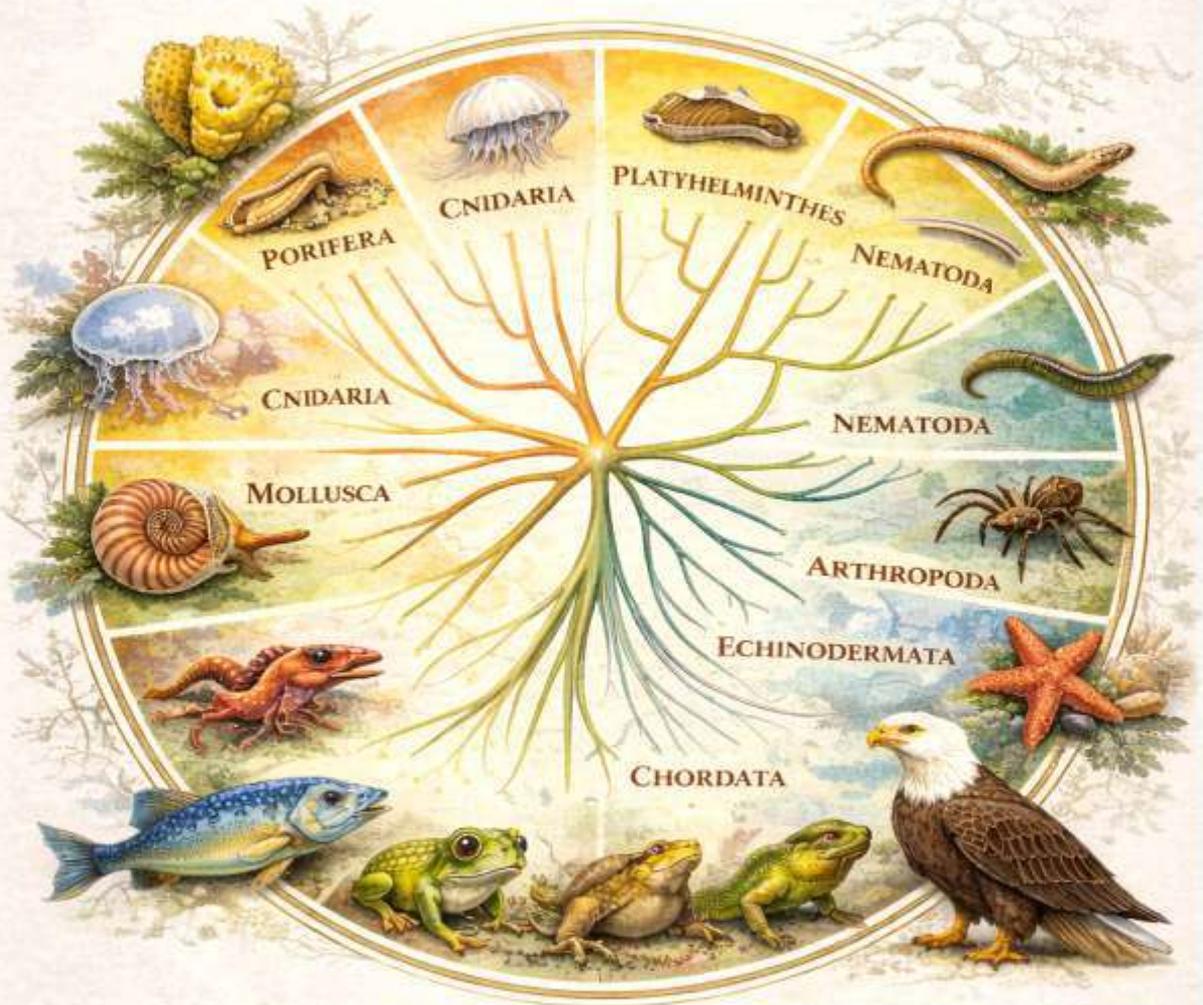


FUNDAMENTALS OF ZOOLOGY



Fish



Ambibiata



Reptile



Bird



Human

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DeepScience

Fundamentals of Zoology

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Published, marketed, and distributed by:

Deep Science Publishing, 2026
USA | UK | India | Turkey
Reg. No. MH-33-0658412
www.deepscienceresearch.com
editor@deepscienceresearch.com
WhatsApp: +91 7977171947

ISBN: 978-93-7185-981-3

E-ISBN: 978-93-7185-245-6

<https://doi.org/10.70593/978-93-7185-245-6>

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Citation: Madhumanti., Khan, S. F., Acharya, S., & Laxmikant., (2026). *Fundamentals of Zoology*. Deep Science Publishing. <https://doi.org/10.70593/978-93-7185-245-6>

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Preface

Zoology is the scientific study of animals- the study of life in all its amazing variety, the intricacy of its structure, the accuracy of its functions, and the continuity of evolution. The animal kingdom includes a magnificent range of organization and adaptation; from the unicellular organisms to highly specialized mammals. The Fundamentals of Zoology has been intended to present the learners with this diversity systematically, coherently and conceptually.

The book is organized in a way that it offers a balanced ground on classical zoology and incorporates the important aspects of the new biological sciences. The introductory units cover animal diversity, starting with non-chordates and then to chordates, thus developing a proper framework of comparative morphology and classification. The focus is made on diagnostic features, evolutionary relationships, and adaptive significance, so the students can see the patterns instead of memorizing the separated facts. The intermediate parts of the text are dealing with cell biology and genetics, and the structural and functional foundation of life. The issues of cell organization, cell division, molecular genetics and inheritance are discussed in a logical order in order to relate structure to functions and mechanism to outcome. The next logical step is developmental biology, which takes students through the processes of gametogenesis, fertilization, and early embryonic development, which demonstrates the process by which complex systems form out of simple ones.

The study of animal physiology is presented in a clear and accurate way, with the description of how organs systems work together to achieve homeostasis. Ecology and evolution are the topics that make the discussion of organism, populations, communities and ecosystems, to emphasize the

interconnections of life. Applied zoology is a final step in the academic process, which shows how knowledge of zoology is applied in the area of agriculture, economy, management of the environment, and human welfare.

Special attention has been given to make sure that ideas are not represented using complicated language in a way that does not affect the scientific integrity. Diagrams are made to improve visualization and facilitate real learning. The practical-based content makes the book conform to the general undergraduate laboratory needs and thus it can be used in academic course work and test preparation.

The intended audience is mostly undergraduate students of zoology and life sciences. Nevertheless, it can also be a valuable source of information to students about to take competitive examinations as well as readers interested in having a systematic introduction to the study of animals.

Zoology is not the study of animals, it is a study of life processes, adaptation, evolution, and ecological balance. Hopefully, this book will capture the interest of people, make them think critically, and appreciate the world of life better.

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UNIT I: Animal Diversity – Non-Chordates

Chapter 1

Principles of Animal Classification

1.1 Scope and Importance of Classification

Zoology starts with an effort to comprehend the enormous variety of the animal kingdom. There is a great variety in size, form, place of life, organization and complexity of animals, which include both microscopic single-celled unicellular animals and highly organized vertebrates. The study of such diversity would be in a chaotic situation without a systematic framework. Animal classification is a means to have that framework, to group organisms into groups, depending upon the same characteristic features and evolutionary connections. It allows biologists to recognize the similarities and differences, trace the lineage relationships, and forecast biological characteristics over the group membership.

Naming is not the only aspect of classification. It involves comparative morphology, embryology, physiology, molecular biology and ecology. When organisms are categorized as groups on the basis of structural and functional similarity, classification can show order of organization and adaptation. These trends are evolutionary and enable scientists to recreate phylogenetic connections. Therefore, classification does not stand still, it changes with the appearance of new evidence based on genetics and molecular research.

The relevance of classification is that it is practical and theoretical. In practice, it helps to communicate between scientists, giving them common names and universally recognized groupings. In theory, it justifies

evolutionary biology through its examples of how different forms emerge out of similar ones. It is also useful in conservation of biodiversity, farming, medicine, and management of the environment; in which precise recognition of species is crucial. Classification thus forms a basis of both zoological studies and an instrument of the practical uses of the biological sciences.

1.2 Foundations of Animal Classification.

The structure and developmental characteristics of animals are used in order to classify them into more complex and developed types. These criteria offer objective criteria of organizing organisms and comprehending their relationships.

Levels of organization

The degree of structure complexity of the body plan in the animals is the level of organization. A single cell is the building block of the body in the simplest forms, e.g. protozoans, where all the vital functions are carried out by the same cell. This is referred to as cellular level of organization. In more complicated groups, the cells are arranged in tissues, tissues in organs and organs in organ systems. The developmental stages of cellular and organ-system levels indicate more and more specialization and efficiency.



Figure 1.1: Figure Showing Levels of Organization in Animals

The figure shows how cellular organization has evolved to become an organ-

system, with increase in structural complexity respectively. It shows the way specialized cells come together to make tissues, tissues coalesce into organs and how organs work in concert with other organs to form organ systems. The analysis of this development points to the evolutionary progress, which demonstrates that more complicated organizations can be divided in order to perform more tasks, coordinate more, and adapt to complex conditions.

Symmetry

Symmetry refers to the pattern of body parts about a central axis. In asymmetrical animals, there is no clear symmetry whereas in radially symmetrical animals, one can partition them into similar halves across several planes running through the middle. Bilateral animals may be categorized into two identical parts along one longitudinal axis. Cephalization, directional motion and environmental response are related to bilateral symmetry, whereby concentration of sense organs is at the anterior part.

Symmetry plays an important role in classification in that it is an indication of evolutionary adaptation. Radial symmetry is generally identified with stagnant or slow moving organisms whereas bilateral symmetry is characterized by movement and increased complexity in the organization.

Germ layers

Animals in embryonic development develop primary layers of cells that are referred to as germ layers. Diploblastic animals have two layers of germ disc, the ectoderm and the endoderm although triploblastic have a third layer the mesoderm. The availability of mesoderm facilitates the development of complex organs and systems in the form of muscles, circulatory structures and excretory organs.

The difference between the diploblastic and triploblastic states is critical as it is a significant milestone in evolutionary terms in terms of structural and functional complexity. The potential of tissue differentiation and organ formation is determined by germ layers.

Body cavity

A fluid filled area between the digestive tract and body wall is referred to as the body cavity, or coelom. Those animals that do not contain a body cavity are called acoelomates. Animals whose false cavity is not lined entirely by mesoderm are pseudocoelomates and those whose false cavity is lined entirely by mesoderm are coelomates. The true coelom enables the organs to move freely, enhance the nutrient distribution, and body size.

The type of body cavity is a big criterion in classification since it will indicate the embryological origin, and also the efficiency of the physiological functioning. The evolution of a coelom can be considered another important step in the evolution of animals.

Segmentation

Segmentation or metamerism is defined as a repetition of similar body parts along longitudinal axis. Segments can be structurally homogeneous (as in annelids and arthropods) or heterogeneous (i.e. differentiated). The process of segmentation increases locomotion and permits regional specialization of body parts.

In a classificatory perspective, segmentation means the evolutionary elaboration of the body organization. It offers the structural plasticity, and facilitates development of specialized appendages and systems.

Table 1.1: Major Criteria Used in Animal Classification

Criterion	Basis	Types / Categories	Significance in Classification
Level of Organization	Degree of structural complexity	Cellular, Tissue, Organ, Organ-system	Indicates evolutionary advancement
Symmetry	Arrangement of body parts	Asymmetrical, Radial, Bilateral	Reflects body plan and lifestyle
Germ Layers	Number of embryonic layers	Diploblastic, Triploblastic	Determines tissue and organ complexity
Body Cavity (Coelom)	Presence of cavity between body wall and gut	Acoelomate, Pseudocoelomate, Coelomate	Important for internal organ development
Segmentation	Repetition of body segments	Metameric or Non-metameric	Indicates structural specialization
Presence of Notochord	Supporting rod-like structure	Present or Absent	Separates Chordates from Non-chordates

This table illustrates the main structural and developmental criteria used in grouping animals such as level of organization, symmetry, germ layers, body cavity, segmentation and the existence of notochord. These criteria, as

interpreted, demonstrate that classification is based on observable biologic characteristics, which are related to evolutionary patterns. All these criteria are indicative of greater complexity, which gives taxonomists the opportunity to organize animals in a continuum of structural development.

The classification and nomenclature The taxonomic hierarchy of the genus and species is presented in the following:

The hierarchical system of categories is used in classification in order to arrange animals in a systematic manner. These groups have general groupings which include numerous organisms up to certain groups which identify individual species. The major ranks are kingdom, phylum, class, order, family, genus and species. The higher order is a more specific grouping, which is defined by shared characteristics.

The common element of classification in terms of classification is the species. Species members have similar morphological dimensions and they can produce offspring by means of interbreeding. The genus groups are ones that bring close related species together whereas higher categories are organisms that are united by more general similarity in terms of structure and growth.

Naming is based on the binomial nomenclature system according to which a species is given a two-part Latinized name. The former refers to the genus and the latter represents the species. This system will provide uniformity which will avoid confusion due to regional common names. Standardized nomenclature fosters the sense of clarity in science communication and interaction on the global level.

There are also evolutionary relationships in the hierarchical structure. The organisms that are within the same genus are of a more recent common ancestor compared to those that are in the same class or phylum. Therefore,

not only does taxonomy organize the diversity, but taxonomy also provides phylogenetic information.

1.4 Current Standards of Classification.

Conventional classification used morphological and anatomical characteristics as a very strong feature. Although these criteria are still significant, recent methods are using molecular and genetic evidence to define evolutionary relationships with more specific accuracy. With improvements in the field of DNA sequencing, taxonomy has become a more objective and data-driven field.

Molecular taxonomy is the comparison of genetic sequence between organisms. Such comparisons demonstrate evolutionary distances and help us to see the relationships that could not be perceived through the morphology alone. As an illustration, two organisms that look superficially homogenous can be genetically distantly related, whereas two organisms with quite different external characteristics can be closely related.

Another contemporary technique is called cladistics that categorizes organisms according to common derived traits or synapomorphies. Cladistics focuses on shared ancestry, as it uses the creation of branching diagrams that reflect evolutionary paths and not necessarily similarity. This method has caused revision of several conventional groupings, with classification now being closer to evolutionary history.

The phylogenetic classification combines the evidence of fossils, embryologic facts and molecular information in order to establish the evolutionary lineages. The dynamic approach recognizes that classification is not static but it is subject to development with ongoing discoveries helping us to improve our knowledge of the history of life.

Current classification is therefore a combination of the classical morphology and the modern molecular biology. It enriches the predictive ability of the taxonomy and improves our comprehension of biodiversity, adaptation and evolution. The combination of genetic analysis and structural observation makes zoology keep polishing their system of organizing the animal kingdom.

Summary of the Chapter

The chapter forms the basis of animal classification. It justifies the need to systematize biological diversity to make it easy to study and comprehend. The application and significance of classification is not only limited to the scholarly literature, but also to the application of classification to the field of biodiversity conservation and applied sciences. The chapter describes the main criteria of classification, the levels of organization, symmetry, the germ layers, body cavity, and segmentation, each of which represents the evolutionary progress. It also describes the level of hierarchical organization of taxonomy and the place of binomial nomenclature in providing scientific uniformity. Lastly, it points out contemporary methods involving the use of molecular and phylogenetic data showing that classification is an active and changing science based on morphology or genetics.

Review Questions

1. Elaborate on what is meant by animal classification and its importance in a study of zoology.
2. Explain the levels of organization that occur in animals.
3. Explain what the different symmetries are and what evolutionary significance they have.
4. Compare diploblastic and triploblast animals.

5. Provide information as to what body cavities in animals are, and what is their importance.
6. What is segmentation? Speak about its contribution to the evolution of animals.
7. Describe the great taxonomic groupings in that order.
8. Explain the rules of binomial nomenclature.
9. Discuss ways in which molecular data have helped in the contemporary classification.
10. Explain the significance of the phylogenetic classification as a means to learn more about the evolutionary relation.

Chapter 2: Phylum Protozoa and Porifera

2.1 General Characters and Classification of Protozoa

Protozoa are one of the simplest and the most basic forms of animal life. They are mostly single cell, microscopic organisms, which carry out all the essential processes in life in one cell. Protozoans are remarkably complex in their functionality, although their bodies are very simple in the structure. Nutrition, respiration, excretion, locomotion and reproduction are performed by the independent cells. This cell independence no longer compares protozoa to multicellular organisms but points out the effectiveness of cellular organization on the most basic of scales.

Protozoa are not only aquatic but also live in freshwater, marine habitat or in some cases, damp land. Some of them are free-living and others are parasitic and can bring diseases to the human beings and other animals. Protozoans are not organized to any actual tissue degree structurally. It is enclosed in a plasma membrane or pellicle, and their cytoplasm is differentiated into ectoplasm and endoplasm in most forms. Developments of organelles include specialized organelles like contractile vacuoles, which are involved in the maintenance of osmotic balance, and food vacuoles, which are involved in digestion.

Protozoa nutrition can be in some form holozoic, saprozoic, parasitic or autotrophic. The diffusion across the cell surface is the way respiration and excretion takes place. One factor is irritability, which is an ability to react to stimuli of the environment, and this quality of protozoans is well-developed because of the presence of special structures, e.g., eyespots or sensitive membranes.

Protozoa are mostly classified according to locomotor structures and mode of life. Their traditionally known major classes are Sarcodina (locomotion by pseudopodia), Mastigophora (locomotion by flagella), Ciliophora (locomotion by cilia) and Sporozoa (non-motile and largely parasitic forms). Even though the modern molecular studies have redefined protozoan taxonomy, such classical groupings are still pedagogically viable when it comes to the structural diversity and functional adaptation. The classification focuses on the evolutionary experimentation at the unicellular level where different types of locomotion and nutrition evolved in one cell.

2.2 Movement and reproduction in the Protozoa.

Protozoa movement is realized by means of specialized extensions of the cytoplasm or organelles. Pseudopodia are temporary extensions of the cytoplasm which are utilized in movement and feeding. They facilitate food absorption by the organism by phagocytosis. The flagella are whip structures that are long in nature and are used to move the organism in fluid places. Cilia are projections, which are hairs short in length, and beat in a rhythmic motion in coordinated patterns offering efficient and fast movement.

It is not only the locomotory organelle type that has an effect on mobility but it also affects ecological adaptation. Pseudopodian organisms are usually not fast moving and can shift their shape and therefore live in changing environments. Form flagellated It is a form adapted to the aquatic environment where it is more likely to survive by active swimming. The ciliated protozoans are highly coordinated and have intricate feeding processes thus showing a high degree of cellular specialization. Therefore, locomotion in protozoa shows how cellular-level structural changes result in functional diversity.

Protozoa reproduce primarily asexually by binary fission, multiple fission or budding. Binary fission refers to splitting up of one parent cell to two identical daughter cells. There are several fission which have many offspring at once and in most cases in favorable conditions. Certain protozoans also have sexual activity like conjugation which entails genetic material exchange between individuals. This interaction increases genetic diversity and versatility.

The protozoa have been successful in their evolutionary endeavors reproductively. Asexual reproduction allows rapid population growth because of rapid asexual reproduction, and genetic variations are also introduced by the occasional sexual processes. A combination of these processes makes protozoa survive in changing environments and adds to the ecological importance of protozoa in aquatic food webs and nutrient cycles.

2.3 General Characters of Porifera

Porifera or sponges are the simplest multicellular organisms. They are cellular in nature unlike protozoa; however, there are no real tissues or organs. The sponge has a porous body which has multiple holes known as ostia where water enters the body. The water leaves the body through a larger hole, the osculum. The wall of the body contains a cavity in the center which is called the spongocoel.

There are mostly marine sponges, but a few freshwater sponges. They are the sessile organisms, and they are attached permanently to the substrata like rocks or the coral reefs. They do not have definite organs in their asymmetrical bodies or radially symmetrical bodies, but functional cells do specific duties. The internal chambers are lined by the choanocytes or collar cells which produce water currents. Such currents support feeding, respiration and excretion.

Sponge nutrition is a holozoic one, and food particles are filtered by water. The active circulation of water also provides effective gas exchange and wastes get eliminated. The skeletal structure is made of calcareous or siliceous spicules or spongin fibers which offer structural support. The ease with which sponges can develop indicates a kind of developmental primitive multicellular evolution in which there was cellular specialization without actual formation of tissues.

The canal system and skeleton of sponges are explained in relation to those of other animals.

The canal system is characteristic of the sponges and it is an evolution innovation that improves the efficiency of feeding. This is a system made up of water channels which enable constant flow throughout the body. There are three major types of canal systems identified as asconoid, syconoid, and leuconoid depending on the level of complexity.

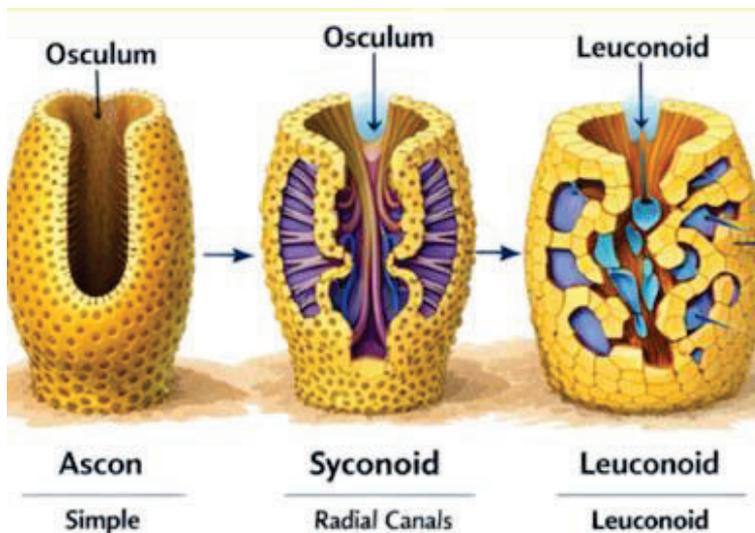


Figure 2.1: Types of Canal Systems in Porifera

The figure illustrates the structural disparity between asconoid, syconoid and leuconoid canal systems. It explains the idea of the complexity which results in the higher surface area of choanocytes and higher effectiveness of filtration. The explanation of this sequence shows the tendency of evolution to greater feeding ability and increased body size. The sponge is capable of absorbing more water as the canal system gets more advanced and hence more nutrients and chances of survival.

Asconoid type is the most simple type, and the water flows directly through ostia to the spongocoel. In the syconoid type, the body wall is curved creating radial canals which multiply surface area. The leuconoid one has a very more complicated system of flagellated chambers and canals, the most sophisticated and efficient form of the flagellated.

The bones of sponges ensure support and protection. It can be made of microscopic spicules of calcium carbonate or silica, or of elastic spongin fibres. The classification of Porifera is based on the type of skeletal material. The body shape is not only maintained by the skeletal structure but also the skeletal structure guards against predation and other environmental forces.

Reproduction and Development: The porifera reproduce using multicellular methods that are akin to those of annelids (worms).

Sponges multiply asexually and sexually. Asexual reproduction is by budding, fragmentation or through the formation of gemmules. The process of growth of a new person out of the parent body is known as budding. With fragmentation, separated fragments are able to form whole organisms through regeneration. The gemmules are hardened resistant structures that are developed under poor environmental conditions, which ensure survival in the environment of stress.

The reproductive mode in the sponges is usually hermaphroditic in which individuals can also produce both sperm and eggs at varying times. Fertilization is normally internal as it takes place inside the body cavity. The zygote will grow to form a free-swimming larva, which later settles and grows to be a sessile adult. The life cycle of the larva is a means of dispersion and hence colonization of a new habitat.

