

LESSON: 1

THE CONCEPT OF ZOOLOGY

Defining Zoology

Zoology is the branch of biology which deals with the study of animal life. It includes all the aspects of animals' life. The term zoology is combination of two Greek words "zoon" means animals and "logos" means to study.

History of Zoology

History of zoology is as old as history of man. Greeks and Romans were the first to document animal life. Muslim scientists gave many discoveries in the field of zoology. Modern Scientists revolutionized the knowledge about animal life.

What do we study in zoology?

Animal life is very fascinating to human being. It includes a great variety of animals ranging from microscopic invertebrates to very large size vertebrates. Beautiful domestic pets, gorgeous wildlife and stunning aquatic animals are all studied under the heading of zoology. When we see living organisms different questions rise in our mind like;

How and where they live?

What they eat?

What they do?

The answer to all questions is given by observing the animals living in natural environment, studying their activities (feeding, growth and reproduction) structure and function of different body parts up to molecular level.

LESSON 2

SIGNIFICANCE OF ZOOLOGY

The knowledge of zoology is important for survival of man and other animals on this earth. It helps us to know about different types of animals living on earth. It tells us how life is sustaining on this earth. The knowledge of zoology has helped mankind to improve environment, health and food quality.

Improving Health

The knowledge of zoology is helping to improve the health of human and other animals. We are able to understand the mechanism of diseases and their modes of transmission. Many diseases

like cancer, hepatitis and AIDS which were previously thought to be uncontrolled can now be prevented and cured. Many others like diabetes and cardiovascular diseases can be avoided by adopting health life style. Many medically important hormones and proteins are now days are obtained from transgenic animals.

More and Better Quality Food

Rapidly increasing population of world demands more and better food. More food is required to feed more than 7 billion population of the world. Many breeds of animals have been developed which provide more meat, milk, eggs. Dairy industry, poultry and aquaculture are well established and running at commercial scale. Quality of food has been improved with more nutrition value. Selective breeding and genetic engineering are two lines of research for production of more and better quality food.

Improving Environment

More than 1.5 million species of animals have been documented. Animals have critical role in maintaining ecosystem. Beautiful birds and animals also have esthetic value. The knowledge of zoology is important in maintaining their natural habitat and protecting them from extinction. Many animals play their role in cleaning the environment. For example vulture and other scavengers eat dead bodies of other animals. Similarly small aquatic animals remove toxic metals and other pollutants from water bodies. Many animals are sensitive to pollutants and act as bioindicator of different pollutants.

LESSON 3

APPLICATIONS OF ZOOLOGY

Zoology covers the areas ranging from basic structure of animals to their industrial application. There are four major areas of with direct applications of zoology:

1. Medical Research

In medical research the first step is the diagnosis of a disease. Many diseases are due to animals which cause and transmit them. Advancement in techniques and protocols have enabled the scientists to understand that how a person is affected by a disease and what are the underlying mechanism for specific disease. For example *Aedes* mosquitos are responsible for spread of dengue. Once the mode of action is known, the disease may be controlled by taking preventive measures and proper medication. New drugs are designed, their mode of action and effects are first studied on animal models then they are used by human.

2. Agriculture

Study of zoology helps us to understand the life of different insects, pests, rodents, birds and mammals. Many crop pests are the food of insects and birds. They may be used to control the pest. The phenomenon is called **biocontrol**. In comparison to chemical control, there is no risk of developing resistance in crop pests. **Animal husbandry** is the farming of animals to produce meat, milk and eggs while **aquaculture** is the culturing of aquatic animals and plants. Beekeeping for the production of honey and wax is called **apiculture** while rearing of silkworm for production of silk is called **sericulture**.

3. Industry

Billion dollar medical industry is based on many animal and plant products. Vaccines which typically contain weak or killed disease causing agents are used to immunize human, farm animals and pets against different disease causing agents. Antibodies are also used for passive immunity where immune system is too weak or needed not to be activated. Growth hormones are used in children with suppressed growth. Leather industry products like bags, shoes, jackets sofas and hundreds of other goods are made from hides of animals.

4. Environmental Role

Biodiversity of an ecosystem is the total number of different species of plants and animals. Biodiversity of earth is decrease rapidly, mainly of habitat destruction by human (anthropogenic) activities. It is the knowledge of zoology which is helping to reduce the biodiversity loss by habitat protection through national parks, game reserves and other protective places. Zoo and safari parks have great aesthetic value.