Reproductive versatility of sponges indicates its flexibility in spite of structural simplicity. Asexual reproduction allows the speedy increase of the local population, whereas sexual reproduction initiates a gene variation and ensures long-term survival. Life cycle of Porifera is therefore indicative of balancing between stability and adaptability which is typical to early multicellular organisms.

Summary of Chapter

Chapter 2 also introduces two basic groups which constitute the earliest stages in the evolution of the animal life: Protozoa and Porifera. Protozoa are unicellular organisms whose organization is at the level of cells, all the vital functions are carried out by a single cell. Their simplicity does not mean that they lack functional specialization, as they have organelles that help in locomotion, nutrition, excretion and reproduction. Their classification is mainly determined by locomotory structures in the form of pseudopodia, flagella and cilia which are variations of structural diversity in a unicellular structure. Asexual modes of reproduction dominate in protozoa, although some of them have sexual reproduction that promotes genetic variation and adaptability.

Porifera are the most simple multicellular organisms, and are characterized by cellular level of organization, lack of actual tissues or organs. The resistant body system and canal system ensure that they feed on filters,

breathe and release wastes. The growing sophistication of canal systems as asconoid, syconoid, and leuconoid canals reflect the evolution to the efficiency level. The support and protection is done by the skeletal structure made of spicules or spongin fibers. There are both asexual and sexual reproduction, and the colonization and dispersion are guaranteed by the larval stages. Protozoa and Porifera in combination illustrate the unicellular to multicellular change, the first steps to the evolution of animals.

Review Questions

1. Elaborate on the overall aspects of Protozoa.
2. Discuss the principles of Protozoa classification.
3. Describe the various forms of locomotion of Protozoa.
4. Explain the survival through the different types of reproduction in Protozoa.
5. Summary the overall characters of Porifera.
6. Describe the canal system of the sponges.
7. Distinguish asconoid, syconoid and leuconoid canal systems.
8. Explain the skeletal structures of Porifida and how they are important.
9. Talk about asexual reproduction in sponges.
10. Demonstrate the sexual reproduction and larval development in Porifera.

Chapter 3

Phylum Coelenterata to Annelida

3.1 General Characters of Cnidaria

Cnidaria or Coelenterata is one of the oldest multicellular animal lineages with a tissue-level organization. These are primarily aquatic and almost solely marine, having some freshwater representatives. They are radially symmetrical with diploblastic bodies comprising of a pair of primary germ layers (the ectoderm and endoderm) which are separated by a non-cellular mesoglea. It is a sign of an early stage of evolution but in this context, Cnidarians have specialization.

Cnidaria are characterized by the occurrence of specialized cells of stinging called cnidocytes that harbor nematocysts. The structures serve the purpose of capturing prey, defense, and anchoring. The body is normally found in two morphological forms, namely polyp and medusa. The polyp is a sessile and cylindrical polyp where the mouth faces the sky, whereas the medusa is free swimming and umbrella shaped.

Cnidarians have a gastrovascular cavity having a single opening that caters to ingestion and egestion. Their body plan is relatively simple as evidenced by the absence of a complete digestive tract. Nonetheless, the existence of a nerve net is one of the precursors of nervous coordination. Reproduction can be both asexual and sexual, and it can be polyp and medusa alternations. All these traits demonstrate how the cellular organization evolves into the tissue-level of organization in the evolution of animals.

3.2 Polymorphism in Cnidaria

Polymorphism is a phenomenon whereby there are more than one structural or operational type of individual of one species. Polymorphism in Cnidaria is

particularly pronounced in the context of colonial species that can be exploited to carry out highly specific functions by a variety of zooids. As an example, some polyps are adapted to feed, others procreate, and others defend themselves. This division of labor improves the efficiency of the colony to survive.

Polymorphism is also evident in most hydrozoans in the form of polyp and medusa stages in the life cycle. The polyp phase commonly asexually reproduces producing medusae then proceeds to sexual reproduction. This interchangeability of forms assures of a rapid and genetic variation. The evolutionary importance of polymorphism is the greater adaptation and specialization without reducing structural simplicity.

Polymorphism illustrates that functional complexity can be accomplished even by relatively simple organisms by differentiation. It is an early form of division of labor, a concept which is more perfected in higher animal groups.

3.3 Characteristic features of the Platyhelminthes.

Platyhelminthes, also referred to as flatworms, are bilaterally symmetric and triploblastic in nature. They have three germ layers (ectoderm, mesoderm and endoderm) in contrast to Cnidarians, which enable the functions of more complex tissues and organs to form. Nevertheless, they are acoelomates, which do not have a real body cavity. The gap between the digestive tract and the body wall is occupied by either mesenchymes or parenchymes tissue.

The body of the flatworms is dorsoventrally flattened; this allows the organism to facilitate diffusion of gases and nutrients because this organism lacks a circulatory system. The digestive system is immature and there is only one hole that doubles up as a mouth and anus. In parasites, such as tapeworms, the digestive tract can completely be lost, and the nutrients are taken up through the body surface.

The process of excretion is done through flame cells, which create a primitive excretory system referred to as protonephridia. The nervous system is made of a ladder structure comprising nerve cords of longitudinal pattern. Most platyhelminths are hermaphroditic and have both male and female reproductive organs. Evolutionary specialization to survive in the host organism is manifested in parasitic adaptations in the form of hooks, suckers, and resistant egg shells. The change of radial to bilateral symmetry of this phylum is very important evolutionary development.

3.4 Nematoda Characteristics.

Nematodes (also known as roundworms) are bilaterian, triploblastic and pseudocoelomate. An intermediate in the evolution of body cavities is the occurrence of a pseudocoel, a body cavity which is not entirely lined by mesoderm. This pore acts as a hydrostatic skeleton, which allows movement and internal distribution of nutrients.

Nematodes have an elongated and cylindrical body with no segments with a tough cuticle that shields it against adverse environmental factors. In comparison with the flatworms the nematodes have a full digestive system consisting of distinct mouth and anus which is a higher form of organisation. Such an organization of the structure enables food continuous processing and effective digestion.

Excretory system is simple, and in most cases, it comprises of gland cells or canals. The pharynx and longitudinal nerve cords are encircled by a nerve ring which is part of the nervous system. The reproduction is usually sexual and sexes are distinct and sexual dimorphism is also widely prevalent. Most nematodes are free-living and some are parasitic, attacking plants, animals and humans. The progressive structural complexity in the development of a

complete digestive tract and pseudocoel reflects development of structural complexity in comparison to previous phyla.

3.5 General Organization of Annelida.

Annelids are a significant developmental breakthrough, which has seen the development of actual coelom and segmentation. They are bilaterally symmetrical, triploblastic and coelomate animals. The organism is broken into repetitive parts or metameres, with septa in between. Segmentation is more flexible, locomotion is efficient and specialization is regional.

The existence of a real coelom entirely lined by mesoderm facilitates the movement of internal organs independently and a closed circulatory system. The digestive system is complete and has designated areas of ingestion, digestion and absorption. The circulatory system is highly developed and it provides an easy movement of oxygen and nutrients.

The excretory system comprises of segmented nephridia. There is advanced coordination in the nervous system as it has a dorsal brain and a ventral nerve cord that contains segmental ganglia. The process of respiration takes place at the surface of the body or specific structures like gills in certain forms. It can be sexual or asexual and most of the annelids are hermaphrodites.

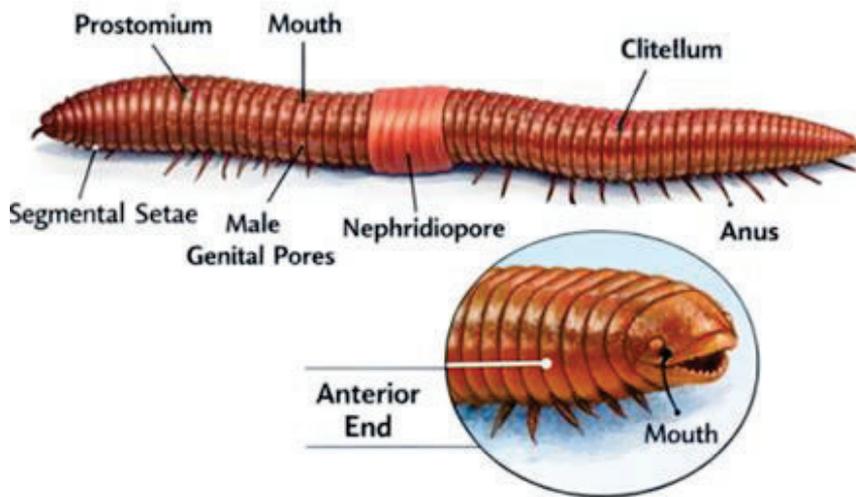


Figure 3.1: External Morphology of Earthworm

The figure illustrates the body segmentation of an earthworm, the presence of which features the prostomium, clitellum, setae and the body segmentation. This morphology is interpreted with regard to the functional value of segmentation in locomotion and specialization. The clitellum denotes the reproductive maturity, and setae anchor movement. This exogenous organism captures the combination of segmentation, coelom growth and the complexity of organ-systems that characterize the annelids relative to the previous phyla.

The evolutionary path of Cnidaria in Platyhelminthes and Nematoda towards Annelida depicts an evolutionary pattern. This is the shift to bilateral symmetry, to triploblastic organization, to the presence of body cavity, to segmented body plans, and the absence of body cavity, triploblastic organization, and unsegmented body plans. The structuring differentiation and efficiency of each successive phylum indicate the evolutionary progression of the animal kingdom.

Summary of Chapter

Chapter 3 follows the evolutionary path of the development of tissue-level organization in Cnidaria to the complex segmented body plan of Annelida. Cnidarians are animals which are diploblastic, radially symmetrical with cnidocytes and a gastrovascular cavity. Their polymorphism and alternation of generation depicts their early functional specialization over a simple body plan. Platyhelminth transition brings about bilateral symmetry and triploblastic structure, which allows more complex tissues and organ systems to be formed, but there is no actual body cavity.

Nematodes are an additional step for having a pseudocoel and full digestive system, which signify enhanced physiological efficiency. The hydrostatic skeleton with the protective cuticle leads to the improvement of adaptation to various environments. Annelids represent a significant evolutionary milestone in the formation of true coelom, segmentation, closed circulation system, and organization of organ-systems. The specialization of the body and the efficient locomotion are made possible by segmented body plan. Generally, the chapter identifies an explicit evolutionary pattern, that is, growing structural sophistication, creation of body cavities, the development of segmentation, and streamlining of organ systems.

Review Questions

1. Write about the overall morphologies of Cnidaria.
2. describe polymorphism Cnidaria using appropriate examples.
3. Write about the salient characteristics of Platyhelminthes.
4. Elaborate on the structure of Nematoda.
5. Distinguish between acoelomate, pseudocoelomate and coelomate.
6. Discuss the meaning of bilateral symmetry in the evolution of animals.

7. Explain how Annelida is generally organized.
8. Talk about the benefits of segmentation among the annelids.
9. Compare digestive system of the Platyhelminthes and Nematoda.
10. Follow the evolutionary development of Cnidaria to Annelida.

Chapter 4

Phylum Arthropoda and Mollusca

4.1 General Characters and Classification of Arthropoda

Arthropoda is the most diverse and largest phylum of the animal kingdom, which is an astounding diversity of structure and domination of the ecology. The animals of this phylum are triploblastic, bilaterian and segmented and coelomate. Arthropods have the most peculiar characteristic of being jointed appendages, which are flexible and efficient in locomotion, feeding and sensory perception. The body is generally broken down into head, thorax and abdomen or cephalothorax and abdomen, in some groups.

The body is enclosed in a chitinous exoskeleton that helps in providing the body with protection and structural support. To grow this hard shell has to be periodically shed in a process called molting or ecdysis. The existence of exoskeleton is a significant evolutionary development, which decreases water loss and provides mechanical strength, which has gone a long way in the land success of arthropods.

The organization in arthropods is well-developed at the level of organization of an organ-system. The digestive system is complete and the method of respiration is gill, tracheae or book lungs according to the habitat. The circulatory system is open as the hemolymph is in the body cavities. The nervous system consists of the dorsal brain and the ventral nerve cord that has segmental ganglia, which helps in advanced behavioral and sensory reactions.

Arthropoda classification is done in terms of division of the body, the type of appendages and the mode of respiration. The major classes are Insecta, Arachnida, Crustacea and Myriapoda. Insects are two-legged with pairs,

arachnids have four legs and have no antennae, crustaceans are mainly aquatic with two pairs of antennae and myriapods have multiple segments of the body and many legs. Such classification is a result of adaptive radiation, in which structural changes have allowed arthropods to be in almost every ecological niche.

4.2 Metamorphosis and Economic significance of Arthropods.

Metamorphosis is an extraordinary biological process in much arthropods especially insects. It is characterized by different developmental stages that are morphologically and functionally different. In total metamorphosis, the stages of development are egg, larva, pupa and adult. The larval form is adapted to feeding and growth whereas the adult form is adapted to reproduction and dispersion. In incomplete metamorphosis, there are egg, nymph and adult stages and the nymph is similar to a diminutive adult.

Metamorphosis is an evolutionary solution which minimizes the competition between juvenile and adult forms of competition by enabling the juvenile and adult forms to colonize different ecological niches. It improves survival and reproductive success by various functional roles partitioning across developmental stages.

Arthropods are highly economically significant. The importance of insects is that many of them are pollinators, which leads to agricultural output and stability of the ecosystems. Silkworms give a product known as silk, whereas honeybees give honey and wax. The crustaceans constitute a key part of the world fisheries. Nevertheless, some arthropods are agricultural pests, which destroy agricultural crops and preserved grains. Others are the vectors of human and animal diseases. The ecological and practical importance of arthropods is both positive and negative, hence their economic contribution to the environment.

4.3 Mollusca Characters in General.

The second largest animal phylum is Mollusca which consists of diverse soft-bodied non-segmented animals with coelomia. Molluscs are bilaterian and triploblastic, but most have secondary asymmetry brought about by developmental changes. The body is usually split into head, muscular foot and visceral mass. It has a unique characteristic in its mantle which is a fold of a tissue which secret a calcareous shell in most species.

Depending on the species, the muscular foot is adapted either as locomotile, burrowing, or attaching. Internal organs are located within the visceral mass, and they include digestive, circulatory and reproductive systems. The majority of molluscs have a radula, a feeding organ, a rasp. In bivalves however, there is no radula and the feeding takes place by filter mechanisms.

In aquatic species the process of respiration takes place by means of gills and in the terrestrial species by means of a lung-like system. The circulatory system is typically open but the cephalopods have a closed system. Nervous system is different with single ganglia to highly developed brains in high evolved animals such as octopuses.

Mollusca are classified according to the shell structure, body form and complexity. During the major classes, it consists of Gastropoda, Bivalvia, and Cephalopoda. Gastropods normally contain one coiled shell, bivalves contain two shell valves, and cephalopods contain complex nervous systems and tentacles. The Molluscs exhibit adaptive diversification, with a presence in the marine, freshwater and terrestrial environments.

4.4 Structure and Torsion of the Mollusca.

Mollusc has a basic structural plan which consists of a mantle cavity which contains gills, openings of excretory and reproductive systems. The shell is

secreted by the mantle, and can either be external or internal or nonexistent. The coelom is diminished and it is mostly connected with the pericardial cavity and the gonads.

Another distinct feature of gastropods is torsion which is a process of development where the visceral mass spins 180 degrees as the larva develops. Due to this the mantle cavity and anus lie in front of the head. The benefit of torsion is considered to be defensive in nature because it enables the head to swiftly withdraw into the mantle cavity. Nonetheless, it also brings about some structural asymmetries.

The concept of torsion is used to understand how developmental adjustments may cause major shifts in body structure. It is an evolutionary adaptation that will increase survival, although it distorts the original bilateral symmetry of the organism. These two features of molluscan construction (molluscan structure and torsion) exhibit conservation of basic body plan and adaptive innovation.

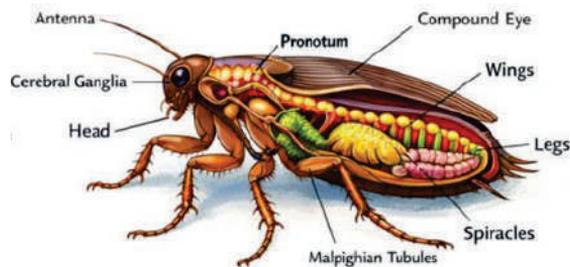


Figure 4.1: Generalized Body Plan of Cockroach

This figure illustrates the body segmentation of an average arthropod which is partitioned into a head, thorax, and abdomen, with jointed appendages being joined to particular parts. It emphasizes aspects like antennae, compound eyes, wings, legs and abdominal segments. This body plan

interpretation demonstrates how the segmentation and specialization of appendages assist in providing efficient locomotion, sensory perception as well as adaptability. The arthropod evolutionary specialization presents in the differentiation of body parts presupposes the functional division as well as preserves the structural wholeness.

Summary of the Chapter

This chapter discusses two of the most versatile and most successful phyla of animals Arthropoda and Mollusca. Arthropods are characterised by a segmented body, jointed extremities and a chitinous shell which are the features that have helped them conquer a vast diversity of terrestrial, aquatic and aerial environments. They are organized in their organ-system level that has full digestive tract, open circulatory system, special respiratory structures and a well-developed nervous system. The group in the phylum is based on structural change related to adaptation resulting in large groups like insects, arachnids, crustaceans and myriapods. Metamorphosis is a pronounced biological scheme dividing the stages of development into different functional stages, decreasing the competition of the species and increasing the survival. Arthropods play significant roles with respect to ecology and economics both as useful bees in the production of resources and as harmful pests and vectors of disease.

The arthropods exhibit striking adaptive diversity, but there is also evidence of striking adaptive diversity in the Molluscs, which are structurally distinct. Their unsegmented bodies are soft and arranged into head, muscular foot, and visceral mass and the mantle frequently secretes a protective shell. Ecological specialization is manifested through differences in feeding, respiration as well as complexity of the nervous system in marine, freshwater and terrestrial environments. An example where evolutionary changes can

cause changes in the body position and enhance survival merits is the developmental phenomenon of torsion in gastropods. These two phyla are examples of structural innovations in exoskeleton, jointed appendages, mantles, and torsion, which lead to functional efficiency and evolution in the animal world.

Review Questions

1. Explain the overall features of Phylum Arthropoda.
2. Explain the structural characteristics that make arthropods successful in their evolution.
3. describe how Arthropoda is classified using distinguishing characteristics of major classes.
4. Explain metamorphosis and the various types of metamorphosis (complete and incomplete).
5. To explain the economic significance of arthropods, appropriate examples.
6. Discuss the overall representations of Phylum Mollusca.
7. State structure and functions of the mantle and muscular foot in molluscs.
8. Inclusively describe how Mollusca can be classified by major classes.
9. Explain torsion in gastropods and how it has evolved.
10. Compare complexity of organization of Arthropoda and Mollusca.

UNIT II: Animal Diversity – Chordates

Chapter 5

General Characters and Classification of Chordates

5.1 Origin and General Features of Chordates

Chordates are an advanced and evolutionary group of animals. They consist of a great variety of organisms, the simplest ones to the most sophisticated vertebrates, including human beings. A common evolutionary ancestry can be observed in the defining characteristics of chordates appearing somewhere in their life cycle. Chordates study is essential in the development of vertebrates, structural specialization as well as functional integration at organ-system level.

The derivation of chordates is a topic which has received a lot of scientific research. There is comparative embryological, molecular biology, and paleontological evidence that the chordates have invertebrate ancestors, and may have a common ancestor with echinoderms. Early chordates must have had bilateral symmetry which was simple, a dorsal support apparatus, and openings on their hornworm which supported filter feeding. These primitive features evolved and became specialized through modification over time which resulted in the various chordate lineages over evolutionary time.

Chordates are bilaterally symmetrical triploblastic with coelomate animals. In the vast majority of advanced forms they are organ-system level and closed circulatory. The main characteristics that differentiate chordates and non-chordates are a post-anal tail, pharyngeal gill slits, a dorsal hollow nerve cord and a notochord. These features might only occur during embryonic

development in higher vertebrates but their occurrence at any stage of life is a sure way to identify chordates.

Cephalization, internal skeleton, and the ability to have an efficient circulatory system and nervous system enabled chordates to attain structural complexity and ecological adaptability. The support did not limit development as the exoskeleton of arthropods did because it had an endoskeleton. The development of large body size and complicated locomotor mechanisms were supported by this structural advantage.

Chordates have various habitats such as marine, freshwater, terrestrial and aerial. Their evolution is evolutionary flexibility and structural refinement as evidenced by their adaptive radiation. The origin and overall characteristics of the chordates are thus a major evolutionary step in that they signify the shift to a more complex and specialized animal kingdom.

5.2 Nerve Cord, Gill Slits and Notochord.

A notochord is a pliable rod-shaped structure that is located by the back part of the body between the digestive tract and the nerve cord. It supports axially and acts as an early skeletal component. In lower chordates, the notochord continues to exist throughout life whereas in vertebrates it gets substituted by the vertebral column in development. The morphological importance of the notochord is that it served as a structural basis on which the vertebral column was evolved. It facilitates effective attachment of muscles and coordination.

Another characteristic of the chordates is the dorsal hollow nerve cord. It is located over the notochord and forms the central nervous system in vertebrates over which becomes the brain and the spinal cord. Chordates and non-chordates are differentiated by the dorsal location and hollowness of the nerve cord which are usually centrally located and ventral in nature. The evolution of a central nervous system stimulates the sense of perception,

coordination, and reaction to the external stimuli. This organizational pattern leads to developed patterns of behavior and adaptive ability.

Gill slits in the pharynx are apertures in the lateral walls of the pharynx. These slits are used in the respiration of aquatic chordates, to enable the water to flow over breathing surfaces. In vertebrates living on land, they present themselves in the embryo and they are later translated into the ear-related and throat-related structures. The fact that it has gill slits suggests an evolutionary relationship with water ancestors, and the adaptation of the early chordates to water filter feeding and respiration.

The notochord, dorsal hollow nerve cord and the pharyngeal gill slits are these three features that constitute the structural basis of the chordate body plan. They however depict how evolutionary adaptations of simple structures can bring about different functional adaptations to more complex vertebrates.

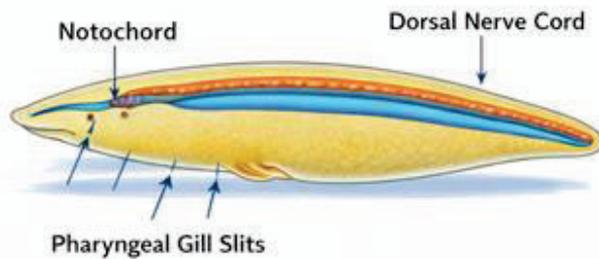


Figure 5.1: Basic Chordate Body Plan

The illustration shows structural organization of a chordate in fundamentals with dorsal hollow nerve cord, notochord, pharyngeal gill slits, post-anal tail and coelomic cavity. It gives the visual representation of the spatial layout of these defining features in the longitudinal axis of the body. This body plan is explained with an emphasis on the continuity of evolution, in which the exact core structures are the blueprint to the development of the vertebrates.

The coordination of the support, nervous system, respiratory apertures indicates fusion of structure-function which forms the basis of chordate complexity.

5.3 Subphyla of Chordata

The phylum Chordata consists of three large subphyla regarding the conservation and evolution of features of the chordate: Urochordata, Cephalochordata, and Vertebrata.

One of the marine organisms in the Urochordata or Tunicata is the ascidians. Chordate characteristics can only be found in the larval stage of these animals. The larva has a notochord and dorsal nerve cord which are lost in metamorphosis into an adult form. The adult usually is sessile and is enclosed in a tunic made up of tunicin. The existence of chordate characteristics during the larval stage is an indication that urochordates have retained the evolutionary structures, a source of information on the evolution of the chordates.

Amphioxus is an example of organisms in Cephalochordata. In these forms, the notochord runs the entire length of the body and continues to be present as long as one lives. Pharyngeal gills slits and the dorsal nerve cord are well developed. Cephalochordates are an intermediate between invertebrates and vertebrates having the primitive chordate features with bilateral symmetry, and segmented muscles.

The most advanced subphylum, Vertebrata, is defined by the fact that as they grow they have replaced the notochord with a vertebral column. Vertebrates have a highly developed brain which is enclosed in a cranium, two limbs and well-developed organs. Formation of a vertebral column offered greater security to the spinal cord as well as structural support. Vertebrates exhibit a

high level of adaptive radiation and are distributed in almost all ecological niches.

The comparable subdivision of chordates into subphyla indicates more and more structural complexity and specialization. It shows the evolutionary path of simple marine filter feeders to highly organized vertebrates with the ability of complex behaviors and domination.

5.4 Classification of Vertebrata.

There are major classes of vertebrates which are determined in terms of morphology, physiology and reproductive. These are Pisces, Amphibia, Reptilia, Aves and Mammalia.

Pisces or fishes are mainly aquatic vertebrates that breathe by gills and swim by the use of fins. They are streamlined with scales all over. Amphibia are the transition to terrestrial life and have the dual mode of respiration and undergo metamorphosis. Reptilia are mainly terrestrial vertebrates where the skin and shelled eggs are dry and scaly thus adapted to land reproduction. Feathers, wings and endothermy which allow flight and thermoregulation characterize Aves. Advanced physiological regulation and parental care is seen in mammalia which have hair, mammary glands as well as well-developed nervous systems.

The outline classification of the vertebrates indicates adaptation to different environments in a progressive manner. The inclusion of structural changes like lungs, limbs, feathers and mammary glands are the evolutionary innovations, which increase survival. Vertebrate classification analysis indicates the patterns of divergence and specialization based on the primitive chordate body plan.

The chordates with all their distinguishing features and evolutionary variability represent an example of a structural integration and adaptive complexity among the animals.

Summary of the Chapter

The chapter provides the basic features and classification of chordates which is a highly developed and evolutionarily important group in the animal kingdom. It starts with a study of the origin and the character of chordates highlighting their triploblastic, bilaterally symmetrical and coelomate structure. The existence of a notochord, dorsal hollow nerve cord, pharyngeal gill slits, and a post-anal tail at some point in the development characterizes chordates compared to all other animal groups. These aspects are some of the major evolutionary innovations that formed the basis of the complex vertebrate and ecological success.

The chapter also describes the structural and functional significance of the notochord, nerve cord and gill slits with regard to their evolutionary change in higher vertebrates. The notochord forms the precursor of the vertebral column, the dorsal hollow nerve cord forms the central nervous system, and the pharyngeal gill slits are suggestive of the water origin of the group. A combination of these features leads to the primitive chordate body plan upon which the structure of all vertebrates is based.

The specialization and progressive complexity of structure can be understood in terms of the division of Chordata into three subphyla, namely Urochordata, Cephalochordata, and Vertebrata. Urochordates only have chordate features during the larval stage, the cephalochordates have it for life, and the vertebrates have complex extensions such as vertebral column, and well-developed organ systems. The outline group of vertebrates exhibits adaptive radiation in aquatic, terrestrial, and aerial environments with the

major classes exhibiting successive physiological and structural novelties. On the whole, the chapter introduces the chordates as a family of organisms that are connected by the key anatomical peculiarities but became different due to evolutionary mechanisms.

Review Questions

1. Explain the overall features that make chordates different as compared to non-chordates.
2. Talk about the evolutionary evidence on the origin of chordates.
3. describe the composition and importance of the notochord.
4. Explain what is the dorsal hollow nerve cord and its evolutionary significance.
5. Share the arrangement and role of chordate pharyngeal gill slits.
6. Describing the characteristic differences between the three subphyla of Chordata.
7. Compare Cephalochordata and Urochordata.
8. describe the features of Vertebrata.
9. Provide a rough taxonomic description of vertebrates that have key characteristics.
10. Talk of the evolutionary importance of the primitive chordate body plan.

Chapter 6

Pisces and Amphibia

6.1 General Characters of Pisces

Fishes or pisces are the first and oldest type of vertebrates. They are mainly aquatic organisms which are adapted to live in the fresh water and marine environments. The body of fishes is usually streamlined and this saves on the resistance during the process of swimming and also enables it to move freely through the water. This fusiform form is related to building adaptation to a water environment where the movement is mostly dependent on the flexibility of the body and the coordination of the fins.

Fishes are ectothermic organisms and this implies that the temperature of their bodies changes in relation to the surrounding environment. The body is normally broken down into head, trunk and tail. Scales cover the skin, and these scales could be placoid, cycloid, ctenoid, or ganoid, according to the group. Scales cover the body, and decrease friction when swimming. The skin also secretes mucus that makes one lose more water resistance and the ability to resist pathogens.

Fishes breathe using gills and these organs are highly vascularized and these gills are specialized organs that extract dissolved oxygen in water. Through the mouth, water flows through the gill filaments and the gaseous exchange occurs. The circulatory is closed and the system is usually made up of a two chambered heart which has one atrium and one ventricle. The blood circulation is in one circulation, i.e. heart to gills and proceed to the remaining part of the body.

Fishes also have both the paired and unpaired fins which give it balance, steering and propulsion. Paired fins comprise of pectoral and pelvic fin

whereas unpaired fin is in form of dorsal, anal and caudal fin. Caudal fin is vital in forward movement. Aquatic vertebrates have a distinct sensory organ called the lateral line system that detects vibrations and shifts in pressure of water which is helpful in navigation and prey detection.

The nervous has a good development, and there are separate parts of the brain that orchestrate the sensory input and motor output. The reproduction mode is usually sexual with the majority of fishes undergoing an external fertilization process. Embryonic eggs are normally deposited in water, and they hatch externally. The overall pisces traits reflect their adaptation to live in water and this is the first phase of evolution of vertebrates.

6.2 Classification of Fishes

There are three major groups of fishes that are distinguished by skeletal structure and morphological features Agnatha, Chondrichthyes, and Osteichthyes.

The jawless fishes are known as agnatha, and are thought to be the most primitive vertebrates. They are without paired fins and have cartilaginous skeleton. It has a circular mouth that is suction adapted. These models depict the initial conditions of the vertebrates prior to the development of jaws.

Sharks, rays and skates are considered chondrichthyes or cartilaginous fishes. They have a cartilaginous skeleton completely. They have placoid scales and more than one gill slit without an operculum. Most of the cases of fertilization are internal. This group has a major evolutionary improvement with the development of jaws and a pair of fins.

The greatest and the most varied group of fishes are known as osteichthyes or bony fishes. Bone is the major component of their skeleton. They also have an operculum over the gill openings and normally have swim bladder

which controls buoyancy. The swim bladder enables fishes to have balance in water without the need to keep on swimming. This group exhibits a wide range of adaptive radiation both in marine and freshwater.

The evolution of the fishes can be seen in the division into jawless primitive fishes and the further evolution into highly bony fishes with specially designed structures of buoyancy, feeding, and respiration.

6.3 Adaptations in Fishes

Fishes have a lot of adaptations that make them survive in water bodies. The body shape is streamlined which lowers the resistance of water and enhances swimming performance. Of importance is the availability of fins that offer manoeuvrability and stability. The effective predation and varied feeding mechanisms are possible due to the evolution of jaws.

Gills are special organs used in respiration that has been modified to suit the extraction of oxygen out of water, which contains less oxygen than air. The efficiency of absorption of oxygen is optimized by the countercurrent exchange process within the gill lamellae. Lateral line system improves the awareness of the environment and identifies the movement and vibrations in the water around.

Bony fishes have a major adaptation of regulating buoyancy using the swim bladder. It permits the vertical movement of water column without excessive use of energy. Cartilaginous fishes This group of fishes does not possess a swim bladder, but they achieve buoyancy by having a large oil-filled liver and by constant motion.

Another important adaptation is osmoregulation because fishes need to regulate the internal level of salt and water in different aquatic habitats. Gills

are used to pass excess salts by the marine fishes whereas dilute urine is excreted by freshwater fishes in large volumes to avoid water over Loading.

All these adaptations demonstrate the fact that structural and physiological changes make fishes useful in exploitation of aquatic ecosystems.

6.4 General Characteristics of Amphibia.

Amphibia is an intermediate between the aquatic and terrestrial vertebrates. The root amphibia refers to dual life of these creatures, as their life cycle is both an aquatic lifestyle as a larvae and a terrestrial lifestyle, as adults. Amphibians are nocturnal and live in wet places because their skin is critical in respiration.

Body is separated into head and trunk and a short tail is present in some cases. The skin is smooth, moist and glandular, devoid of scales. Mucous glands maintain the skin wet as a way of cutaneous respiration. There are species with poison glands which protect against predator attacks.

Amphibians have a variable respiration with the development stage. The gills of larvae are used to breathe underwater and later the adults acquire lungs to breathe in the air. The skin respiration is still significant in life. The circulatory system consists of the three chambered heart having two atria and one ventricle causing a partial mixing of the oxygenated and deoxygenated blood.

The amphibians contain two pairs of pentadactyl limbs that are used in walking and jumping. Another significant evolutionary change in regard to limbs is the evolution of the terrestrial locomotion. Nervous system is more developed than in fishes and its sensory adaptation towards life on land is better.

The external fertilization normally occurs in the water. Eggs have no protective shell and they should be kept wet. Amphibians are therefore an essential evolutionary transition zone between wholly aquatic fishes and wholly terrestrial vertebrates.

6.5 Metamorphosis in Frog

The case of frog is an example of metamorphosis that occurs between the larva and an adult. The life cycle will start with the fertilized eggs laid in water. The embryo forms a tadpole which is like a fish in form and functionality. The tadpole has gills, a swimming tail and is a herbivore.

In metamorphosis, there are radical morphological and physiological changes. The lungs substitute the gills and allow the aerial respiration. Excessive limbs grow out first the hind limbs then the forelimbs. The tail slowly recedes and the form of the adult appears. It is dietary change that is manifested in a change of the digestive system such that it becomes a carnivorous system rather than a herbivorous one.

The circulatory system is developed to a three chambered heart in the form of an adult heart in place of the two chambers heart that is present in the larva. These transformations depict adaptation to life on land and still depending on water to reproduce. Metamorphosis is regulated at the hormonally governed level through thyroid hormones and regulates developmental shifts.

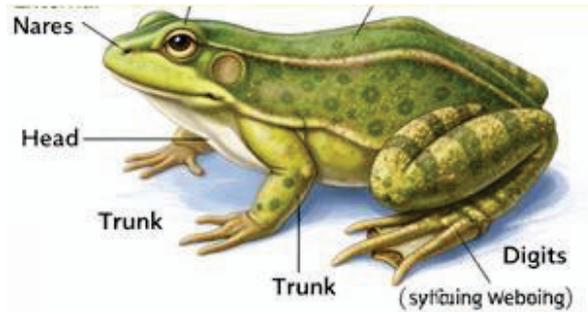


Figure 6.1: External Morphology of Frog

The figure illustrates the external structural aspect of a frog which consists of the head, trunk, limbs, eyes, tympanum and webbed hind feet. It points out some of the adaptations like strong hind limbs to jump, webbed feet to swim and protruding eyes to see widely into the field. The meaning of this morphology shows that there is functional integration between aquatic and terrestrial adaptations. The streamlined body facilitates swimming whereas limbs facilitate terrestrial locomotion. This bilateral adaptation highlights the evolutionary status of the amphibians as intermediate vertebrates.

The examination of Pisces and Amphibia shows a gradual change between totally aquatic vertebrates to organisms that are able to utilize the terrestrial environment. Evolutionary progress is demonstrated by structural innovations like limbs, lungs, and altered circulatory structures, and evolutionary regression is demonstrated by the fact that they still have aquatic reproductive dependence.

Summary of the Chapter

This chapter focuses on two significantly significant vertebrates- Pisces and Amphibia stating their structure, classification, and evolutionary importance. Fishes are the first vertebrates based solely on the aquatic existence. Special

adaptations include their streamlined body, fins, gills, scales, and their system of lateral line which show that they can move well in the water, breathe in and take in the surrounding, and perceive the water. The separation of fishes into jawless, cartilaginous and bony groups indicates the development of fishes through the evolutionary stages of the primitive skeletal structures to the further evolution with the increased structure complexity. The examples of adaptations include swim bladder, countercurrent exchange mechanism in gills and osmoregulatory systems; these demonstrate how fishes help achieve physiological balance in various aquatic environments.

Amphibians are a kind of transition between the vertebrates and the aquatic creatures, a point of contact between the life on water and the life on the land. They exhibit their dual mode of being in their life cycle that consists of an aquatic larval stage and a terrestrial adult stage. Moist glandular skin, lungs, pentadactyl limbs and a three chambered heart are structural features that suggest land-based adaptation, whereas the requirement to reproduce in water suggests continuity in evolutionary relation with their aquatic ancestors. An example of extreme developmental change is metamorphosis in frog, which goes through respiration, locomotion, circulation and diet changes. Collectively, Pisces and Amphibia show how the evolutionary change in water to land occurred with the sequential changes in structures and physiological adaptations facilitating the proliferation of the vertebrates into new ecological niches.

Review Questions

1. Write about the overall Pisces characters.
2. describe the major grouping characteristics of fishes.

3. Talk of the adaptations of fishes, both structural and physiological, to aquatic life.
4. Write down about the respiratory and the circulatory system of fishes.
5. describe the more or less characters of Amphibia.
6. Talk about how the amphibians were adapted to life on land and in the water.
7. Explain the structure and the role of amphibian skin.
8. Describe how frog metamorphoses.
9. Comparison of the circulatory system of fishes and amphibians.
10. Explain the evolutionary value of Amphibia as a transitional group.

Chapter 7

Reptilia and Aves

7.1 General Characters of Reptilia

Reptilia also constitute a major step in the evolutionary history of vertebrates and the appearance of the fully terrestrial vertebrates that do not have to rely on water to reproduce. They developed out of the amphibian progenitors and were able to adapt to living in the dry on-land environments. The evolution of tough skin, effective lungs, internal fertilization and shelled eggs enabled the reptiles to inhabit in various ecological settings, such as deserts, forests and water bodies.

Reptiles are finned, triploblastic, bilaterian, coelomate vertebrates of the well-developed organ-system level. The common division of their body is into head, neck, trunk and tail. The skin is dry, cornified, and epidermal scales or scutes of keratin. These scales reduce the loss or wastage of water and offer a shield against mechanical damage and predation. In contrast to amphibians, reptiles do not have the cutaneous mode of respiration and completely rely on the lungs to exchange gases.

The respiratory system is highly developed with the lungs having higher amount of internal surface area to maximize the absorption of oxygen. There is improvement in the circulatory system compared to the amphibians. The majority of reptiles have a three chambered heart whose ventricles are not completely separated exposing the mixing of oxygenated and deoxygenated blood. The further specialization is in the form of heart which is four-chambered by Crocodilians.

Reptiles have two sets of pentadactyl limbs which are evolved to crawl, run or swim, although snakes lack limbs. Bones are well developed which gives

the skeletal system structural support and efficient locomotion. Compared to the nervous system of the amphibians, the nervous system is more developed featuring better cerebral hemispheres and sensory organs. Sight and smell are highly developed, which helps in hunting and being aware of the environment.

The reptiles reproduce through internal fertilization. The evolution of amniotic egg is an important evolutionary change. The egg has additional embryonic membranes: the amnion, chorion and allantois which shield and supply the embryo so that it could develop on land and did not require the presence of water. This adaptation is a significant turn in the evolution of the vertebrates which made the reptiles the first fully terrestrial vertebrates.

7.2 Class and Adaptations of Reptiles.

The reptiles are grouped into a few major orders according to their morphological and anatomical features, especially their skull structure, and the dentition. Notable ones are Testudines (turtles and tortoises), Squamata (lizards and snakes), Crocodilia (crocodiles and alligators), and Rhynchocephalia.

Testudines are distinguished by armored shell of the dorsal carapace and the ventral plastron made of bone. The shell is fused to their ribs and vertebrae giving them remarkable defense. The largest family of reptiles belongs to Squamata: they have flexible skulls, and in snakes the loss of the limbs. Crocodylians are semi-aquatic reptiles that have their jaws, tails powerful, and a heart consisting of four chambers, which is a high level of structure organization. The primitive forms that have remained reptilian are found in Rhynchocephalia.

Reptiles are highly adapted to live in land life. The skin is hardened and stops desiccation and the lungs are well developed and guarantee efficient

breathing. Amniotic egg keeps the embryo safe of environmental risk and the embryo does not need aquatic breeding sites. The nitrogenous waste is excreted mainly as uric acid and this saves water which is an essential adaptation to survive in dry environments.

Basking, as a behavioral adaptation involved, allows the body temperature to be controlled, since reptiles are ectothermic, and require heat sources in the environment. Their muscular physique and clawed limbs assist them during terrestrial movement and predatory abilities are improved with the aid of sensory adaptations. All these adaptations made reptiles dominate the ecosystems of the land in the Mesozoic era.

7.3 General Characters of Aves

Aves, which are birds, are highly specialized vertebrates that are adapted to fly. They have passed through reptilian ancestors and still bear some of reptilian features, including oviparity and scaled legs. Nevertheless, birds have many structural and physiological adaptations that differentiate them with reptiles and provide locomotion in the air.

Birds are endothermic, which means that they do not have their body temperature depending on the environment. They are streamlined and their bodies are covered with feathers, which are to insulate them as well as to serve in flight. The forelimbs are adapted into wings and hind limbs are adapted into walking, perching or swimming.

The bone structure of birds is light but strong and pneumatic (air) bones which lowers the body weight and still maintains body strength. The bones are rigidly joined to a number of bones to give it the ability to fly. The sternum is extended and has a keel to which powerful muscles of flight are attached. Lungs and a complex system of air sacs make up the respiratory

system and they are responsible to maintain constant supply of air and efficient exchange of oxygen even when one is exhaling.

Birds have a very efficient circulatory system and their heart is four chambers and totally separates the oxygenated and deoxygenated blood components. This division promotes high rates of metabolism in flight and endotherm. The digestive system is adapted, and the structures include the crop to store food temporarily and gizzard to digest with the help of the mechanism.

Bird reproduction is internalized and eggs are laid in hard shells. Parental care is highly developed which increases offspring survival. The nervous system and the sense organs are also well developed and acute vision and coordination are required to fly and navigate.

7.4 Flight Adaptations in Birds

Flight represents the most unique form of adaptation in birds and has structural, muscular, and physiological adaptations. The reduced resistance to air, through the streamlined body, is combined with aerodynamic surfaces made up of the feathers. The wings have flight feathers that give the wings lift and thrust and tail feathers which assist in steering and balance.

The legs that were used as forearms are developed into wings that have long bones and powerful muscles. The pectoral muscles, especially the pectoralis major, are very large and are connected to the keeled sternum and they produce strong wing strokes. The skeleton is lightweight, hollow-boned, and a combination of a few elements is done, and this makes the body mass lesser even in the state of strength.

Air sacs in the respiratory system facilitate the constant supply of oxygen and high metabolic rates. The avian birds can maintain energy-demanding

flight behavior by means of endothermia. The four chambered heart and high circulatory system provide effective spread of oxygen and nutrients.

A well-developed cerebellum that is related to coordination and balance is part of the neurological adaptations. Good eyesight helps in navigation, detection of prey, and evading of obstacles. These combined adaptations reflect evolutionary perfection that can support powered flight.

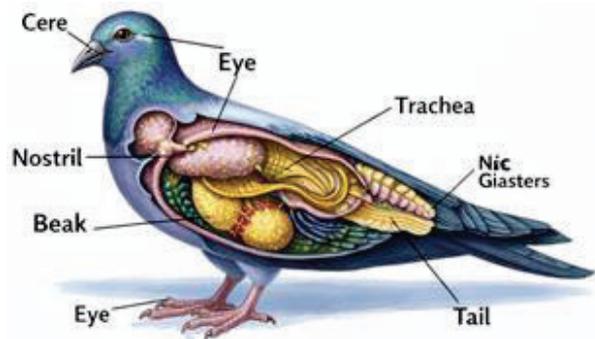


Figure 7.1: Structure of Pigeon

The figure shows the external anatomic characteristics of a pigeon, such as the head, beak, neck, wings, trunk, tail, and scaled hind limbs. It emphasizes the body shape and some feathers of arms and wings. This morphology has been interpreted based on the issue of functional specialization in flight. The wings enjoy the lift and propulsion, tail helps in steering and the light body structure lessens the gravitation. Such an organizational appearance demonstrates the presence of skeletal, muscular, and respiratory adaptations required to move about the air.

The evolutionary history of Reptilia and Aves can be seen to be very much connected with each other, the birds being formed out of reptilian ancestral species, but with spectacular specialization. Reptiles are the earliest entirely terrestrial vertebrates to have amniotic eggs, and birds have a high grade of adaptive ability to flight and endotherm. Combining these groups, a gradual

change in evolution, structural innovativeness and extension of ecosystems in the history of vertebrates are depicted.

Summary of the Chapter

In this chapter, we have discussed two higher classes of vertebrates, Reptilia and Aves, and focus on their structure, classification and evolutionary importance. The first complete terrestrial vertebrates are reptiles, which are dry, keratinized-skinned, with well-developed lungs, internally fertilized and bearing an amniotic egg. These adaptations removed the need to use water to reproduce and allowed reptiles to live in innumerable land environments. Differences in body structure, ecological adaptation, and skull structure are expressed in their classification into major orders. The evolutionary success of these creatures was due to structural and physiological adjustments (water-conserving excretion, strong ossified skeleton, and efficient respiration).

Birds are the descendants of reptiles that have amazing flight and endothermic specialization. Their feathers, wings, pneumatic bones, and strong flight muscles are structural modifications that may be used in aerial locomotion. Animal characteristics like four chambered heart, air sac, and high rate of metabolism contribute to the sustained level of activity during flight. Such reproductive measures as hard-shelled eggs, parental care increase offspring survival. This chapter demonstrates that, there is an evolutionary continuity between reptiles and birds, in addition to the highly-developed structural and functional changes that make the aves highly specialized vertebrates.

Review Questions

1. Give the characters of Reptilia in general.

2. Discuss the major order features of reptiles classification.
3. describe structural changes of reptiles in terrestrial life.
4. Explain how and why the amniotic egg is organized.
5. Discuss the evolution of reptiles and birds.
6. Explain the overall characters of Aves.
7. Describe the skeletal and muscular changes of birds to flight.
8. Talk about respiratory changes of birds which help them fly.
9. Compare the circulation of reptiles and birds.
10. Explain the exoskeleton of pigeon and illustrate the purpose of the pigeon having such a skeleton.

Chapter 8

Class Mammalia

8.1 General Characteristics of Mammals

Mammalia is the most civilized category of vertebrates, which is highly organized, complex, and has excellent development of behavior. Mammals have their roots in reptilian ancestors and are characterized with a mixture of primitive and advanced characteristics, which differentiate them among other forms of vertebrates. They are endothermic species, which have the ability of keeping their internal temperature constant regardless of the environmental changes. It is a thermoregulatory capability that enables mammals to live in a diverse climate environment, including the polar areas and the tropical forests.