Animals have also an important role in controlling environmental pollution. Scavengers are the animals which keep the environment clean by eating up dead bodies of animals. Many small soil and aquatic animals remove toxic pollutants. This process is called bioremediation.

LESSON 4

Fundamental Properties of Life

“The ability to reproduce is Life.” What would be if there is a single male or female rabbit?? Life has no perfect definition but certain characteristics.

1. Living organisms have unique and complex composition of biomolecules which differ from other molecules in their structures.
2. Living organism have ability to reproduce (sexual and asexual reproduction). They inherit different properties from their parents.

3. Living organisms have genetic material in the form of DNA or RNA which is used to encode different enzymes and other proteins.
4. Metabolism is all types of chemical changes in the body during which animals derive energy, synthesize molecules of body need and detoxify the harmful molecules.
5. Living organisms interact with their environment. The branch of biology in which we study the interaction of living organisms with their environment is called ecology.

LESSON 5

ONE WORLD VIEW

Although life appears very diverse but there is a structural and functional unity in all forms of life. Life shares same properties.

a. Genetic Unity

Almost all forms of life have same genetic blue prints (DNA). DNA of bacteria plants and animals has same chemical composition. It carries genetic information. Genetic code is almost same.

b. Common Structural Organization

All the prokaryotes and eukaryotes are made up of cells. Cell is both the structural and functional unit of life. Cells of all living organisms have striking similarities.

c. Common Evolutionary Forces

All the animals are uniformly acted upon by same type of evolutionary forces like genetic drift, inbreeding, selection and mutation. This is one reason of close similarity in the living organisms.

d. Common Environment

All the organisms living on this earth have same type of physicochemical environmental factors. They face same type of environmental conditions. They get food from same environment.

Due to basic similarities in living organisms scientists are of the view that life has a common origin. Evolutionary theory is also based on the idea that all organisms evolved from a common ancestor.

LESSON 6

SPECIALIZATIONS IN ZOOLOGY

Specializations on the basis of field of study

1. **Anatomy:** It is the study of the structure of complete organisms and their body parts.
2. **Physiology:** The study of the function of organisms and their body parts.
3. **Cell biology (Cytology):** Study of the structure and function of cell and its components.
4. **Molecular Biology:** Molecular biology is the study of structure and function of the macromolecules (e.g. proteins and nucleic acids, Lipids) essential to life.
5. **Histology:** Study of organisms at tissue level is called histology.
6. **Embryology:** Study of development of embryo from fertilized egg.
7. **Genetics:** Study of the mechanisms of transmission of traits from parents to offspring.

LESSON 7

SPECIALIZATIONS IN ZOOLOGY

Specializations on the basis of animal group

1. **Protozoology:** Protozoology is the study of protozoa. It deals with the characterization, taxonomy and medical importance of protozoa.
2. **Nematology:** Nematology is the scientific discipline concerned with the study of nematodes, or roundworms.
3. **Entomology:** Entomology is a branch of zoology which deals with the study of insects.
4. **Malacology:** Malacology is the branch of invertebrate zoology that deals with the study of the mollusca.
5. **Ichthyology:** Ichthyology is the branch of zoology concerned with the study of fishes.
6. **Herpetology:** Herpetology is the branch of zoology that deals with the study of amphibians and reptiles.
7. **Ornithology:** It is the branch of zoology concerned with the study of birds.
8. **Mammalogy:** It is the branch of zoology that deals with the study of mammals.

LESSON 8

ANIMAL DIVERSITY

Animal diversity is the number of different types of animals living on this earth. The total diversity of life documented is about 1.74 million.

Group	Described	Estimated
Chordates	64,788	80,500
Mammals	5,487	5,500
Birds	9,990	>10,000
Reptiles	8,734	~10,000
Amphibians	6,515	~15,000
Fishes	31,153	~40,000
Invertebrates	1,359,365	6,755,830
Echinoderms	7,003	~14,000
Arthropods	~1,149,248	~5,750,000
Mollusca	~85,000	~200,000
Annelida	16,763	~30,000
Nematods	25,000	~500,000
Platyhelminthes	20,000	~80,000
Cnideria	9,795	
Porifera	6,000	~18,000

Scientists estimate species range from 5 to 30 million. However, the more accurate estimate about current diversity of earth is between 8.7 ± 1.3 million. It means about 80% species have to be described yet. Every species survives on earth for approximately 1 million year. Scientists estimate that more than 99% species have got extinct from this earth.