Among the most noticeable traits of mammals is the fact that women have mammary glands and use the milk to feed the young. The adaptation guarantees the parenting and an increase in the survival of the offspring. We have hair or fur covering the body, that gives insulation as well as protection. Even though some aquatic forms may have reduced hair, it is one of the defining aspects of their existence at some point of development.

Several glands are present in the skin of mammals such as sweat glands, sebaceous glands, scent glands. Another significant aspect of sweat glands is their role in thermoregulation since the glands help lose heat by evaporating. The sebaceous glands keep the skin and hair in good condition. It has a well-ossified skeletal system and the skull has two occipital condyles, thus enhanced articulation with the vertebral column. The lower jaw is composed of one dentary bone, which is a great evolutionary improvement in comparison with reptiles.

The heart of mammals is four chambers, which provide total segregation of deoxygenated and oxygenated blood and sustains high metabolism. The respiratory system has well-developed lungs that have alveoli, which enhances the gaseous exchange surface area. There is a muscular diaphragm between the thoracic/abdominal cavities, which increases the effectiveness of breathing.

It has a highly developed nervous system particularly the cerebrum is the part of the nervous system that is involved in high levels of intelligence, memory and complex behavior. Sensory organs are also well adapted and many species have acute vision, hearing and olfaction. Mammals are typically viviparous, that is, they bear living offspring, but monotremes are egg-layers. The fertilisation process is internal and in most cases, the embryo develops with a placenta, which feeds the embryo. These common aspects show evolutionary perfection and ecological superiority among the vertebrates.

8.2 Classification of Mammalia

Mammals are further divided into three subclasses according to reproduction characteristics and anatomy, which include: Prototheria, Metatheria, and Eutheria.

Prototheria consists of the mammals that lay eggs like monotremes. Such animals are primitive, such as oviparous and nippleless. The young laps on the milk that is secreted on the skin surface. Prototherians are also a transition state between the reptiles and higher mammals.

The metatheria or marsupials are mammals which give birth to rather immature offspring that proceed to mature in a pouch called marsupium. Placenta is either undeveloped or poorly developed. Marsupials are found to have intermediate features between monotremes and placental mammals.

The most diverse group is Eutheria or placental mammals. They have a well developed placenta that helps in the prolongation of the embryo development in the uterus. Placental mammals are highly adapted, and they inhabit terrestrial, aquatic, and aerial environments. Subclass orders in this group are Primates, Carnivora, Rodentia, Chiroptera, and Cetacea among others.

The classification of mammals indicates gradual reproductive success and structural elaborate complexity. The shift in development of eggs to placental shows evolutionary development with regards to embryonic nutrition and parental expenditure.

8.3 Adaptive Radiation of Mammals.

Adaptive radiation is the differentiation of a population of organisms into different forms suited to different physical environments. Mammals exhibit a wide divergent evolution, allowing them to colonize almost all the habitats on the planet. This diversification manifests itself in the diversity of limb structure, dentition, size and feeding patterns.

The earth mammals can be adapted either to running, burrowing, climbing, or digging. Cursorial mammals have long limbs to move faster, whereas fossorial mammals have well-developed forelimbs to excavate. Mammals living in trees have grasping limbs and prehensile tails such as arboreal mammals.

Aquatic mammals like whales and dolphins have streamlined bodies, less hind limbs and modified forelimbs in the form of flippers. Their circulatory and respiratory systems are diving and long submersion adapted. Forelimbs adapted to serve as wings are found in aerial mammals including bats which have elongated digits and membrane-covered skin.

In mammals, dentition is a dietary adaptation. Herbivorous ones have wide molars and grind plant food, carnivorous have sharp canines and carnassial teeth and cut flesh, and omnivorous ones have both. This difference in the structure of the teeth brings out ecological specialization.

Adaptive radiations can be used to explain the flexibility of evolution and structural change in mammals to adapt to environmental pressures. It shows how a shared body plan may be modified to a large number of forms that fit different ecological functions.

8.4 Economic Significance of Mammals.

Mammals are important to the human society and the ecosystem. Many of the domesticated mammals offer important resources in the form of milk, meat, wool, leather and labor. Animals play an important role in food production and agriculture. Companion animals have social and psychological advantages.

Wild animals play a role in providing an ecological balance by controlling the population of prey and also engaging in nutrient cycles. Some mammals are pollinators/ seed dispersers, and they help in maintaining biodiversity. Medical science, physiology and genetics have benefited through research done with mammals.

Nonetheless, not all mammals are pests or vectors of diseases, which can impact on crops and humans. The preservation of endangered mammalian species is important because their habitat is destroyed, and environmental change is experienced. The economic significance of mammals therefore has both positive impacts and control issues.

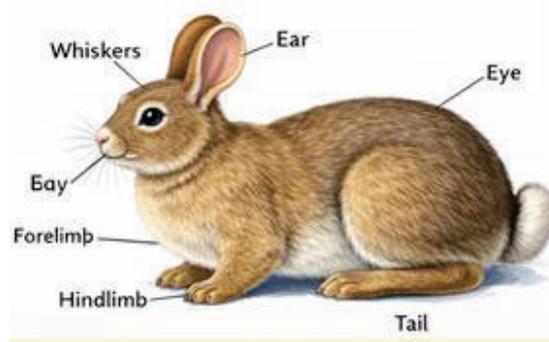


Figure 8.1: External Features of Rabbit

The illustration shows the extrinsic anatomy of a rabbit, which comprises head, trunk, limbs, pinnae, vibrissae, and tail. It brings out features like long hind legs to help it jump, huge external ears to help it hear well and thick fur to keep it warm. A view of this morphology would show a change to terrestrial life, fast movement and a sense of the environment. The skeletal, muscular, and sensory adaptations are integrated in the structural organization characteristic of mammals, and this represents the general characteristics defining the class Mammalia.

Summary of the Chapter

The chapter is about the structural organization, classification, adaptive radiation and economic significance of mammals which is the most developed of vertebrates. The characteristics of the mammals include the mammary glands, hair, endothermy, four chambers of the heart, muscular diaphragm and highly developed brain. These characteristics aid in effective metabolism, temperature and complex behavior as well as high offspring survival. The reproductive strategies used differ between the egg-laying monotremes and the marsupials that develop pouch and the highly developed placental mammals that have extended intrauterine growth. This

development is an indicator of rising reproductive specialization and investment in parents.

The division of mammals into Prototheria, Metatheria, and Eutheria is an example of evolutionary progress in the structure of the embryo and the complexity of physiologic functions. Extensive adaptive radiation has been observed in mammals who inhabit land, water and air. The ecological specialization and evolution of divergent pattern of limbs, dentition and body structure is represented by structural modifications. They are economically significant, playing a role in agriculture, industry, ecological balance, and scientific research and are also a conservation issue. All in all, mammals are a high-point of evolution in vertebrates, with a series of structural sophistication, physiological efficiency, and complexity of behavior.

Review Questions

1. Write about the overall features of mammals.
2. Discuss the structural characteristics that make mammals different among other vertebrates.
3. Discuss the subclassification of Mammalia with distinguishing characteristics of subclasses.
4. Compare monotremes, marsupials and placental mammals.
5. Discuss the placental mammal adaptations of reproductive features.
6. Explain what is adaptive radiation in mammalian organisms giving examples.
7. Discuss the adaptation of limbs in other ecological groups of mammals.
8. Describe the importance of dentition in the adaptation of mammals.
9. Economic significance of mammals.

10. Discuss the external characteristics of rabbit and discuss how it is functional.

UNIT III: Cell Biology and Genetics

Chapter 9

Cell Structure and Function

9.1 Cell Theory

The basic structural and functional element of life is the cell. Cells make up all living organisms, ranging in complexity between the unicellular protozoan and multicellular mammals. The development of the cell theory was the turning point in the world of biological sciences which presented a common scheme of the organization and continuation of life. The history of microscopy in the seventeenth and nineteenth century allowed scientists to view the structure of cells, which resulted in the creation of principles.

The cell theory is based on three classical postulates. To begin with, any living organism consists of one or more cells. Second, the fundamental structure and functioning unit in the organisms is the cell. Third, the division of cells brings about all the cells. However, contemporary interpretations go further and acknowledge that hereditary information is stored in cells and is transmitted between one generation and the next as well as that all metabolic activity is vested in cells.

The relevance of the cell theory is in the fact that it is universal. It creates the continuum between the simple and complex organisms proving that the structural complexity is the result of the organization and specialization of cells. In eukaryotes, differentiation occurs so that cells are specialized to carry out specialized functions, although they still maintain the basic properties that are characteristic of cell theory. The concept brings together such biological processes as growth, development, reproduction and heredity, under a shared cellular system.

The other concept of cell theory also focuses on the dynamic attribute of the cells. Cells are not homogenous compartments but places of active biochemical reactions, energy changes and genetic regulation. The knowledge about cell structure and cell functioning thus gives the basis to the study of physiology, genetics, development and pathology.

9.2 Prokaryotic and Eukaryotic Cells.

Structural organization and complexity give the broad categorization of cells into prokaryotic and eukaryotic. The prokaryotic cells are rather simple, do not have a proper nucleus and organelles that are enclosed in membranes. Their genes are found in a nucleoid area and are not surrounded by some sort of nuclear wall. Examples of prokaryotic organisms are bacteria and archaea.

The prokaryotic cells are generally small and the cytoplasmic structure is simple. They have ribosomes that serve in the synthesis of proteins, but they do not have organelles like mitochondria, endoplasmic reticulum, and Golgi apparatus. Transport is controlled by plasma membrane, and most prokaryotes have a rigid cell wall to protect themselves and support their shape. Although simple in terms of construction, prokaryotes are highly diverse and adaptable in terms of their metabolism.

Eukaryotic cells on the other hand are complex and bigger. They have a clearly defined nucleus that is surrounded by a nuclear membrane. Cytoplasm has a large number of membrane-bound organelles, which separate functions in cells. Such compartmentalization makes it more efficient and enables specialized biochemical processes to run concurrently without interference.

Eukaryotic cells can be found in protist, fungi, plants, and animals. In multicellular organisms, tissue and organ development occur as a result of cell differentiation. Higher organizational complexity is indicated by the

existence of cytoskeleton, complex endomembrane systems and specialized organelles. The difference in prokaryotic and eukaryotic cells is an indication of the evolution of evolved and complex cellular structure.

9.3 Structure and Functions of Cell Organelles.

Eukaryotic cells have specialized organelles, which have a specific function in cell survival and coordination. The cell control center is the nucleus which is made up of genetic material in form of chromosomes. It controls the expression of genes and coordination of cellular functions. The nucleus is surrounded by the nuclear envelope which has pores through which it selectively exchanges materials.

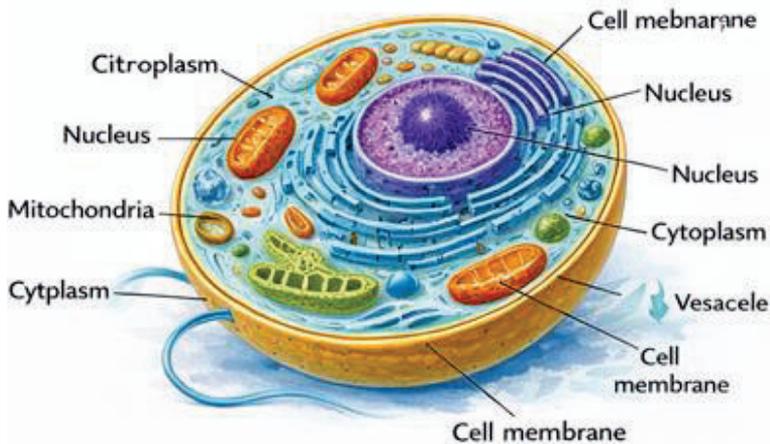


Figure 9.1: Structure of a Typical Eukaryotic Cell

The figure shows the structural arrangement of a eukaryotic cell as it points out the nucleus, mitochondria, endoplasmic reticulum, Golgi apparatus, ribosomes, lysosomes, and plasma membrane. It shows the organellar space distribution in the cytoplasm and the structural association. This diagram is perceived with an emphasis on compartmentalization as one of the main characteristics of eukaryotic cells. The organelles have their limits, which

guarantee efficiency and coordination of metabolic processes. The combination of these parts indicates the intricate structure of the cellular functioning.

Mitochondria are organelles that have a dual membrane and they are involved in cellular respiration as well as in production of ATP. The inner membrane develops cristae, which augment the surface area in which enzyme reactions take place. Mitochondria can also be called the powerhouses of the cell because of their contribution towards energy production.

Endoplasmic reticulum (ER) is a system of tubules and sacs of membranes. Rough ER is covered with ribosomes and is engaged in the process of the synthesis and transport of proteins. Smooth ER synthesizes the lipids and eliminates harmful substances. Golgi appends, packages and releases proteins and lipids arriving at the ER.

Ribosomes constitute a non-membranous protein and RNA structure, and these are protein synthesis sites. The lysosomes have hydrolytic enzymes which aid in intracellular digestion and recycling of cell contents. The peroxisomes are involved in oxidative reactions and detoxification.

The cytoskeleton is a skeleton of microtubules, microfilaments and intermediate filaments which offer structural support as well as intracellular transportation and cell division. During the mitotic cycle, centrosomes and centrioles are involved in the formation of the spindle.

Table 9.1: Structure and Functions of Major Cell Organelles

Organelle	Structural Features	Major Functions
Nucleus	Double membrane, nuclear pores, nucleolus	Controls cellular activities; stores genetic material
Mitochondria	Double membrane, cristae, matrix	Site of cellular respiration; ATP production
Endoplasmic Reticulum	Network of membranous tubules; RER and SER	Protein synthesis (RER); lipid synthesis and detoxification (SER)
Golgi Apparatus	Stacked flattened sacs (cisternae)	Modification, packaging, and secretion of proteins
Ribosomes	Non-membranous, rRNA and protein	Protein synthesis
Lysosomes	Membrane-bound vesicles with enzymes	Intracellular digestion
Centrosome	Pair of centrioles	Spindle formation during cell division

The table shows how the structural features of organelles are correlated with the specific functions of organelles in the cell. It associates membrane structure, internal structure, and enzyme content with physiological functions like energy generation, protein synthesis, translocation inside the cell and waste elimination. This tabular representation can be interpreted to bring out the principle that cellular efficiency is based on structural specialization. All the organelles play a different role towards the general cellular homeostasis thus depicting the idea of division of labor at the microscopic scale.

9.4 Cell Membrane and Mechanisms of Transport.

Cell membrane or plasma membrane is the outer boundary of the cell and controls its interaction with the external environment. It consists of a phospholipid bilayer containing dissolved proteins, carbohydrates and cholesterol molecules. The fluid mosaic model portrays this arrangement characterized by chaos and movement and structural versatility.

The phospholipid bilayer is made up of hydrophilic heads and hydrophobic tails respectively. This structure forms a semi-permeable membrane that is selective to permeable substances. Membrane proteins can be used in functions like transport, enzymatic activity, cell recognition and signal reception.

Passive and active mechanisms of transport across the cell membrane take place. Passive transport does not involve the use of energy and it involves diffusion, facilitated diffusion and osmosis. Diffusion is the movement of the molecules of an area of high concentration to an area of low concentration. Facilitated diffusion involves the use of carrier/channel proteins to aid in the movement of certain substances. Diffusion of water through a semi-permeable membrane is called osmosis.

Active transport involves the use of energy in the form of ATP and transports substances in their direction to the opposite of their concentration gradient. Specialized transport proteins mediate this process, e.g. pumps. Bulk transport is represented by endocytosis and exocytosis. Endocytosis is the process of absorption of material into the cell with the help of forming vesicles and exocytosis is the release of substances outside the cell.

The homeostasis of the cell depends on the cell membrane. It controls transport thus achieving the best internal conditions of metabolic processes.

The membrane structure-transport interaction proves the dynamism of the cells with their surrounding.

Cell structure and cell function have been studied and have shown that life on a cellular level is highly organized, compartmentalized, and regulated. Since cell theory up to the specialization of organelles and membrane dynamics, cellular organization forms the basis of the explanation of all biological systems.

Summary of the Chapter

This chapter describes the conceptual basis of the cell structure and cell functioning, which defines the cell as the basic structure and functioning unit of life. The cell theory principles offer a common denominator applicable to all forms of life and highlight the fact that cells originate out of the existing ones and become the points of metabolic processes and genetic perpetuation. The difference between prokaryotic and eukaryotic cells underlines the evolutionary development of the simple cell organization that does not feature membrane-enclosed organelles to cells with high compartmentalization and structural complexity.

The chapter also discusses the organization and the role of the large cell organelles and how specialization and division of labor in the cell leads to efficiency and coordination of biological mechanisms. The organelles that include the nucleus, the mitochondria, the endoplasmic reticulum, and the Golgi apparatus have different but combined functions in ensuring cellular homeostasis. The fluid mosaic model of the plasma membrane addresses selective transport by passive and active pathways, allowing the internal and external environment to be controlled. All in all, the chapter highlights the fact that cell organization, structural specialization and controlled transport

systems are the basis of growth, development, and other physiological functions in all living things.

Review Questions

1. Describe and define the postulates of cell theory.
2. Compare the characteristics of prokaryotic cells and eukaryotic cells.
3. Give an account of the composition and characteristics of the nucleus.
4. Describe the mitochondria role in cell respiration.
5. Talk about structure and functions of endoplasmic reticulum and Golgi apparatus.
6. Explain the structure and function of ribosomes and lysosomes.
7. Describe the fluid mosaic model of cell membrane.
8. Comparison of passive and active transport.
9. Explain the mechanism of endocytosis and exocytosis.
10. Describe the role of structural specialization of the organelles in the overall cellular work.

Chapter 10

Cell Cycle and Cell Division

10.1 Phases of Cell Cycle

Cell cycle is a highly regulated series of events by which a cell increases, reproduces its genetic information and separates to become two adult cells. It provides continuity of life through stable conveyance of genetic information between one generation of cells and the other. Growth, embryonic development, tissue repair, and organ maintenance of multicellular organisms involved regulated cell division. In single celled organisms, this is the major mode of reproduction. Cell cycle is thus a continuation process and a source of biological diversity.

The interphase and the mitotic (M) phase are considered broad divisions of the cell cycle. The longest phase is interphase which comprises of three stages G 1 (first gap phase), S (synthesis phase), and G 2 (second gap phase). Even though the process of interphase was once regarded as a form of rest, it is now known to be a phase of great biochemical activity and division preparation.

At the G 1 stage the cell grows in size, makes proteins and replicates some organelles. Metabolic activity is elevated in cells. The cell determines the internal and external conditions, and it provides sufficient nutrients and energy reserves, lack of DNA damage before undergoing the process of DNA replication. The G 1 stage is critical as it represents a choice: cells can move onto the S stage, enter into repair or leave the cycle to enter a quiescent state, which is called G 0.

The S phase is the stage, which is marked by replication of the DNA. Chromosomes replicate to create two same sister chromatids that are

attached to a centromere. The process of DNA replication is very precise as there are proofreading mechanisms that minimize the number of errors. Histone proteins are synthesized together with the DNA synthesis to ensure new replicated DNA is packaged with histone proteins to form chromatin. The proper completion of the S phase is necessary to have an equal division of genetic material in the course of division.

G 2 stage occurs after the DNA replication. At this phase, the cell produces proteins that are needed in the process of mitosis such as the parts of the spindle apparatus. The cell checks against the mistakes in the DNA replication and corrects the observed defects. The G 2 phase is a last preparation phase before mitosis sets in.

The M phase consists of mitosis (division of nucleus) and cytokinesis (division of cytoplasm). It leads to production of two daughter cells that contain the same genetic contents. These phases are sequentially developed to guarantee genetic stability and a synchronized increase in cell proliferation.

Other cells, including neurons and cardiac muscle cells, undergo differentiation and permanently enter into the G 0 phase. Others are able to leave the cycle temporarily and come back in under certain stimuli. Tissue homeostasis depends on the capacity of cells to maintain entry and exit into the cycle.

10.2 Regulation of Cell Cycle

Molecular mechanisms strictly regulate the process of the cell cycle, taking into account the timing and exactness of every stage. Checkpoints, protein interactions, and signaling pathways are some of the ways that regulate the cellular conditions. In case of lack of such control, cells can divide uncontrollably or they can collect errors in genes.

The cell cycle has three major checkpoints, which are the G 1 checkpoint, the G 2 checkpoint, and the metaphase (spindle) checkpoint. The G1 point identifies the readiness of the cell to replicate the DNA. It confirms the size of cells, nutrients and integrity of DNA. In case of detection of DNA damage, repair mechanisms are initiated, then S phase is not entered.

The G 2- checkpoint makes sure that the replication of the DNA has taken place correctly and the cell is ready to enter into mitosis. Any abnormalities observed put the process on hold until the errors are rectified. Checkpoint, called as metaphase, which takes place during the mitosis process, makes sure that all the chromosomes are in the right places at the equatorial plate and that they are bound together with spindle fibers before being separated.

The cell cycle regulatory machinery entails the cyclin and cyclin-dependent kinases (CDKs). Cyclins are the proteins, the concentration of which changes according to the different stages of the cycle. CDKs are enzymes, which are activated upon interaction with certain cyclins. Target proteins are phosphorylated by the cyclin-CDK complexes, which activate the transition between one stage and another.

Proteins like p53 are tumor suppressor proteins which are very important in ensuring genomic stability. In the case of damage to the DNA, p53 triggers the repair mechanisms or leads to apoptosis when the damage is unrepairable. The loss of such control of the regulation may result in unregulated cell division and cancer.

Therefore, cell cycle is regulated to maintain correct replication and division to maintain genetic integrity and prevent disease.

10.3 Mitosis

Mitosis is a nuclear division which forms two genetically identical daughter cells out of one parent cell. Growth, tissue repair, regeneration and asexual reproduction of many organisms are necessary in the presence of growth. Mitosis makes sure that the number of chromosomes is fixed in the host cells.

There are four primary stages involved in mitosis namely prophase, metaphase, anaphase and telophase. The stages entail the exact structural modifications that promote correct chromosome allocation.

It is during the prophase that the chromatin condenses into chromosomes that can be seen. The chromosome is made up of two sister chromatids attached at centromere. The nucleolus fades away and the nuclear envelope starts disintegrating. Centrosome moves to other poles and spindle fibers start to develop.

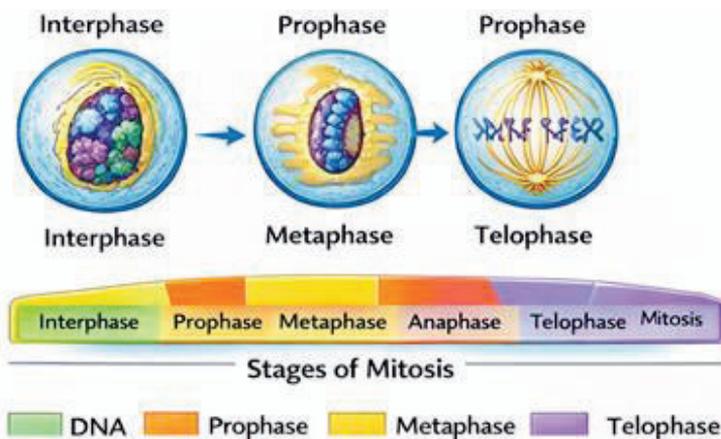


Figure 10.1: Stages of Mitosis

The figure shows the stepwise sequence of mitotic phases, with the condensation of chromosomes during the prophase, equatorial positioning during the metaphase, separation of chromatids during the anaphase and reconstitution of the nucleus during the telophase. The meaning of this

sequence is the accuracy of chromosome segregation. The successive steps of cell division guarantee each cell division that the resulting daughter cells contain the same number of chromosomes, which remain genetically stable and is diploid.

During metaphase, the chromosomes are arranged in a single line at the equator of the cell at a single point that is known as the metaphase plate. Each chromosome has centromeres where the spindle fibers adjoin to the centromere. This is coordination that guarantees equal segregation of chromatids.

During anaphase centromeres replicate and sister chromatids are separated. The spindle fibers become shorter and drag the chromatids towards the opposite poles. This division ensures that all the daughter cells inherit one copy of every chromosome.

During telophase the chromatids approach the poles and condense to create chromatin. Each group of chromosomes re-forms nuclear membranes and the nucleolus appears again. This is followed by cytokinesis which separates the cytoplasm in two cells. This happens in animal cells by the formation of a cleavage furrow; in plant cells, a cell plate is formed.

Mitosis ensures genetic stability and aids in growth and repair of the tissues.

10.4 Meiosis

Meiosis is a specialized form of cell division that is used to generate haploid gametes in those organisms that reproduce sexually. It is divided into two consecutive divisions which are meiosis I and II resulting in four genetically different daughter cells.

The first meiosis is the reductional division. At the prophase I, homologous chromosomes are joined together in a process known as synapsis. The

crossing over is between the non-sister chromatids and genetic material transfers resulting in variation. The complex chromosomal processes are observed in the prophase I, which is further divided into leptotene, zygotene, pachytene, diplotene, and diakinesis.

During metaphase II, the pairs of homologous chromosomes are positioned in the equator. During anaphase I, the identical chromosomes separate and move to different poles leaving behind sister chromatids. The haploid cells are the result of Telophase I.

Meiosis II is similar to mitosis. The cell division is anaphase II, which results in the formation of four haploid daughter cells. Such cells are genetically different as a result of crossing over and independent assortment.

Meiosis is a process that maintains the level of chromosomes within a generation. The genetic stability is maintained by removing the number of chromosomes in the gametes and by recovering diploidy during fertilization. Meiosis leads to genetic variation which results in evolution and adaptation.

Wilson (1996) discusses the significance of cell division.

Biological continuity and diversity depends on cell division. Mitosis allows tissues to grow, repair a damaged cell and regenerate. In single celled organisms, it is a way of reproduction. Meiosis enhances sexual reproduction and genetic variation encourages genetic variation.

Meiosis and fertilization ensures the permanent chromosome number with the production of variety. Proper cell division will avoid genetic errors building up. Division or disruption may cause any of the following; chromosomal abnormalities, developmental disorders, or cancer.

The cell cycle and cell division depict the nature of living systems dynamism. By means of strict control as well as controlled structural

alterations, cells provide the continuity, adaptation, and survival of life, across generations.

Summary of the Chapter

This chapter describes the chronological order of events and increased controls of the cell cycle and cell division. A cell cycle is composed of interphase and mitotic phase with the former being further separated into G₁, S and G₂. At these phases, the cell proliferates, replicates its DNA, builds up necessary proteins and gets ready to divide. These stages are duplicated and distributed properly as a result of proper coordination of these stages. Genomic stability and control in uncontrolled proliferation of cells occurs due to the presence of checkpoints and regulatory proteins like cyclins and cyclin-dependent kinases.

The separation of the cell that results in mitosis is responsible to give rise to two genetically identical cells known as the daughter cells which helps to preserve the number of chromosomes and enables growth, repair as well as asexual reproduction. In contrast, meiosis is a specialized division which reduces the number of chromosomes by a half and produces genetic variation as a result of crossing over and independent assortment. Meiosis and fertilization maintain the number of chromosomes of the species through generations, and this enhances the diversity of evolution. As a whole, cell division is necessary in development, heredity, regeneration, and survival and its control is crucial in sustaining normal physiological functioning.

Review Questions

1. Explain the stages of cell cycle.
2. Describe the importance of interphase during cell division.
3. Talk about the functions of checkpoints in controlling the cell cycle.

4. Provide a description of the role of cyclins and cyclin-dependent kinases.
5. Explain the key events of mitosis.
6. Talk about the distinction between the processes of mitosis and meiosis.
7. Describe how the crossing over occurs and the importance of the process in meiosis.
8. Explain the meiosis I and meiosis II.
9. Discuss about the biological importance of mitosis.
10. Describe the significance of meiosis in ensuring genetic continuity and variation.

Chapter 11

Principles of Genetics

11.1 Mendel's Laws of Inheritance

Genetics refers to the part of biology that addresses the issue of heredity and variation, which is how the traits are passed on to the parents. Gregor Mendel through his experiments on pea plants was the forerunner of classical genetics. Through a very delicate choice of contrasting traits and controlled cross-pollination, Mendel developed several basic principles, which are used to explain the pattern of inheritance. His work revealed that the control of inheriting is made by discrete units, which will come to be known as genes and not blending of parental traits.

Mendel came up with the Law of Dominance according to which in the case of two contrasting alleles in an organism, one can suppress the other in the heterozygous form. The phenotype has the dominant trait whereas the recessive trait is not expressed but not lost. This principle is what makes some characteristics emerge in a particular generation and emerge in the next generations.

According to the Law of Segregation allele pairs segregate during gametogenesis in such a way that a gamete has only a single allele of a particular trait. In fertilization, the alleles will recombine at random and once more reconstruct the paired state. This law explains the ratios that can be predicted in the offspring of known genotyped parents when they are crossed.

According to the Law of Independent Assortment, alleles of other genes are independent in the assortment during the formation of the gametes, although the genes are present on different chromosomes or are very far apart on the

same chromosome. This law has been used to explain the inheritance of several characteristics simultaneously and also results in characteristic ratios of phenotypic in interhybrid crosses.

The laws of heredity set by Mendel stated heredity is dependent on certain mathematical rules. Despite subsequent discoveries of exceptions, e.g. incomplete dominance, codominance, and linkage, the principles underlying genetic inheritance are based on the findings of Mendel.

11.2 Monohybrid and Dihybrid Cross.

The monohybrid cross is related to the transmission of one pair of divergent characteristics. As an example, in the case of a crossed homozygous dominant and recessive cross, all members of the first filial generation (F₁) would have the phenotype of the dominant. Crossing of these F₁ individuals gives a phenotypic ratio of 3:1 in F₂, which is the expression of the dominant and the recessive phenotype. The genotypic ratio is 1: 2: 1, which represents allele segregation.

The Law of Segregation is directly demonstrated with the help of the monohybrid cross. It proves that alleles do not combine during the formation of gametes. The ratio which is predictable proves that the inheritance within is regulated by particulate factors and not through blending.

A dihybrid cross involves the study of the inheritance of two traits at the same time. A cross between individuals who are heterozygous with the two phenotypes leads to a F₂ generation ratio population of 9: 3: 3: 1. In this ratio, there is independent assortment of alleles. The dihybrid cross therefore gives experimental evidence to the Law of Independent Assortment.

The following crosses show the principles of probability when applied to genetics. Prediction of genotypic and phenotypic results is commonly

performed by using punnett squares. Monohybrid and dihybrid crosses are analyzed and this study is the foundation of understanding more complicated patterns of inheritance and genetic interactions.

11.3 Chromosomal Basis of Inheritance.

The chromosomal theory of inheritance combines the points of Mendelian theory with those of the cytologic observation. It suggests the presence of genes on the chromosomes and that the manner in which the chromosomes behave during the meiosis process is what determines patterns of inheritance. The homologous pairs consist of chromosomes and one chromosome is inherited by each parent. Homologous chromosomes separate during meiosis in different gametes, and this is similar to the Law of Segregation of Mendel.

Independent assortment occurs since the homologous pairs of chromosomes randomly align at the metaphase plate during the meiosis I. This haphazard position results in the variation in the mixture of maternal and paternal chromosomes in gametes. The process of crossing over in prophase I leads to interchange of genetic material between homologous chromosomes, which leads to production of recombinant offspring.

The determination of sex in most organisms also gives more support to the chromosomal basis of inheritance. The presence of XX in human beings leads to the development of females whereas XY leads to development of males. Having sex-linked characteristics like being color blind, a pattern of inheritance can be demonstrated to be related to this particular chromosome.

Chromosomal theory integrated both genetics and cell biology by showing that genes are physical entities and they are located in the form of a linear structure in chromosomes. This finding formed the foundations of the modern molecular genetics.

11.4 Mutation and Variation

Mutation is a sudden genetic change which is inherited. It can be associated with changes in the DNA sequence, structure of the gene or the quantity of chromosomes. Genetic variation majorly involves mutations which serve as raw material to evolution.

The gene mutations can be as a result of substitution, insertion or deletion of nucleotides. The changes have the potential to modify the structure and functionalities of proteins. The structural changes that occur in chromosomal mutations include deletions, duplications, inversion and translocations. Changes in chromosome numbers i.e. aneuploidy and polyploidy are also mutations.

Although most of the mutations are neutral or harmful, others have adaptive benefits in particular environmental situations. These variations are acted upon by natural selection favoring beneficial ones. The evolutionary processes therefore require mutation and variation.

Due to mutation as well as recombination during meiosis and random fertilization, variation comes up. Genetic variability of populations improves survival and adaptation to the new environment.

11.5 Molecular Structure of DNA

The hereditary basis is a deoxyribonucleic acid (DNA). Its finding of the double helical structure was a mechanistic description of replication and gene expression.

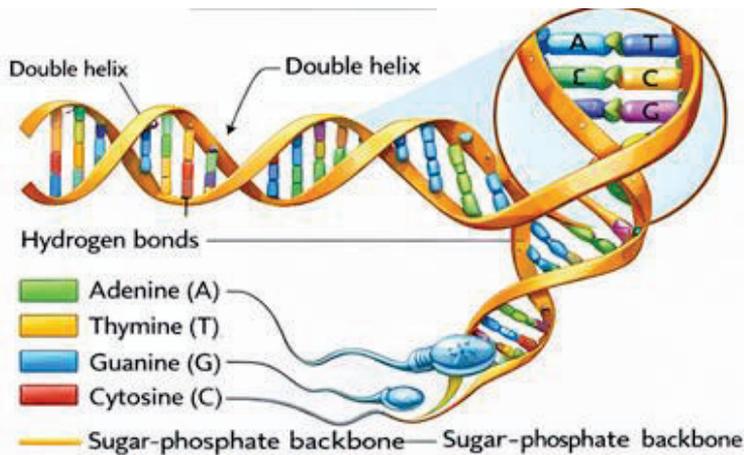


Figure 11.1: Structure of DNA

The figure illustrates the structure of the DNA that is in a double helical form with two antiparallel strands that are wound around a shared axis. It emphasizes the pairs of sugar and phosphate backbone as well as the complementary pairs between adenine and thymine, and guanine and cytosine. The interpretation of this structure demonstrates the process of genetic continuity mechanism. To make sure that the replication process takes place correctly, complementary base pairing is provided, and the order of the bases is a genetic information that makes proteins.

DNA is made up of nucleotides that are made up of deoxyribose sugar, a phosphate group and a nitrogenous base. These bases are cytosine, guanine, adenine and thymine. The complementary bases are stabilized by the hydrogen bonds between the bases. The replication enzymes can work effectively because the strands are oriented in an antiparallel manner.

The genetic code is the order of the sequence of the nucleotide which determines the synthesis of the proteins via transcription and translation. DNA has a molecular structure that describes the mechanism of storage, replication and transfer of genetic information.

Table 11.1: Differences Between DNA and RNA

Feature	DNA	RNA
Full Name	Deoxyribonucleic Acid	Ribonucleic Acid
Sugar	Deoxyribose	Ribose
Nitrogen Bases	A, T, G, C	A, U, G, C
Strands	Double-stranded	Usually single-stranded
Location	Nucleus, mitochondria	Nucleus and cytoplasm
Function	Stores genetic information	Protein synthesis and gene expression
Stability	More stable	Less stable

The table illustrates structural and functional differences between DNA and RNA such as differences in type of sugar, types of nitrogenous bases, strand structure, stability and biologic functions. These differences are interpreted by focusing on complementary functions in the cell. DNA is the potential form of genetic information, and RNA is the one that is involved in protein production and gene expression. Structural differentiation between deoxyribose and ribose sugars helps in discrepancy in stability, which is in agreement with their different biological functions.

The laws of genetics, dating back out to Mendelian inheritance, and the molecular structure, explain the persistence of genetic information through generations and the process of variation. Heredity, evolution, and contemporary biotechnology can be explained by these concepts.

Summary of the Chapter

This chapter introduces the key principles of genetics, starting with the laws of inheritance of Mendel, and going as far as the molecular frame of DNA. The experiments conducted by Mendel revealed the laws of dominance, segregation and independent assortment and proved that the inheritance is dictated by discrete units called genes. Examples of monohybrid and dihybrid crosses of experimental interest furnish evidence of these principles, and also demonstrate the predictable patterns of phenotypic and genotypic ratios. These traditional genetic theories are the foundations of learning about the process of the transfer of traits between one generation and another.

Chromosomal theory of inheritance combines both the ideas of Mendel with those of cytology, describing the fact that genes are on chromosomes and that their action in the process of meiosis explains the patterns of inheritance. Genetic diversity is caused by such processes as segregation, independent assortment and crossing over. The raw material of evolution is mutation and variation which introduces new genetic changes. DNA as the genetic material works at the molecular level, and its double helical structure facilitates the accurate replication and storage of information. The structural variations between RNA and DNA are based on the complementary functions in heredity and protein synthesis. The combination of these principles has been used to explain the transmission, expression and modification of genetic information which is the basis of modern biology.

Review Questions

1. Describe the laws of inheritance as pioneered by Mendel.
2. Give an example of a cross between two individuals of the same hybrid and explain the resulting phenotypic and genotypic ratios.

3. Identify a dihybrid cross and explain its relevance to the showcase of independent assortment.
4. Talk about the chromosomal inheritance.
5. Describe how meiosis plays out in favour of the laws of Mendel.
6. Provide a definition of mutation and explain various forms of mutation.
7. Discuss about where genetic variation comes in and why it is important.
8. Explain the molecular makeup of DNA?
9. Establish the difference between DNA and RNA.
10. Discuss the way in which DNA structure provides continuity of genes.

UNIT IV: Developmental Biology and Animal Physiology

Chapter 12

Gametogenesis and Fertilization

12.1 Spermatogenesis

Gametogenesis is the division in which an exclusive reproductive cell, or gametes, is developed. This process in males is known as spermatogenesis and it takes place in the seminiferous tubules of the testes. Spermatogenesis is vital in the generation of haploid sperm cells that are able to fertilize the female gamete. This starts when one reaches puberty and goes on to the reproductive life of the male giving birth to millions of sperm in per day.

Spermatogenesis starts at spermatogonia which are diploid cells of the germ which are found on the side of the seminiferous tubules. These cells mitogate and reproduce their numbers to generate primary spermatocytes. The primary spermatocytes undergo meiosis I where the homologous chromosomes pair up and segregate giving rise to two haploid secondary spermatocytes. Every secondary spermatocyte is subjected to meiosis II in which two haploid spermatids are produced. Therefore, a single spermatocyte eventually gives rise to four spermatids.

The spermatids then pass through a process spermiogenesis transformation. At this phase they develop into fully grown spermatozoa. Structural alterations consist of condensation of the nucleus, making up of the acrosome out of the Golgi apparatus, the development of a flagellum to move around, and the concentration of mitochondria in the middle piece to provide energy. Superfluous cytoplasm is lost leading to sperm cells that have been streamlined to move.

The hormones that control spermatogenesis include the follicle-stimulating hormone (FSH) and luteinizing hormone (LH), which stimulate the testes. Interstitial cells produce testosterone that aids in the development of sperm. This process guarantees genetic variability due to a process of meiotic recombination and the production of several gametes to increase the chances of fertilization.

12.2 Oogenesis

The formation of female gametes, ova or eggs is called oogenesis. It takes place in the ovaries and it starts in embryonic development. In contrast to spermatogenesis that leads to the production of millions of gametes at any given time, oogenesis only leads to the production of a few mature ova throughout the reproductive lifespan of a female.

The process starts with the oogonia that are diploid germ cells that divide by mitosis to form the fetus. These cells develop into first-degree oocytes and go into meiosis I and they are held up at the prophase I till puberty. During the menstrual cycle at puberty, the hormone stimulation leads to completion of meiosis I in the chosen primary oocytes. This division results in one big secondary oocyte and a smaller polar body. The asymmetric segregation makes sure that the secondary oocyte gets the majority of cytoplasm and nutrients that are required by the embryo to develop.

The secondary oocyte enters meiosis II and stays at the metaphase II stage until fertilization takes place. In case fertilization occurs, the second round of meiosis is done, which yields a mature ovum and a second polar body. In case of non-fertilization, the secondary oocyte deteriorates.

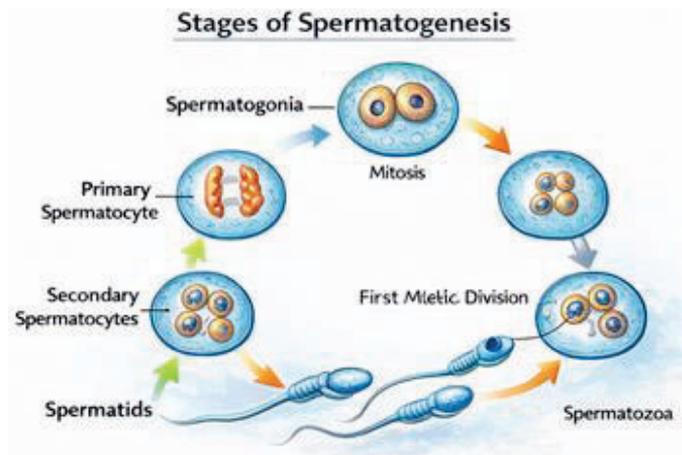


Figure 12.1: Stages of Spermatogenesis

Unequal cytoplasmic division and prolonged meiosis characterize oogenesis. These characteristics make the ovum large, nutrient endowed and able to sustain early embryonic growth. The ovum maturation and ovum release are co-ordinated by hormonal regulation, which involves the FSH, LH, estrogen, and progesterone.

12.3 Structure of Gametes

Gametes are specialized haploid cells, which are used in sexual reproduction. The sperm (male gamete) is generally small, flagellar and morphologically designed to send genetic information to the ovum. It is made of a head, middle piece and tail. The head has a condensed nucleus and it is crowned by the acrosome which carries enzymes that help in breaking the protective layers of the egg. The middle part has a number of mitochondria that serves to give the body energy to move. The flagellum or tail of the sperm pushes the sperm towards the ovum.

The ovum is a large female gamete that is non-motile and cytoplasmic. It has a haploid nucleus, and cytoplasmic reserves which help in the early embryonic developmental phases. Mammals have protective layers that

surround the ovum including zona pellucida and corona radiata. These layers control entry of sperms and avoid polyspermy.

The functional specialization is manifested by the structural differentiation of sperm and ovum. The sperm is specialized to be mobile and encodes genetic materials whereas the ovum is specialized to provide nourishment and sustenance to the growing embryo.

12.4 Process of Fertilization

Fertilization is a combination of male and female gametes, which leads to the production of a diploid zygote. It reinstates the diploid set of chromosomes and embryonic development takes place. In the majority of animals, fertilization is either external in water, or internal in the female reproductive tract.

It starts as the sperm attaches to the ovum covering its outer layers. Capacitation is a process that occurs in mammals in which sperm are improved to penetrate the egg. This is followed by the acrosomal reaction whereby enzymes that are released by the acrosome break down the zona pellucida to enable the sperm to penetrate the ovum plasma membrane.

Combination of sperm and ovum membranes results in the introduction of sperm nucleus into the cytoplasm. This causes cortical responses in the ovum to inhibit the entry of more sperm in the ovum to guarantee monospermy. Miosis II in the ovum is completed when the ovum is fertilized. These male and female pronuclei then merge to produce a zygote, which is a diploid.

Metabolic processes are active in the zygote during fertilization; cleavage and embryonic development leads to the formation of embryos. It also identifies the genetic sex of the offspring in most organisms.

12.5 Significance of Fertilization

Fertilization is an important aspect of sexual reproduction and continuity of genes. It replenishes the number of the diploid chromosomes, which secures stability of genetic information in successive generations. The genetics are a blend of two parents and this brings variation and this increases flexibility and evolution.

The hybridization of the gametes triggers developmental processes in the zygote, which results in cleavage and multi-cell structures. A sex chromosomal species also determines sex through fertilization. Fertilization helps in the survival and evolution of the populations due to the incorporation of different genetic traits.

The process of gametogenesis and fertilization is what will guarantee continuation of the species. Although gametogenesis results in production of specialized haploid cells via the meiosis, fertilization brings them together to give rise to a genetically distinct individual. This is demonstrated by the combination of cellular, genetic and hormonal processes that maintain life.

Summary of the Chapter

In relation to reproduction, this chapter describes gonadogenesis and fertilization as they guarantee reproduction and the continuation of life. Spermatogenesis is the production of haploid sperm cells in the testes by means of a mitotic and meiotic separation and structural differentiation. It gives birth to many motile gametes that were developed to be able to deliver genetic material. On the other hand, oogenesis takes place in the ovaries and leads to the development of one large and nutrient-packed ovum, after a lopsided division of cytoplasm. Meiosis in males and females produces genetic variation as a result of recombination and independent assortment.

Functional specialization has been reflected by the structure of gametes: sperm is small and motile with acrosome and flagellum, whereas ovum is large and has cytoplasmic reserves needed in the initial stage of development. Fertilization is a process that entails the merging of the male and female gametes, resumption of the diploid tally and embryonic development. It guarantees genetic continuity, sexual specification in most species, and the introduction of variation that is needed to adapt and evolve. The combination of gametogenesis and fertilization is the compilation of cells, genetic and hormonal processes to ensure the continuation of species.

Review Questions

1. Explain how spermatogenesis takes place.
2. describe the oogenesis process and identify its peculiarities.
3. Oppose spermatogenesis and oogenesis.
4. Write about the arrangement of the sperm cell and its functional value.
5. Discuss how the ovum is put together and what its development adaptations are.
6. Explain the fertilization mechanism of mammals.
7. Does the acrosomal reaction occur? describe its involvement in fertilization.
8. Discuss the process of fertilization and how it reestablishes the diploid number of chromosomes.
9. Explain the importance of meiosis during gametogenesis.
10. Fertilization is a biological process that is important in the sexual reproduction process. Explain the importance of fertilization.

Chapter 13

Early Embryonic Development

13.1 Types of Eggs

Embryonic development starts as soon as fertilization has taken place and is composed of a combination of coordinated cellular processes that convert a multicellular embryo out of a single-celled zygote. The character and course of the initial development is much influenced by the kind of egg, and specially by the quantity and distribution of the yolk. Yolk is a source of food to the embryo being developed and its amount also plays a major role in determining cleavage patterns and developmental mechanisms. There are two categories of eggs, microlecithal, mesolecithal and macrolecithal, according to the amount of yolk. Microlecithal eggs have extremely small quantities of yolk which are uniformly scattered within the cytoplasm. They commonly occur in mammals and some invertebrates. Mesolecithal eggs have a moderate level of yolk usually accumulated at one pole like in amphibians. The Macrolecithal or telolecithal eggs have a concentration of yolk at one end as is seen in birds and reptiles.

The eggs can also be categorized based on the yolk distribution as isolecithal (evenly distributed), telolecithal (highly concentrated toward one pole), and centrolecithal (yolk is concentrated in the centre as in insects). The arrangement of yolk defines the cleavage of zygote. Both in eggs that contain a lot of yolk, cell division can be confined to certain areas.

During the oogenesis, the egg is determined as polar, which forms animal and vegetal poles. The animal pole is generally a pole that has less yolk and experiences a more vigorous cell division whereas the vegetal pole is one

that has a lot of yolk and its cell division is rather slow. This polarity is important in the future embryonic axes and tissue differentiation.

Therefore, the kind of egg has a direct impact in both the cleavage pattern and the later embryonic development and its developmental strategy. Divergences in the structure of the eggs are adaptive reactions to the environmental factors and reproductive policies.

13.2 Cleavage

Cleavage is the process of the subsequent quick mitotic divisions, which follow fertilization. These fissures convert the unicellular zygote to a multicellular one known as the blastula. As opposed to normal division of cells, cleavage is repeated nuclear division with little embryonic growth. This causes the size of individual cells also referred to as blastomeres, to gradually reduce.

Yolk quantity and distribution affects cleavage patterns. In microlecithal eggs, cleavage typically occurs in a whole embryo i.e. holoblastic. Holoblastic cleavage can be either equal or unequal and results in blastomeres of the same or different size respectively. Cleavage in mesolecithal eggs is also a holoblastic but unequal one as a result of concentration of yolk at the vegetal pole.

Conversely, the eggs of macrolecithal species are subjected to meroblastic cleavage, in which division is not complete as the large yolk suppresses cleavage fissures. In birds, cleavage is a discoidal cleavage that only takes place in a minute cytoplasmic area referred to as the blastodisc. In insects, cleavage is superficial, which only takes place at the fringe of the egg.

The planes of cleavage are also tilted differently. Radial cleavage leads to symmetrical pattern of blastomeres, spiral cleavage leads to a twisting

pattern, bilateral cleavage leads to early symmetry and rotational cleavage which is observed in mammals has unusual cleavage patterns.

13.3 Blastulation

After cleavage, blastulation takes place and the blastula is formed, a hollow or partially hollow sphere of cells which surrounds a fluid filled cavity known as the blastocoel. Blastula structure is different when the egg type and cleavage pattern are different.

In animals whose cleavage is holoblastic, the blastula normally develops a sphere-shaped structure of the cells that surround a blastocoel in the middle. The cleavage is unequal in amphibians such that the blastocoel is pushed towards the animal pole. In reptiles and birds, the blastula is flat and it rests on a mass of yolk.

The blastocoel is also found to be significant in terms of giving space to allow cell migration during gastrulation. It inhibits early contact between the various cell layers, and promotes morphogenetic movements. The early cell division is completed with the formation of the blastula and the beginning of differentiation and tissue organization.

In mammals, the blastulation generates a specialized organ that is referred to as the blastocyst. The blastocyst is composed of an outer cell layer termed as trophoblast and which helps in the formation of the placenta and an inner cell mass which forms the embryo itself. This phase depicts more complexity in embryonic structure.

Blastulation is a step where the simple cell multiplication takes a step towards organized tissue differentiation. It creates the form upon which subsequent developmental occurrences are to take place.

13.4 Gastrulation

Gastrulation: This is one of the key steps in embryonic development where the simple blastula is re-formed to form a multilayered structure known as the gastrula. This phase is characterized by massive cell migration and reorganization which forms the primary germ layers and body axes.

Gastrulation is initiated by invaginations, involutions or migrations of local cells. These movements differ in all organisms but have the same purpose formation of ectoderm, mesoderm and endoderm. The blastocoel is partially or entirely replaced with new space known as the archenteron which later forms the digestive tract.

Gastrulation in the amphibians includes invagination of the vegetal pole to create a structure called the blastopore. The cells move inwards and intersperse between the inner and outer layers forming the mesoderm. In birds and mammals, gastrulation includes the development of a primitive streak, in which cells move towards the centre, as a result of which germ layers are formed.

The body plan of the organism is determined at gastrulation. It establishes anterior-posterior, dorsal-ventral and left-right axes. The molecular signals that control gene expression and differentiation mediate the rearrangement of cells during this stage.

Germ Layer Formation During Gastrulation

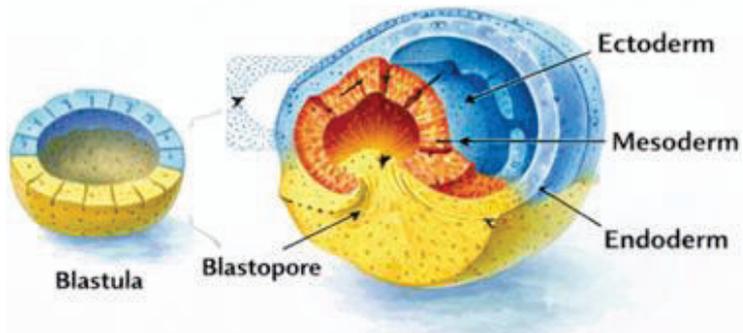


Figure 13.1: Germ Layer Formation During Gastrulation

Figure shows how the blastula differentiates into a gastrula with the emphasis on the development of ectoderm, mesoderm, and endoderm by means of cell migration and invagination. It shows how archenteron develops, and the way the germ layers are arranged in relation to one another. This process is important in the formation of the basic body plan and hence its interpretation. Gastrulation is a critical time in embryogenesis, as the spatial organization of the germ layers who will develop into organs and specialise into tissues.

13.5 Formation of Germ Layers

Germ layer formation is one of the most important product of gastrulation. The ectoderm is the most outer layer and it gives rise to parts like the epidermis, nervous system and organs of sense. The mesoderm that develops between ectoderm and endoderm give rise to the muscle, bones, circulatory system, and reproductive organs. The deepest layer is the endoderm and experiences the derivation of the lining of the digestive tract and related organs like the liver and pancreas.

Gene regulation and intercellular signaling regulate the differentiation of the germ layers. The cells in each layer gain certain identities and the formation of the organs at the later stage of development. Three major germ layers define the difference between triploblastic and diploblastic forms of animals.

Structural and functional integration of the embryo during the development process is guaranteed by the coordination of germ layers. Each of the layers comes into contact with the rest, which affects tissue patterning and organogenesis. Mistakes at this phase may cause developmental disorders.

The development of the embryo during the early embryonic stages (cleavage until formation of the germ layer) is an example of the amazing transformation that occurs to a single cell into a complex and organized embryo. These are processes that show strict coordination of cell division, movement and differentiation that forms the foundation of multicellular organisms.

Summary of the Chapter

This chapter explains early embryonic development starting with embryonic structure and classification of eggs and move on to cleavage, blastulation, gastrulation and formation of germ layer. The nature and location of the yolk in the egg is very important in the establishment of the cleavage pattern and initial developmental stages. The process of cleavage is characterized by the mitotic divisions that multiply cells without much growth resulting into the formation of the blastula. Blastulation forms a hollow cellular network that preconditions the embryo to the far-scale cellular rearrangements.

The developmental process is defined at gastrulation, which is a pivotal point in the development of the embryo, in which a simple blastula is restructured into a multilayered gastrula. It is the stage which defines the primary body axes and results in the development of the three germ layers, ectoderm,

mesoderm and endoderm. The formation of organogenesis is based on the formation of certain tissues and organs by each germ layer. The mechanisms outlined in this chapter explain how these cellular division, migration, and differentiation processes allow a single-celled zygote to form a structurally-organized embryo and the cellular division, migration, and differentiation processes are specific and intricate.

Review Questions

1. Sort eggs according to the amount and distribution of the yolk.
2. Discuss the effects of yolk on the cleavage patterns.
3. Discuss the various examples of cleavage.
4. Explain and define the blastulation and the structure of the blastula.
5. Talk about the importance of the blastocoel during embryogenesis.
6. Explain gastropod gastrulation in amphibians.
7. Discuss the development and the purpose of the primitive streak in mammals and birds.
8. Position Germ layers Explain the meaning of germ layers and name the three major germ layers.
9. Explain derivatives of ectoderm, mesoderm and endoderm.
10. Discuss why gastrulation is important in setting up of the fundamental body plan.

Chapter 14

Fundamentals of Animal Physiology

14.1 Digestive System

The digestive system has the role of ingesting, digesting, absorbing, and assimilating food and the disposition of unabsorbed waste. The digestive system in animals is complex depending on the diet and the degree of organization. Since the most primitive digestive processes involve basic intracellular digestion in single-celled organisms, to the intricately adapted alimentary canals in vertebrates, the adaptations of digestive systems are necessary to make sure that nutrients necessary to support growth, maintenance and reproduction are effectively used.

In vertebrates, the digestive tract is a full alimentary tract running between the mouth and anus, with other related glands like salivary glands, liver and the pancreas. The food is digested in the mouth where mechanical digestion starts with the help of mastication and chemical digestion with the help of salivary enzymes. The bolus of food moves through the esophagus to the stomach whereby muscular movements and gastric juices also digest proteins.

The major location of digestion and absorption is the small intestine. The pancreatic and intestinal glands enzymes digest carbohydrates, proteins, and lipids into absorbable molecules. The intestinal lining of the small intestine has villi and microvilli, which enhance a higher surface area in which nutrients are efficiently absorbed. The absorbed nutrients are either released into the blood stream or lymphatic system to circulate to the body tissues.

The large intestine takes in water and electrolytes, and the excrements are spread out through the anus. Neural and hormonal mechanisms control the

digestive system and coordinate the enzyme secretion and motility. Efficient digestion assures of energy production and metabolic balance which is essential in the survival of animals.

14.2 Respiratory System

The respiratory system is the system that promotes the exchange of the gases between the body and the outer surroundings. Oxygen is needed to carry out cellular respiration, and carbon dioxide is needed to be eliminated as a metabolic byproduct. The respiratory system differs in structure between animals as a result of adaptation to the environment.

The gills are usually the characteristic features of aquatic animals, and they offer a huge area of diffusion through which water gases enter the blood. Countercurrent exchange mechanism promotes the efficiency of oxygen absorption. Use of lungs by terrestrial animals. Lungs are made up of many alveoli which enhance exchange of gases.

In mammals including human beings, air flows into the body through the nasal passage, trachea, pharynx, larynx, and bronchi to the alveoli located in the lungs. The walls of the alveoli are very thin and well endowed with capillaries, which facilitates quick exchange of oxygen in blood and carbon dioxide in blood. The diaphragm and intercostal muscles help in breathing movements.

The respiratory efficiency is based on the ventilation, diffusion and blood transport. The circulatory system is closely related to the respiratory system to sustain the supply of oxygen and eliminate carbon dioxide. Adequate breathing is necessary to maintain the aerobic metabolism and energy synthesis.

14.3 Circulatory System

The circulatory system circulates the oxygen, nutrients, hormones and waste products of the body. It secures co-ordination between organ systems and homeostasis. Depending on the type of animal circulation patterns can be open or closed.

In open circulatory system the blood or hemolymph moves in body cavities and direct bath-bath to tissues. The system is common in most invertebrates. With closed circulatory system, the blood is contained in the vessels and thus it is efficiently and controlled circulated. The vertebrates have closed circulatory systems.

The heart is a muscular organ, which in mammals, pumps blood into the blood vessels (arteries, veins, and capillaries). It has got four chambers, two atria and two ventricles. The deoxygenated blood is delivered to the right side of the heart and pumped to the lungs (pulmonary circulation) whereas an oxygenated blood is delivered to the body by the pumping of the left side of the heart (systemic circulation).

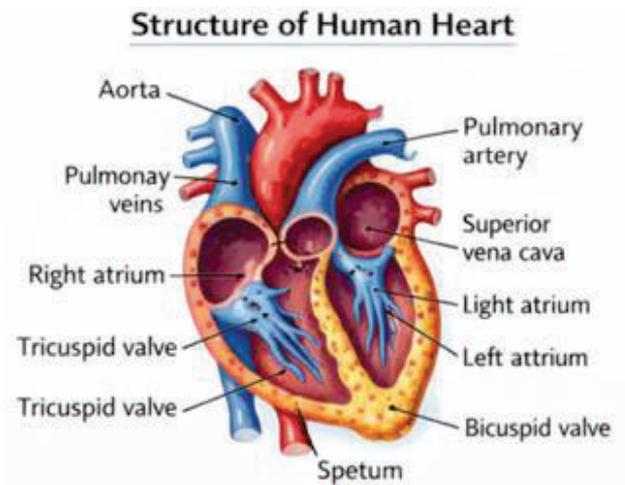


Figure 14.1: Structure of Human Heart

The figure illustrates the four-chambered shape of the human heart comprising of right and left atria, right and left ventricles, valves, and greater blood vessels. It depicts the partitioning of the oxygenated and deoxygenated blood with septa and valves. This structure is interpreted in such a way that it gives emphasis on functional efficiency in the double circulation. The total separation does not allow mixing of blood so that the blood delivers maximum oxygen to tissues and helps to sustain high metabolic rates.

The circulatory system consists of blood elements like red blood cells, white blood cells, platelets and blood plasma as well. Oxygen is carried to the body by red blood cells through the process known as hemoglobin, white blood cells help in immunity, and platelets help in clotting. The combined action of the heart, vessels, and blood is what keeps the physiological balance.

14.4 Excretory System

The excretory system eliminates metabolic wastes products and maintains water and electrolytes homeostasis. Cellular metabolism generates nitrogenous wastes like ammonia, urea and uric acid, which have to be disposed of or they cause toxicity.

The primary excretory organs of the vertebrates are the kidneys. Kidneys have many functional units, which are called nephrons. The glomerulus receives blood and the filtration takes place. The filtrate flows through tubules and selective reabsorption and secretion occurs. Glucose and ions are useful substances that are reabsorbed, and the waste products are left in the filtrate to be excreted in the form of urine.

The nature of the nitrogenous waste discharged differs with animals. Aquatic animals frequently release the ammonia into water, and terrestrial mammals release urea that needs a lesser amount of water to get rid of. Uric acid is excreted in birds and reptiles and it will help to conserve water in arid places.

The excretory system is also important in keeping the pH in check as well as blood pressure. It helps maintain homeostasis and internal stability by regulating the volume of fluids and the level of the electrolytes.

14.5 Nervous and Endocrine Systems.

Body functions are coordinated and regulated by the nervous and endocrine system. The nervous system responds quickly and in the short term by electrical impulses whereas the endocrine system is involved in long-term processes by hormones.

The brain and the spinal cord comprise the central nervous system, and the peripheral nerves make up the nervous system. The impulses are conveyed by the neurons with the help of the synapses, which allow communicating between the sensory receptors, integration centres, and effectors. Reflexes give instant protection mechanisms without delay and the upper brain functions aid in learning and memory.

The endocrine is a system of glands that provide hormones that are released into blood. The hormones control growth, metabolism, reproduction and homeostasis. Key endocrine glands consist of gonads, pancreatic, adrenal glands, thyroid and pituitary glands. Feedback mechanisms tend to regulate hormones to stabilize them.

The coordination of physiological responses is guaranteed by the integration of nervous and endocrine systems. As an illustration, stress responses entail neural stimulation as well as hormonal discharge. These systems, in combination, provide internal balance and allow adaptation to the changes in the environment.

Animal physiology shows the interaction of organ systems in order to support life. Nourishment is delivered through the digestive system, oxygen

through respiration, the distribution of materials through circulation, the elimination of wastes through excretion and the coordination through regulatory systems.

Summary of the Chapter

In this chapter, the basic concepts of animal physiology are described through the analysis of the key organ systems that body needs to maintain a natural balance. Digestive system guarantees the digestion of food, uptake of nutrients, and removal of unfixated substances, hence making energy and building blocks required to grow and metabolize. It is through the respiratory system that the body carries out the gaseous exchange and provides oxygen to the cells and eliminates carbon dioxide as a by-product. These are processes that are closely intertwined with the circulatory system that carries gases, nutrients, hormones, and metabolic wastes around the body. An example of structural specialization is the four-chambered heart in mammals that facilitates high metabolic needs and efficient double circulation.

The excretory system keeps the homeostasis by removing nitrogenous wastes and water and electrolyte balance. The kidneys maintain the internal chemical balance through filtration, reabsorption and secretion. The physiological functions are co-ordinated and regulated by the nervous and endocrine systems. The nervous system facilitates fast communication and instant reactions by using electrical impulses whereas the endocrine system offers slower yet long term regulation with controlling hormones. These systems will work in a coordinated way to produce a homeostasis, environmental response, and survival of the organism.

Review Questions

1. Explain the anatomy and the mechanical activity of the digestive system.

2. Discuss the digestive and absorption process of mammals.
3. Explain the respiration organization and process in humans.
4. Compare closed and open circulatory systems.
5. Explain the structure and the workings of the human heart.
6. Demonstrate how urine is formed in the kidney.
7. Compare excretion of ammonia, uric acid and urea.
8. Provide a description of the nervous system organization.
9. Discuss the roles of the significant endocrine glands.
10. Explain how the various organs interact to achieve homeostasis.

UNIT V: Ecology, Evolution and Applied Zoology

Chapter 15

Principles of Ecology

15.1 Levels of Ecological Organization

Ecology is a sub-discipline of biology that focuses on interactions of organisms and their surroundings. It tries to examine the relationship of living organisms to each other and to the physical aspects that affect their survival, distribution as well as abundance. Ecological analysis is systematized into hierarchical levels, with each level of hierarchy being more complex and more integrated.

The smallest ecological organization is the individual organism. Every organism is a part of the environment that responds to the abiotic factors like temperature, light, water, and nutrients. The survival and reproductive success are determined by adaptation at the individual level.

A population is a group of people of the same species in a specified geographic region at a given time. Factors that are studied in population ecology include, population size, population density, rate of population growth, birth rate of a population, mortality and dispersal patterns. The population interaction affects the genetic diversity and evolution.

A community consists of populations of diverse species that live and interact in the same region. Some of the interspecific relationships studied by community ecology include competition, predation, mutualism, commensalism, and parasitism. Species diversity, dominance and ecological succession will determine the structure of a community.

An ecosystem is a functional organization that consists of a community of living organisms and the abiotic environment. It focuses on the circulation of energy and recycling of nutrients among the living and non-living parts. The size and complexity of ecosystems can be of small ponds to large forests and oceans.

The topmost degree of ecological organization is the biosphere which is the totality of ecosystems on earth. It is a combination of the interactions of the atmosphere, hydrosphere, lithosphere, and the living organisms worldwide. Knowledge of such levels is what makes it possible to study the process of ecology in a systematic manner.

15.2 Ecosystem Structure and Function.

An eco system is a system of biotic and abiotic components that interact. The biotic elements are the producers, consumers and decomposers. Organic compounds are built up by solar energy and are produced by the producers, mainly the green vegetation and the photosynthetic microorganisms. Consumers gain energy through feeding on other organisms and decomposers recycle dead organic matter through the release of nutrients into the environment.

Some of the abiotic components are the physical and chemical elements which are sunlight, temperature, water, soil, and minerals. These affect the productivity and the distribution of species. How an ecosystem is organized and how these parts interact is represented in the structure of an ecosystem.

Ecosystem functioning entails energy circulation and cycling of nutrients. The energy gets into the ecosystem by photosynthesis and passes through trophic levels by feeding relationship. Energy is not recycled like nutrients, it is lost as heat at each trophic level in a cyclical manner as per laws of thermodynamics.

Ecosystems have a major functional feature in productivity. The rate with which producers transform solar energy into chemical energy is known as primary productivity. Secondary productivity is energy uptake by the consumers. The level of stability in the ecosystem is dependent on the balance of production and decomposition.

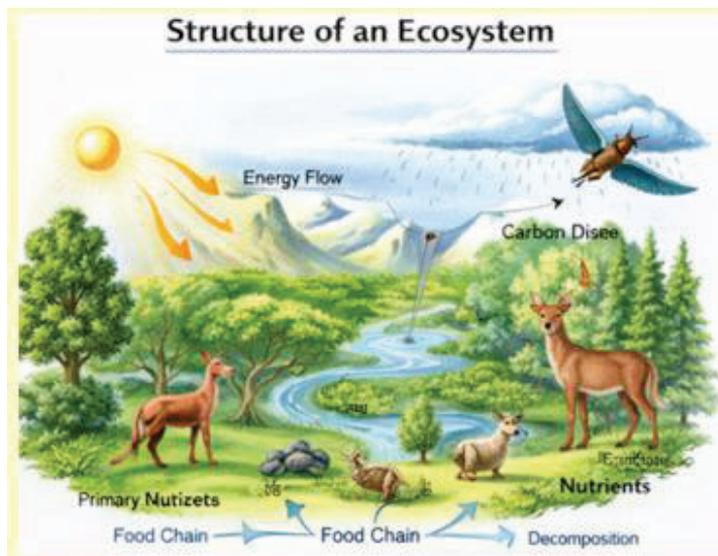


Figure 15.1: Structure of an Ecosystem

The figure indicates how the biotic elements; producers, consumers, and decomposers relate to abiotic factors; sunlight, soil, water, and nutrients. It is a diagrammatic view of how energy moves to the higher trophic levels through the producers and how nutrients can be recycled through the decomposers. This structure has been interpreted in a manner that gives importance to functional integration. The energy moves in one way direction, but nutrients move in a circular way providing ecological balance and sustainability.

15.3 Food Chain and Food Web

Food chain is an order of organisms where energy and nutrients are transferred as one organism preys on another. It starts with the producers, then the primary consumers (herbivores) and secondary consumers (carnivores) and tertiary consumers. All stages of the chain indicate troic levels.

The food chains are of two major types: grazing food chain and detritus food chain. Food chains that feed on grass begin with green plants and end up with carnivores. Detritus food chains commence with dead organic material and they involve decomposers and detritivores. The two provide stability on the ecosystems.

Natural ecosystems can seldom have linear feeding relationships. Rather, organisms engage in interlocking structures referred to as food webs. Food webs are complex feeding interactions concerning a food chain made of several food chains. Food webs increase the level of resilience in an ecosystem by offering alternative routes of energy flow.

Species diversity leads to an increase in the complexity of food webs. The impact of a disturbance of a single species can have an impact on several trophic relationships, which demonstrates how organisms depend on each other in an ecosystem.

Energy flow and ecological pyramids 15.4.

Energy circulation in the ecosystems is based on the fact that energy decreases at consecutive trophic levels. The amount of energy that is passed on to primary consumers is merely a small part of what producers obtain and to the higher troic levels even less. Metabolic processes lose most of the energy in form of heat.

Ecological pyramids diagrammatically illustrate the trophic structure and energy changes in the ecosystems. They can represent numbers, biomass or energy of each trophic level.

Table 15.1: Types of Ecological Pyramids

Type of Pyramid	Represents	Shape	Example
Pyramid of Numbers	Number of organisms at each trophic level	Upright or Inverted	Grassland (upright), Tree ecosystem (inverted)
Pyramid of Biomass	Total biomass at each trophic level	Upright or Inverted	Forest (upright), Pond ecosystem (inverted)
Pyramid of Energy	Flow of energy through trophic levels	Always upright	All ecosystems

The table illustrates the three broad categories of ecological pyramids; pyramid of numbers, pyramid of biomass and pyramid of energy, in terms of their structural features and ecological implications. The interpretation highlights that although there is the possibility of pyramids of numbers, biomass being sometimes inverted based on the type of ecosystem, the pyramid of energy is always upright, since there is unidirectional loss of energy at every trophic level. This presentation strengthens the idea of energy restriction within ecosystems and the significance of the producers to maintain higher trophic levels.

Energy flow follows the second law of thermodynamics which points out that transformation of energy is inefficient and part of the energy is lost in

the form of heat. This is the reason why the food chains seldom extend beyond four or five trophic levels.

15.5 Biogeochemical Cycles

Biogeochemical cycles refer to the circulation of vital elements between the physical world and the living organisms. These cycles guarantee that there is a continuous recycling of nutrient which is vital in life.

Evaporation, condensation, precipitation, and transpiration are some of the processes involved in the water cycle, which ensure the availability of water in the ecosystem. Photosynthesis, respiration, decomposition, and combustion of carbon are involved in the process to maintain the quantity of carbon dioxide in the atmosphere.

The nitrogen cycle comprises of nitrogen fixation, nitrification, assimilation, ammonification and denitrification. Fixing Nitrogen-fixing bacteria transform the nitrogen in the atmosphere to forms used by plants. Phosphorus cycle is the flow of phosphorus in rocks, soil, water and living beings.

The cycles provide ecological balance through restoring nutrients. These cycles can be disrupted by the human activities, including deforestation, industrialization, and the excessive use of fertilizers which cause environmental problems such as climate change and eutrophication. The ecological principles explain how living organisms and the environment are connected.

Summary of the Chapter

In this chapter, the author describes the basic principles of ecology by exploring the interactions between organisms and their surrounding in varying levels of organization. The ecological hierarchy continues to the

individual organisms to populations, communities, ecosystems and finally the biosphere. All levels are more complex and dependent on each other. The ecosystems are organized based on biotic factors, such as producers, consumers, and decomposers, and abiotic factors, including light, water and nutrients. Energy flow and nutrient cycling determine their functioning and provide stability and sustainability.

Food chains and food webs are used to describe the chains of energy and nutrients flow in and out of the organisms. The flow of energy is unidirectional and declines at the consecutive trophic levels as ecological pyramids demonstrate. Conversely, nutrients are constantly recycled by the biogeochemical cycles like water, carbon, nitrogen and phosphorus cycles. These cycles guarantee the sources of vital elements to life. The chapter highlights that ecological systems are dynamic systems which require an appreciation of the mechanisms in order to protect the environment as well as manage natural resources in a sustainable manner.

Review Questions

1. What is ecology, and what are its levels of organization?
2. Explain the elements and make up of an ecosystem.
3. Describe the working of an ecosystem.
4. Draw the difference between food chain and food web.
5. Explain grazing and detritus food chains.
6. Discuss energy flow within the ecosystems.
7. Explain the various ecological pyramids.
8. Why is the pyramid of energy never slanting?
9. Describe nitrogen cycle and its key steps.

10. Discuss the value of the biogeochemical cycles to the ecological balance.

Chapter 16

Origin and Evolution of Life

16.1 Theories of Origin of Life

One of the most significant questions in biology is the origin of life on the Earth. Scientific explanations are aimed at comprehending the origin of the first living organisms out of non-living chemical substances. The early concepts were mostly philosophical or religious, though the current study of biology is based on experimental data and biochemical concepts to clarify the origin of life.

The theory of spontaneous generation was one of the first scientific concepts, which suggested that non-living matter directly formed life. This concept proved to be false later as the controlled experiments proved that life can only emerge out of life that is already existing and this concept is called biogenesis. Nonetheless, the denial of spontaneous generation did not exclude the fact that life might have appeared in other conditions of the environment in the remote past.

Abiogenesis as it is known in modern terms is the theory of chemical evolution, which states that life originated through a stepwise process of inorganic molecules interacting in a sequence of chemical reactions. This school of thought holds that the initial earth had reducing atmosphere which was made up of methane, ammonia, hydrogen, and water vapor. Lighting sources, ultraviolet radiation and volcanic heat caused chemical reactions which created simple organic molecules.

The results of laboratory experiments using models of the early conditions on Earth offered experimental evidence in favor of chemical evolution as it showed how amino acids and other organic molecules could be formed out

of inorganic molecules. These basic molecules presumably concentrated in early water bodies, which have been termed a prebiotic soup. In time, complicated macromolecules like proteins and nucleic acids were the result of polymerization.

Membrane-bound aggregates of organic molecules called protocells were an important step towards life. The development of self-copying molecules, especially those resembling RNA molecules, which are able to store information, and to catalyze reactions might have signaled the transition between chemical evolution and biological evolution. This theory has been referred to as the RNA world hypothesis.

Therefore, it is likely that the beginning of life was a series of chemical transformations resulting in the earliest simple, self-replicating cells. These early life forms were likely to be anaerobic and heterotrophic which ultimately evolved to form various life forms through evolution.

16.2 Evidence of Evolution

Evolution is the gradual transformation of living things within one generation to another. There are various pieces of evidence which substantiate the fact of evolution and that current species descend out of similar ones.

Fossil evidence gives a historical account of the past forms of life that are found in the sedimentary rocks. The intermediary forms between major groups are known through fossils, and show the way in which the structure is transformed through gradual stages. The systematic occurrence of organisms in geological layers helps in the idea of descent with modification.

Comparative anatomy provides the structural similarities between organisms. The structures of homologous structures are similar in that the forelimbs on

vertebrates include a comparable structural plan although they perform varied functions. These resemblances show shared origins. Similar analogs, however, have analogous functions but are formed independently, as a result of convergent evolution.

Additional evidence is given by comparative embryology. There are similarities in development in early embryos of various vertebrates which indicate that they share developmental pathways and evolutionary backgrounds. Molecular biology has provided a strong evidence by parallels in the sequences of DNA and the structure of proteins across different species.

Biogeography involves the study of the distribution of organisms in geographical areas. Evolutionary separation of common ancestry can be observed through patterns of distribution, especially on islands and remote continents. All these evidences put together justify the idea of evolution as a unifying concept of biology.

To summarize, the main focus of this section is natural selection, which is an evolutionary mechanism by which living organisms acquire characteristics that increase their fitness (Lieberman, 2008). Mechanism of Natural Selection 16.3 Natural selection is an evolutionary process through which living things inherit properties that enhance their fitness (Lieberman, 2008).

Evolution is mainly caused by natural selection. It was put across by Charles Darwin, and it describes how desirable traits increase in a population, over time. Natural selection acts on the differences within the populations and affects the survival and the reproductive success.

There is diversity in the traits of people within a population as a result of genetic differences in the form of mutation and recombination. Certain

differences come with benefits in particular environments. Organisms that have favorable characteristics have more chances of survival and reproduction and these characteristics are inherited by the offspring. As generations go on, the good qualities become more and more common.

Natural selection does not cause variation but it works on the existing differences. The environment dictates the favors of particular traits. As the environment alters, a particular trait can be beneficial and result in adaptive evolution.

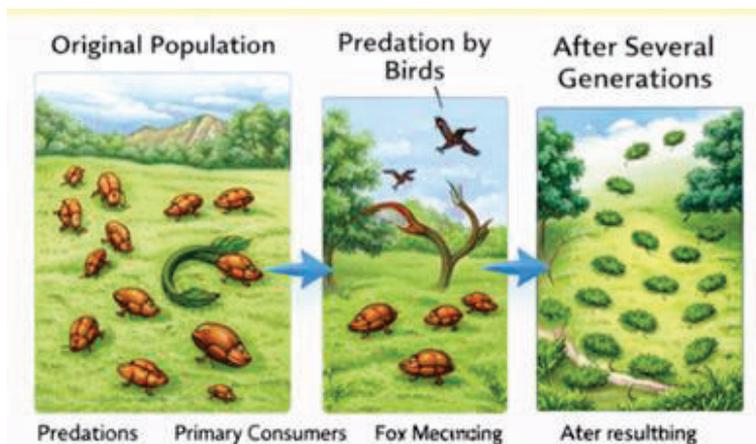


Figure 16.1: Diagram Illustrating Natural Selection

The figure illustrates a population that has varying traits and individuals that best survive in the environment are the ones that survived the most. It shows that people who have favorable traits live and procreate more effectively, which results in the further prevalence of their traits in the next generation. Expressed with the interpretation is that natural selection does not transform the individual overnight but it modifies the population attributes over time. This is what happens to lead to adaptation and diversification.

The different evolutionary patterns that can be brought about by natural selection are the stabilizing selection, directional selection, and the disruptive

selection. These trends affect the population structure and could possibly lead to the emergence of new species.

16.4 Speciation

Speciation refers to emergence of new species out of the current populations. It is associated with the evolution of reproductive isolation, which inhibits the flow of genes between the separating groups. Speciation usually takes place when genetic variation accumulates with time.

Allopatric speciation: this type of speciation results when populations are geographically separated by some barrier like mountains, rivers or continental drift. Isolation will hamper gene flow, and independent evolutionary changes can take place. Genetic incompatibility results in reproductive incompatibility over time.

Sympatric speciation does not involve geographical divergence and usually involves genetic mutation, polyploidy or ecological differentiation. Isolation mechanisms could also be behavioral, temporal, or mechanical and be involved in reproductive separation.

Speciation requires reproductive isolation. It can be prezygotic barriers, like divergences in mating behaviour or time, or postzygotic barriers, like hybrid sterility. As soon as the process of isolation has taken place, the populations develop on their own, creating their own species.

The speciation leads to biodiversity and adaptation. It is the divergent form of evolution that has led to the variety of life that is present today.

16.5 Human Evolution

Evolution of human beings follows the history of modern man. The fossil record suggests that humans have in common ancestry with other primates.

Gradual evolution took place over millions of years in anatomy, brain size and behavior.

Early hominin were bipedal in their locomotion allowing the hands to be available to manipulate tools. Growth of the brain was accompanied with language, culture and social complexity. There are fossil records of transitional forms which exhibit gradual increase in cranial capacity and skeletal structure.

Evolution of human beings is a process of adaptation to the environment. Survival was increased by the invention of tools, taming of fire, and collaboration. The evolution of human beings is the result of evolutionary changes under the influence of natural selection, genetic variation and contact with the environment.

Evolution/Paleontology The chemical, biological, and geological evidence are combined in the study of the origin and evolution of life. Evolution is the reason that explains how all of life is united and diverse since the beginning of the primitive molecules up to more complex beings. The dynamic process of life adaptation and diversification is driven by natural selection, variation, as well as, speciation.

Summary of the Chapter

This chapter looks at how the science of life has tried to explain how life was formed and how the forms have evolved through the ages due to the process. Origins Theories of life focus on the chemical evolution of simple inorganic molecules on the early Earth, in which simple molecules progressively combine to create complex organic molecules, by the action of energy sources like lightning and ultraviolet radiation. The change of chemical processes to biological systems was with the development of self-replicating

molecules and protocells. These primitive life forms gave the basis to later evolutionary diversification.

There is a multiplicity of facts that support the theory of evolution which are fossil evidence, comparative anatomy, embryological similarities, molecular evidence and biogeographical dispersion. All these pieces of evidence confirm that the current organisms have common ancestry and that they have been slowly modified as time goes by. Natural selection is the most significant force of evolution that selects those individuals who have favorable variations and makes them adapt and survive to changing environmental conditions. These selective pressures change the population features over the generations.

Speciation describes the process of the evolution of new species as a result of reproductive isolation and the genetic separation, in case of geographical separation, or any other isolating processes. An example of these evolutionary principles is human evolution, which exhibits gradual transformations in anatomy and behavior of early primates to that of present humans. Altogether, the chapter combines chemical, genetic, and ecological approaches to clarify the unity of life and its diversity on the Earth and explain it by the constant evolution processes.

Review Questions

1. Describe the chemical evolution theory.
2. Explain the experimental data on the origin of life.
3. Explain the significant evidences of evolution.
4. Draw the distinction between analogous and homologous structures.
5. Describe the process of natural selection.

6. Explain the various forms of natural selection.
7. Describe and define speciation and its types.
8. Discuss about reproductive isolation and speciation.
9. Provide the key periods of human evolution.
10. Define the role of natural selection in adaptation and diversity.

Chapter 17

Applied and Economic Zoology

17.1 Apiculture

Applied zoology is concerned with practical use of animals in the benefit of human beings. Apiculture (bee keeping) is the scientific practice of honeybees to produce honey, beeswax, royal jelly and propolis among others. With their importance in the production of commercially valuable substances, honeybees are also important in terms of pollination, which has been found to highly increase the output of agriculture.

Honeybees exist in well organized colonies that have three classes of honeybees namely queen, workers and drones. Only one female who is fertile and is the queen who lays eggs. The sterile females are workers that engage in activities like foraging, larvae nursing, honeycomb construction and hive defense. The males are known as Drones whose main role is to fertilize the queen. Such division of labor is guaranteeing efficient colony functioning.

In the contemporary art of apiculture, there is the application of artificial hives that are used to harvest honey easily without destroying the colony. The Beekeepers take care of the colonies, making sure they provide sufficient supply of food, eliminating diseases and swarming. Honey is extracted using centrifugal extractors and the comb structure is used again.

In addition to honey production, apiculture plays an important role in crop pollination. It is noted that many of the fruit and vegetable crops rely on bee pollination in order to yield more and better. Apiculture, therefore, has direct and indirect economic worth in form of honey product and increased agricultural output respectively.

17.2 Sericulture

The rearing of silkworms to produce silk is known as sericulture. It is an economic zoology that has a great industrial value. The most common type of silkworm species is the type that is related to mulberry plants, the leaves of which are the main food of the larvae.

The silkworm has four life cycle stages namely the egg, the larva and the pupa and the adult moth. Having hatched, the larva is voracious on mulberry and develops quickly with successive molts. It is a cocooned insect when fully developed it dispenses a continuous filament of silk through special glands. The silk filament is made up of a mixture of fibroin protein with sericin as the major composites.

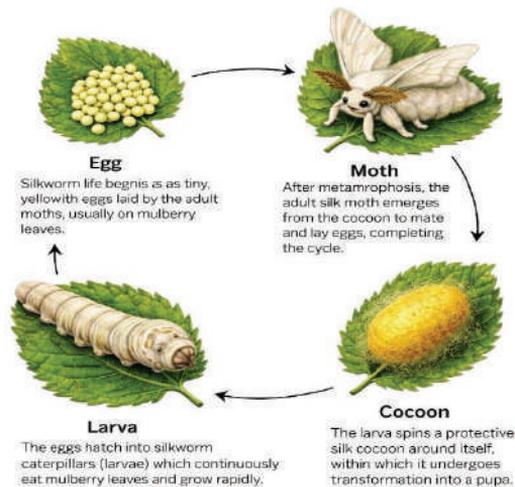


Figure 17.1: Life Cycle of Silkworm

The figure shows the sequential stages in the life cycle of the silkworm, such as egg, larval stages, cocoon formation, pupal stage and development of adult moth. It exemplifies the process of transformation and singles out the cocoon as the economically important stage. The interpretation focuses on

the role of controlled conditions of rearing, where the quality and quantity of silk is determined by the appropriate control of feeding, temperature, and humidity of the environment in which the larvae grow.

Once the cocoons are formed, heat treatment is normally done to kill the pupa inside the cocoons to ensure that the moth does not emerge and ruptures the filament of silk. The cocoon is then reeled into the silk and then made into textile using the silk. Sericulture is a source of revenue to the rural economies and offers job opportunities to the locals.

17.3 Fisheries

Fisheries entails the catching, control and farming of fish and other aquatic creatures as sources of food and commercial products. The fish constitute a significant source of protein among the people of the globe. Fisheries are widely categorized as either capture fisheries or culture fisheries.

Capture fisheries refers to the process of collecting fish in the natural water bodies like oceans, rivers and lakes. Marine fisheries contribute to high percentage of world fish production. Nevertheless, sustainability is endangered by overfishing and habitat destruction.

Fisheries Culture Fisheries or aquaculture is the rearing and breeding of fish in ponds, tanks, or cages. Aquaculture improves the production of fish because scientific management of breeding and feeding and control of diseases are performed. Polyculture systems are composed of species that are compatible in order to maximize productivity.

Fisheries provide food security, employment and economic growth. Aquatic resources should be prevented by exercising sustainable practices, such as controlled harvesting and habitat protection.

17.4 Poultry Farming

Poultry farming refers to the process of raising domestic birds including chicken, duck, turkey among others as a source of meat and production of eggs. It is an important division of animal farming as it is efficient and production is relatively cheap.

Poultry breeds are categorized into layers (egg-producing), broilers (meat-producing) and dual breeds. Scientific poultry farm includes confined housing, balanced diet, vaccination and treatment of diseases. To ensure high growth and productivity, proper ventilation, temperature and hygiene are essential.

The production of eggs is dependent on the genetic factors, the quality of feed and the environmental management. Broiler production is aimed at achieving weight gain in a short period of time. Chicken rearing is a low cost source of animal protein as well as livelihoods in rural and urban regions.

Nonetheless, there should be biosecurity measures to curb spread of certain diseases like the avian influenza. Sustainable poultry practices are more productive, animal-welfare oriented and health conscious of people.

17.5 Animal Husbandry

Scientific management of livestock to produce milk, meat, wool, leather and other products is called animal husbandry. It involves breeding, feeding, health care and general care of the domestic animals like cattle, sheep, goats and pigs.

The desired traits that are enhanced through selective breeding include milk production, rate of growth, and resistance to diseases. The methods of artificial insemination and crossbreeding lead to an increase in productivity

and genetic enhancement. Good nutrition guarantees production, procreation and quality products.

Dairy, sheep and goat farming are concerned with production of milk and wool and meat respectively. Animal care, vaccination, and prevention of diseases are vital parts of animal husbandry. Efficiency and decrease losses are determined by hygienic housing and balanced feed.

Keeping of animals is an important aspect in rural development and national economies. It helps to produce food, offers jobs and leads to sustainable agricultural systems.

The applied and economic zoology show the way the scientific knowledge about animal biology may be applied to benefit humans. Apiculture, sericulture, fisheries, poultry farming, and animal husbandry are some of the activities that combine the biological principles and the management practices, which play an important role in economic development and food security.

Summary of the Chapter

This chapter describes how knowledge of zoology can be put into practical use in enhancing human welfare and economic growth. Apiculture not only stresses the scientific management of honey bees to produce honey, beeswax, and other products but also outlines the significant importance of bees in production of honey, beeswax and other products as well as in pollination and agricultural output. Sericulture concentrates on the culture of silkworms to produce silk, it describes the significance of managing the breeding of the silkworms and the environment in order to produce a high quality of silk. Fisheries are noticed to play an important part in food security by providing food through capture and culture processes and aquaculture is crucial in fulfilling the rising protein requirements.

Organized livestock management is observed in poultry farming and animal husbandry to produce eggs, meat, milk, wool, and other products of animals. Productivity and sustainability are increased through scientific breeding, balanced nutrition, disease control, and the right housing. The chapter highlights the application of biological concepts in conjunction with feasible methods to achieve economic gains and still have a sustainable supply of resources. Applied and economic zoology thus serves as the link between theory and practice in the field of zoology aiding in rural development, creation of employment, and national economies.

Review Questions

1. State the meaning of applied zoology and give its significance.
2. Explain the organization and structure of a honeybee colony.
3. Discuss about the economic significance of apiculture.
4. Provide the description of sericulture and its steps.
5. Elaborate the life cycle of silkworm and its economic value.
6. Distinguish between capture fisheries and culture fisheries.
7. Describe the significance of aquaculture in the production of food.
8. Discuss about scientific management practice in poultry breeding.
9. Explain the concepts and extent of animal rearing.
10. Write about the importance of applied zoology in economic development and food security.

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Practical-Oriented Diagrams

NON-CHORDATES

1. Amoeba – Whole Mount

The irregular body shape of Amoeba should be shown in this diagram with clearly defined pseudopodia, nucleus, cytoplasm (ectoplasm and endoplasm), food vacuole and contractile vacuole. It is the interpretation of the diagram that accentuates its unicellular structure and the functional roles of pseudopodia in locomotion and ingestion. Osmoregulatory adaptation in freshwater can be evidenced by the occurrence of contractile vacuole.

2. Paramecium – Whole Mount

The diagram must depict the body having a shape of the slipper, cilia on the surface, oral groove, macronucleus, micronucleus, food vacuoles and contractile vacuoles. Under the interpretation, specialization is evident in a unicellular organism, such as the coordinated movement of cilia (locomotion) and ingestion. The nuclear duality is a manifestation of division of labor between vegetative and reproductive functions.

3. Sycon (Scypha) – T.S.

This transverse section is expected to show the ostia, incurrent canals, radial canals, spongocoel and the osculum. The interpretation revolves around the canal system which allows the circulation of water to feed and breathe. Simple multicellular organisms are shown to be functionally efficient with coordinated cell layers in structural organization.

4. Hydra – Whole Mount

The diagram is expected to illustrate the tentaculate cylindrical body, mouth, hypostome, basal disc and budding region. Interpretation lays stress on diploblastic structure and radial symmetry. Adaptation to prey capture and defense is manifested by the existence of tentacles that have nematocysts.

5. Taenia – Scolex

The scolex should be drawn with suckers and hooks clearly labeled. The concept of interpretation emphasizes the process of parasitism, especially the features of attachment, which allow to survive in the intestine of the host. Lack of a digestive system is an indication of reliance on host nutrients.

6. Ascaris – Male and Female

Male and female forms should be differentiated using separate diagrams with curved end of the posterior in male and straight end in female and mouth and genital openings. Interpretation brings out sexual dimorphism and adaptation to parasitic existence in the host intestine.

7. Earthworm – Dissection (Digestive System)

Included in the diagram are mouth, pharynx, esophagus, crop, gizzard, intestine and the anus. Interpretation gives perspective to organ-system level structure and regional specialization to ingestion, grinding, digestion, and absorption.

8. Cockroach – Mouthparts or Digestive System

The diagram of the mouthparts is expected to include labrum, mandibles, maxillae, labium, and hypopharynx. Interpretation aims at biting and chewing adaptation. Assuming that the digestive system is depicted, one should indicate structures like foregut, midgut, hindgut and gastric caeca to show digestive specialization.

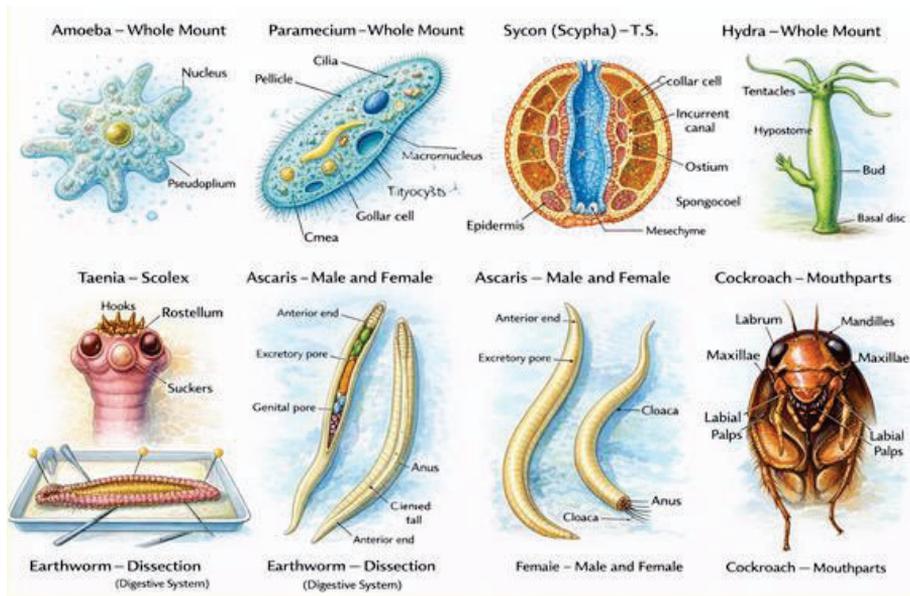


Figure: 1p Structural Diversity and Organization in Non-Chordate Animals

9. Amphioxus – Whole Mount

The diagram should include notochord, dorsal nerve cord, pharyngeal gill slits, myotomes, and post-anal tail. Interpretation emphasizes primitive chordate features and their evolutionary significance.

10. Shark – External Features

Streamlined body, dorsal fin, pectoral fins, gill slits, lateral line and heterocercal tail are to be depicted in the diagram. Interpretation also shows adaptation in water and skeletal structure of cartilage.

11. Frog – Arterial System

Major arteries like carotid, systemic and pulmocutaneous arches must be marked. Interpretation proves the passage through single and double circulation and partial division of oxygenated and deoxygenated blood.

12. Lizard – Heart

Two atria and a partially divided ventricle should be illustrated in the diagram. The focus on progression over amphibians and adaptation to better circulatory performance is placed on interpretation.

13. Pigeon – Digestive System

Beak, crop, proventriculus, gizzard, intestine and cloaca are some of the structures to be labeled. Adaptations to fast digestion and high metabolic rates of flight are emphasised in interpretation.

14. Rabbit – Brain (Dorsal View)

The diagram is to indicate cerebrum, cerebellum, medulla oblongata, and olfactory lobes. Interpretation puts an emphasis on the higher neural growth and coordination in mammals.

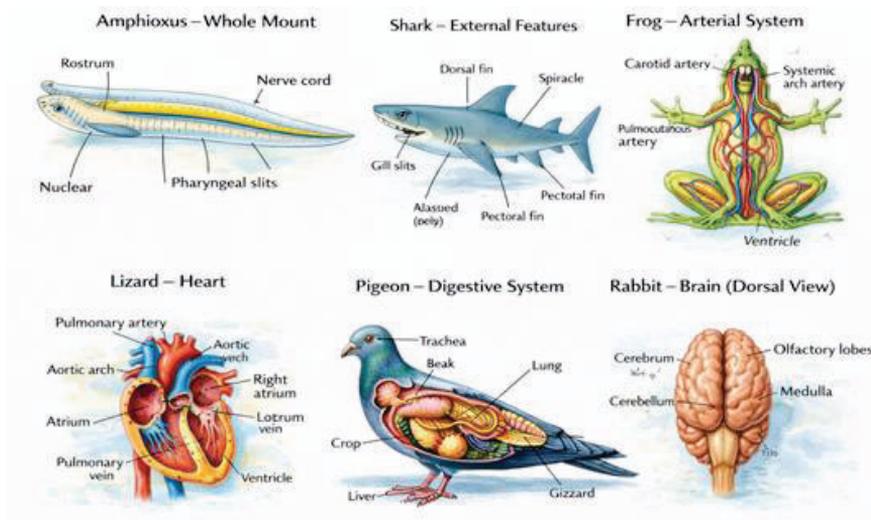


Figure: 2p Cell biology and genetics

15. Typical Animal Cell (Labeled)

The diagram is to be clear and demonstrate the structural organization of a eukaryotic animal cell; the plasma membrane, cytoplasm, nucleus, nucleolus, mitochondria, endoplasmic reticulum (rough and smooth), Golgi apparatus, ribosomes, lysosomes, centrioles, and cytoskeleton. All the organelles need to be drawn in proportional measures and correctly labeled to depict spatial organization in the cytoplasm. The meaning of this diagram is that the process of compartmentalization is the characteristic of eukaryotic cells. The nucleus acts as the control center, mitochondria produces ATP, ribosomes produces proteins and the endomembrane system organizes transport and secretion. The diagram supports the concept of division of labor on the cellular level and shows how structural specialization is the key to the effective metabolic activity.

16. Stages of Mitosis

Prophase, metaphase, anaphase and telophase have to be sequentially represented in this diagram where chromosome condensation, bringing together at equatorial plate, separation of sister chromatids and the reformation of nuclear membranes should be stressed. Spindle fibers and centrosomes are expected to be clearly demonstrated. The interpretation also emphasizes the need to have specific chromosomal segregation as a way of ensuring genetic stability. Mitosis promotes equal segregation of chromosomes to the daughter cells that facilitate growth, tissue repair and regeneration. The diagram is able to visually explain the dynamic process of nuclear division and how this preserves the number of chromosomes.

17. Stages of Meiosis

The diagram must illustrate meiosis I and meiosis II, homologous chromosome pairing, crossing over in prophase I, and alignment in metaphase I, separation in anaphase I and further division in meiosis II. Four cells with two daughter cells should be observed in the final stage. The meaning is attached to the decreasing of the number of chromosomes in the formation of genetic variation by use of recombination and independent assortment. The homologous pairing and crossing over is illustrated by the diagram, showing cytological basis of heredity and variation.

18. Structure of DNA

The diagram is to be made as the model of the double helical, two antiparallel strands, sugar-phosphate backbone, and complementary base pairing of adenine-thymine and guanine-cytosine. The components of the nucleotide and hydrogen bonds should be labeled.

The interpretation brings out the molecular perspective of heredity. The correct replication is provided through complementary base pairing, and the sequence of the nucleotides encoded genetic information through their linear structure. The illustration connects the structure to the function and the manner in which DNA ensures continuity and assists in the production of proteins.

19. Human Karyotype

The diagram must represent 23 pairs of chromosomes in homologous order, comprising of 22 pairs of autosomes and one pair of sex chromosomes. The centromere position and size of chromosomes have to be positioned in order. The explanation lays more stress on the organization of the chromosomes and its contribution to genetic stability. Normal karyotype indicates the normal number of chromosomes and enables one to detect abnormalities with regard to chromosomes. This diagram brings out the cytogenetic foundation of inheritance and medical diagnosis.

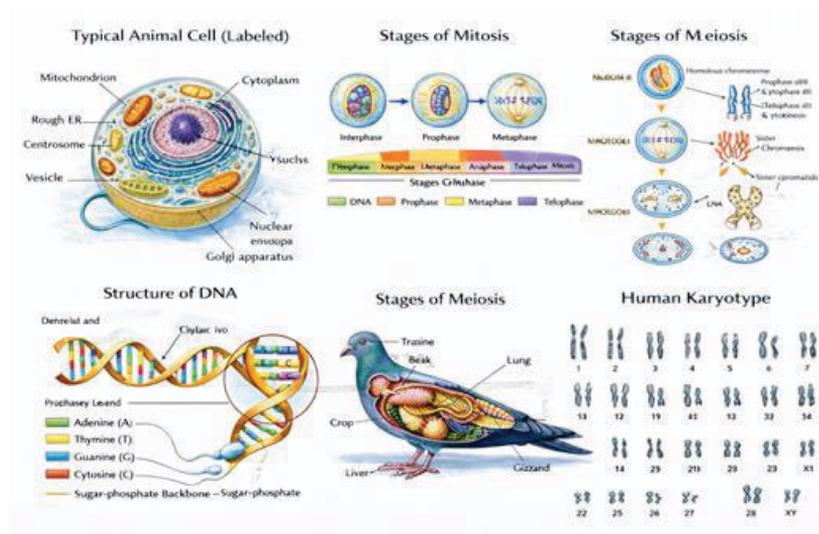


Figure: 3p Developmental biology

20. Frog Egg – Different Cleavage Stages

The schematic must show steps of succession which involve zygote, two cell, four cell and eight cell, morula and early blastula. Unequal cleavage that reflects the features of mesolecithal eggs should be correctly depicted, smaller blastomeres at the animal pole and bigger at the vegetal pole. The interpretation shows the effect of yolk pattern on cleavage pattern. The diagram describes the early cell multiplication in the embryo but without growth, and reveals the formation of polarity to specify body axes later on.

21. Blastula and Gastrula

This scheme is expected to give a comparative perspective of blastula and gastrula stages. Blastula must demonstrate a hollow ball with blastocoel whereas the gastrula must demonstrate invagination, development of archenteron, blastopore and three germ discs - ectoderm, mesoderm and endoderm. It is based on the interpretation of the transformation of a straightforward cellular sphere to a multilayered embryo with established body plan. Gastrulation is a very significant process in developing a fetus as it forms the basic germ layers upon which tissues and organs are formed.

22. Spermatogenesis

The diagram is supposed to depict spermatogenesis, primary spermatocyte, secondary spermatocytes, spermatids, and mature spermatozoa in order in seminiferous tubules. The morphological distinction of sperm, that is, head, middle piece, and tail, should be displayed. The interpretation emphasizes meiotic reduction and differentiation, which leads to haploid male gametes. It illustrates

how mitosis, meiosis and morphological change need to be incorporated to be successful in reproduction.

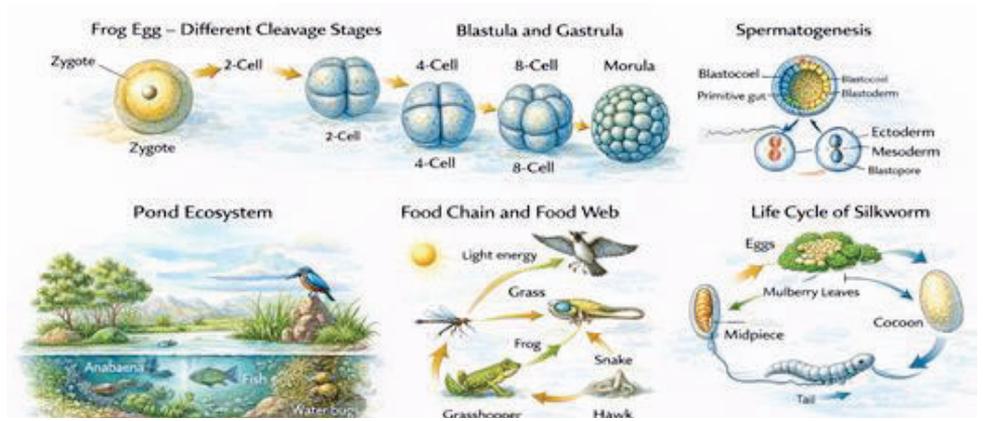


Figure: 4p Ecology and applied zoology

23. Pond Ecosystem

Examples of biotic components that must be indicated in the diagram include phytoplankton, zooplankton, aquatic plants, fish, frogs, insects, and decomposers and abiotic components like water, sunlight, and soil. Energy flowing in producers to consumers, recycling by decomposers, should be indicated by arrows. The translation focuses on the interrelationship between the organisms and the combination of the biotic and the abiotic factors. The pond ecosystem reflects the movement of energy and the cycle of nutrients in a self-sustaining ecological system.

24. Food Chain and Food Web

This diagram must consist of a linear food chain beginning with the producers, primary and tertiary consumers and also a complex food web with feeding relationships among themselves. Arrows should be used to show clearly the direction of energy transfer. The meaning

focused on the idea of trophic levels and ecological interdependence. It describes how the various feeding routes can increase stability and resilience in an ecosystem in the face of loss of species.

25. Life Cycle of Silkworm

The process ought to be depicted in the form of a cycle of an egg, larval instar, cocoon formation, pupa, and adult moth. The cocoon stage must be the most prominent, because it is economically significant. The meaning lays stress on total transformation and its connection to sericulture. It describes the role of controlled rearing and harvesting of the cocoon in the production of silk, the connection of biological processes to the economic use.

All of these practical-oriented diagrams strengthen the theoretical knowledge with the help of visual representation. They put focus on structure, functional relations, developmental course, ecological relations and economic value. It should be properly labeled, drawn in proportions and understandable to have academic payoff and conceptual insight.

Model Question Papers (UGC Pattern)

Model Question Paper – I

Time: 3 Hours

Maximum Marks: 100

Section A – Very Short Answer Questions (10 × 2 = 20 Marks)

Answer all questions. Each question carries 2 marks.

1. Define symmetry in animals and name its types.
2. State Mendel's Law of Segregation.
3. Differentiate between holoblastic and meroblastic cleavage.
4. Name the three germ layers and mention one derivative of each.
5. What is natural selection?
6. Define ecosystem.
7. Mention two adaptations of fishes for aquatic life.
8. What is spermatogenesis?
9. Define mutation.
10. Name the chambers of the human heart.

Section B – Short Answer Questions (Answer any Five) (5 × 6 = 30 Marks)

11. Describe the canal system in Porifera.
12. Explain the general characters of Annelida.
13. Discuss the structure and functions of mitochondria.
14. Describe the phases of the cell cycle.
15. Explain monohybrid cross with suitable example.

16. Discuss metamorphosis in frog.
17. Explain the concept of ecological pyramids.

Section C – Long Answer Questions (Answer any Four) ($4 \times 12 = 48$ Marks)

18. Describe the classification and general characters of Arthropoda.
19. Explain the structure and functions of the human heart with a neat labeled diagram.
20. Describe meiosis and discuss its significance.
21. Discuss the structure of DNA and explain its role in heredity.
22. Explain the mechanism of natural selection with suitable example.
23. Describe early embryonic development up to formation of germ layers.

Section D – Diagram-Based Question ($1 \times 2 = 2$ Marks)

24. Draw a neat labeled diagram of a typical animal cell.

Total: 100 Marks

Model Question Paper – II

Time: 3 Hours

Maximum Marks: 100

Section A – Multiple Choice Questions (10 × 1 = 10 Marks)

1. The notochord is characteristic of:
 - a) Arthropoda
 - b) Mollusca
 - c) Chordata
 - d) Echinodermata

2. The functional unit of kidney is:
 - a) Neuron
 - b) Nephron
 - c) Alveolus
 - d) Villus

3. Crossing over occurs during:
 - a) Prophase I
 - b) Metaphase II
 - c) Anaphase I
 - d) Telophase II

4. The pyramid of energy is always:
 - a) Inverted
 - b) Upright
 - c) Circular
 - d) Horizontal

5. The double helical model of DNA was proposed by:
 - a) Mendel

- b) Darwin
 - c) Watson and Crick
 - d) Lamarck
6. The larval stage of frog is called:
- a) Nymph
 - b) Tadpole
 - c) Maggot
 - d) Pupa
7. The respiratory organ of fishes is:
- a) Lungs
 - b) Skin
 - c) Gills
 - d) Trachea
8. Honey is produced by:
- a) Silkworm
 - b) Housefly
 - c) Honeybee
 - d) Termite
9. The three germ layers are formed during:
- a) Cleavage
 - b) Blastulation
 - c) Gastrulation
 - d) Fertilization
10. Evolution is primarily driven by:
- a) Mutation only
 - b) Natural selection

c) Migration

d) Isolation

Section B – Short Notes (Answer any Five) ($5 \times 6 = 30$ Marks)

11. Adaptive radiation in mammals.
12. Structure of nephron.
13. Dihybrid cross.
14. Canal system in sponges.
15. Food chain and food web.
16. Structure of frog heart.
17. Apiculture and its economic importance.

Section C – Essay Questions (Answer any Four) ($4 \times 15 = 60$ Marks)

18. Discuss the classification and general characters of Mammalia.
19. Explain the structure and functions of cell organelles.
20. Describe spermatogenesis and oogenesis.
21. Discuss the origin and evolution of life with supporting evidence.
22. Explain ecosystem structure and energy flow.
23. Describe Reptilia and their adaptations for terrestrial life.

Model Question Paper – III

Time: 3 Hours

Maximum Marks: 100

Section A – Very Short Answer Questions (10 × 2 = 20 Marks)

Answer all questions.

1. Define coelom and mention its types.
2. What are homologous organs?
3. Name the stages of mitosis.
4. What is torsion in Mollusca?
5. Define population in ecological terms.
6. What is the function of ribosomes?
7. State the Law of Independent Assortment.
8. Name the three types of fishes based on skeleton.
9. What is fertilization?
10. Define speciation.

Section B – Short Answer Questions (Answer any Five) (5 × 6 = 30 Marks)

11. Describe the structure of cockroach mouthparts.
12. Explain the structure of DNA.
13. Discuss the phases of meiosis I.
14. Describe the general characters of Amphibia.
15. Explain ecological succession.
16. Write a note on sericulture.

17. Describe the formation of blastula.

Section C – Long Answer Questions (Answer any Four) ($4 \times 12 = 48$ Marks)

18. Discuss the classification and general characters of Chordata.

19. Explain the mechanism of respiration in humans.

20. Describe the life cycle of silkworm with suitable diagram.

21. Discuss Mendel's monohybrid and dihybrid crosses.

22. Explain early embryonic development up to gastrulation.

23. Describe the structure and functions of the nervous and endocrine systems.

Section D – Diagram-Based Question ($1 \times 2 = 2$ Marks)

24. Draw and label the stages of mitosis.

Total: 100 Marks

Model Question Paper – IV

Time: 3 Hours

Maximum Marks: 100

Section A – Objective Type Questions (10 × 1 = 10 Marks)

1. The functional unit of liver is:
 - a) Nephron
 - b) Alveolus
 - c) Hepatocyte
 - d) Villus

2. The larval form of Cnidaria is:
 - a) Trochophore
 - b) Planula
 - c) Nauplius
 - d) Miracidium

3. Crossing over increases:
 - a) Mutation rate
 - b) Genetic variation
 - c) Chromosome number
 - d) Population size

4. The excretory product of birds is:
 - a) Urea
 - b) Ammonia
 - c) Uric acid
 - d) Creatinine

5. The organ of hearing in frog is:
 - a) Cochlea

- b) Tympanum
 - c) Pinna
 - d) Eustachian tube
6. The study of fossils is called:
- a) Cytology
 - b) Ecology
 - c) Paleontology
 - d) Histology
7. The powerhouse of the cell is:
- a) Nucleus
 - b) Golgi body
 - c) Mitochondria
 - d) Lysosome
8. The primary producers in an ecosystem are:
- a) Carnivores
 - b) Herbivores
 - c) Decomposers
 - d) Green plants
9. The male reproductive cell is:
- a) Ovum
 - b) Zygote
 - c) Sperm
 - d) Embryo
10. Adaptive radiation is best seen in:
- a) Amphibians
 - b) Mammals

c) Sponges

d) Protozoa

Section B – Short Notes (Answer any Five) ($5 \times 6 = 30$ Marks)

11. General characters of Pisces.
12. Canal system in Sycon.
13. Structure of human heart.
14. Cell membrane and transport mechanisms.
15. Biogeochemical cycles.
16. Poultry farming.
17. Mutation and variation.

Section C – Essay Questions (Answer any Four) ($4 \times 15 = 60$ Marks)

18. Describe the general characters and classification of Arthropoda.
19. Explain the structure and functions of cell organelles with suitable diagram.
20. Discuss gametogenesis and fertilization.
21. Describe the mechanism of natural selection and its evolutionary significance.
22. Explain ecosystem structure and ecological pyramids.
23. Discuss the origin and evolution of life with suitable evidences.

Total: 100 Marks

Glossary

Abiogenesis – The theory that life originated from non-living chemical substances through natural processes.

Acrosome – A cap-like structure on the head of sperm containing enzymes that help penetrate the ovum during fertilization.

Adaptive Radiation – Diversification of a group of organisms into different forms adapted to various ecological niches.

Allele – Alternative form of a gene located at the same position on homologous chromosomes.

Allopatric Speciation – Formation of new species due to geographical isolation.

Amnion – Extraembryonic membrane that encloses the embryo in amniotic fluid.

Analogous Organs – Structures that perform similar functions but differ in origin and structure.

Anaphase – Stage of cell division during which sister chromatids or homologous chromosomes separate and move to opposite poles.

Aneuploidy – Condition in which chromosome number deviates from the normal diploid number.

Apiculture – Scientific rearing and management of honeybees for production of honey and other products.

Archenteron – Primitive gut formed during gastrulation.

Arthropoda – Phylum characterized by jointed appendages and chitinous exoskeleton.

Autotroph – Organism capable of synthesizing its own food from inorganic substances.

Bilateral Symmetry – Body plan in which the body can be divided into equal halves along one plane.

Biogeochemical Cycle – Circulation of chemical elements between living organisms and the environment.

Biosphere – Global sum of all ecosystems on Earth.

Blastocoel – Fluid-filled cavity within the blastula.

Blastula – Early embryonic stage formed after cleavage.

Budding – Asexual reproduction in which a new individual develops from an outgrowth of the parent body.

Canal System – System of water circulation in sponges for feeding and respiration.

Centromere – Constricted region of chromosome where sister chromatids are joined.

Chordata – Phylum characterized by notochord, dorsal nerve cord, and pharyngeal gill slits.

Cleavage – Series of rapid mitotic divisions following fertilization.

Coelom – Body cavity lined by mesoderm.

Community – Assemblage of populations of different species living in a particular area.

Crossing Over – Exchange of genetic material between homologous chromosomes during meiosis.

Cyclin – Regulatory protein controlling progression of cell cycle.

Cytokinesis – Division of cytoplasm following nuclear division.

Decomposer – Organism that breaks down dead organic matter into simpler substances.

Dihybrid Cross – Genetic cross involving two pairs of contrasting traits.

DNA – Deoxyribonucleic acid; molecule carrying genetic information.

Ecosystem – Functional unit consisting of living organisms and their physical environment.

Ectoderm – Outermost germ layer forming skin and nervous system.

Endoderm – Innermost germ layer forming digestive tract lining.

Endothermic – Organism that maintains constant internal body temperature.

Fertilization – Fusion of male and female gametes forming a zygote.

Food Chain – Linear sequence of organisms transferring energy.

Food Web – Network of interconnected food chains.

Gamete – Haploid reproductive cell.

Gastrulation – Process forming three germ layers in embryo.

Gene – Unit of heredity located on a chromosome.

Genotype – Genetic constitution of an organism.

Germ Layers – Primary layers (ectoderm, mesoderm, endoderm) formed during development.

Haploid – Having a single set of chromosomes.

Heterozygous – Condition with two different alleles for a trait.

Homologous Organs – Structures similar in origin but different in function.

Homeostasis – Maintenance of stable internal environment.

Karyotype – Arrangement of chromosomes in a standard format.

Larva – Immature stage morphologically different from adult.

Linkage – Tendency of genes located close together on a chromosome to be inherited together.

Meiosis – Cell division reducing chromosome number by half.

Mesoderm – Middle germ layer forming muscles and circulatory system.

Metamorphosis – Transformation from larval to adult stage.

Mitosis – Nuclear division producing two identical daughter cells.

Mutation – Sudden heritable change in genetic material.

Natural Selection – Process by which advantageous traits increase in frequency in a population.

Notochord – Flexible rod-like structure present in chordates.

Organ System – Group of organs working together to perform specific functions.

Osmosis – Diffusion of water across a semi-permeable membrane.

Oviparous – Animals that lay eggs.

Phenotype – Observable characteristics of an organism.

Placenta – Organ connecting developing embryo to maternal tissue.

Population – Group of individuals of the same species in a given area.

Producer – Organism that synthesizes food through photosynthesis.

Prokaryote – Cell lacking a membrane-bound nucleus.

Recessive Trait – Trait expressed only in homozygous condition.

Respiration – Process of gas exchange and energy release in cells.

RNA – Ribonucleic acid involved in protein synthesis.

Sericulture – Rearing of silkworms for silk production.

Speciation – Formation of new species.

Symbiosis – Close interaction between different species.

Taxonomy – Science of classification of organisms.

Trophic Level – Position an organism occupies in a food chain.

Zygote – Diploid cell formed after fertilization.