LESSON -9

ANIMAL HIERARCHY

Animal hierarchy is the arrangement of animal into different groups and subgroups on the basis of their relatedness/similarities. The branch of science that deals with the naming and classification of organisms into different groups and subgroups on the basis of relatedness is called **taxonomy**. Each group of classification is called a taxon. Overall sequence of hierarchy of classification of animals is as follow:

- Kingdom
- Phylum
- Class

- Order
- Family
- Genus
- Species

The smallest group of classification system is species.

a. Species

Species is a group of animals which can interbreed and produce fertile offspring. It is the group of animals with maximum similarities. e.g., dogs, cats, horses and elephants.

b. Genus

Closely related species form a genus. Genus name starts with a capital letter and italicized e.g., *Panthera*. *Panthera* is genus of five living wild cats i.e., lion, tiger, jaguar, leopard and snow leopard

c. Family

Closely related genera form a family. e.g., Felidae and Hominidae.

d. Order

Closely related families form an order. e.g., Carnivora and Primates

e. Class

Similar orders are grouped together form a class. e.g., Amphibia, Reptilia, Aves and mammalia.

f. Phylum

It is the principal category of classification. Classes with some common features are grouped to form a phylum. e.g., echinodermata and chordata.

g. Kingdom

Kingdom is the highest rank of classification. All the living organisms are distributed into five kingdoms i.e., monera, protista, fungi, plantae and animalia. All the animals are included in kingdom animalia

h. Domain

In 1977 Carl Woese divided the cellular organisms in three domains. i.e., archaea, bacteria and eukarya.

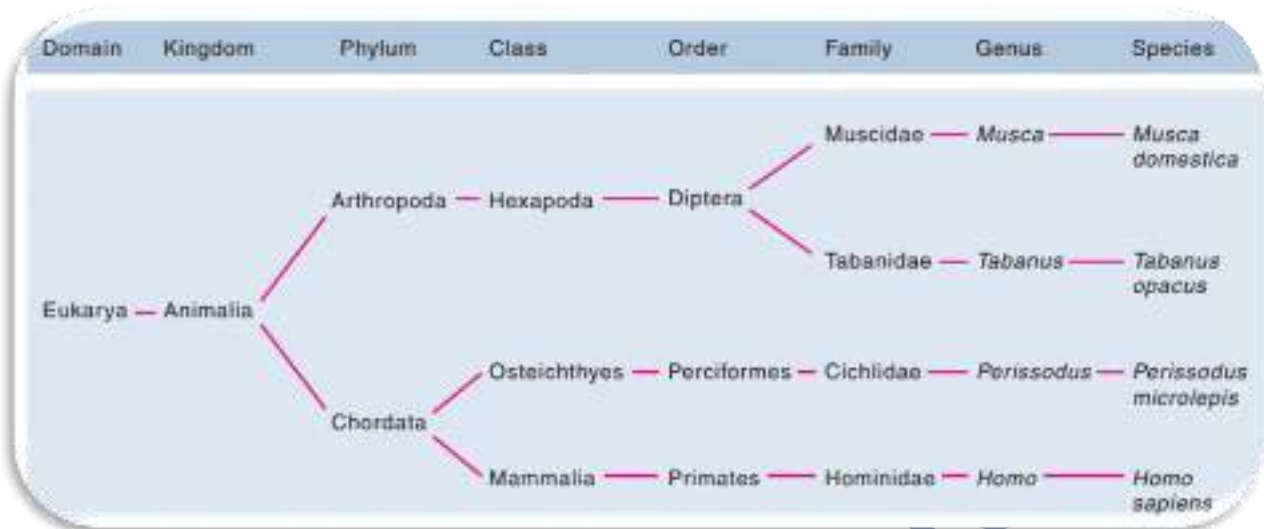


Fig1. Hierarchy of house fly (*Musca domestica*), horse fly (*Tabanus opacus*), cichlid fish (*Perissodus microlepis*) and human (*Homo sapiens*) (Ref. Miller and Harley. Zoology. 5th Edition)

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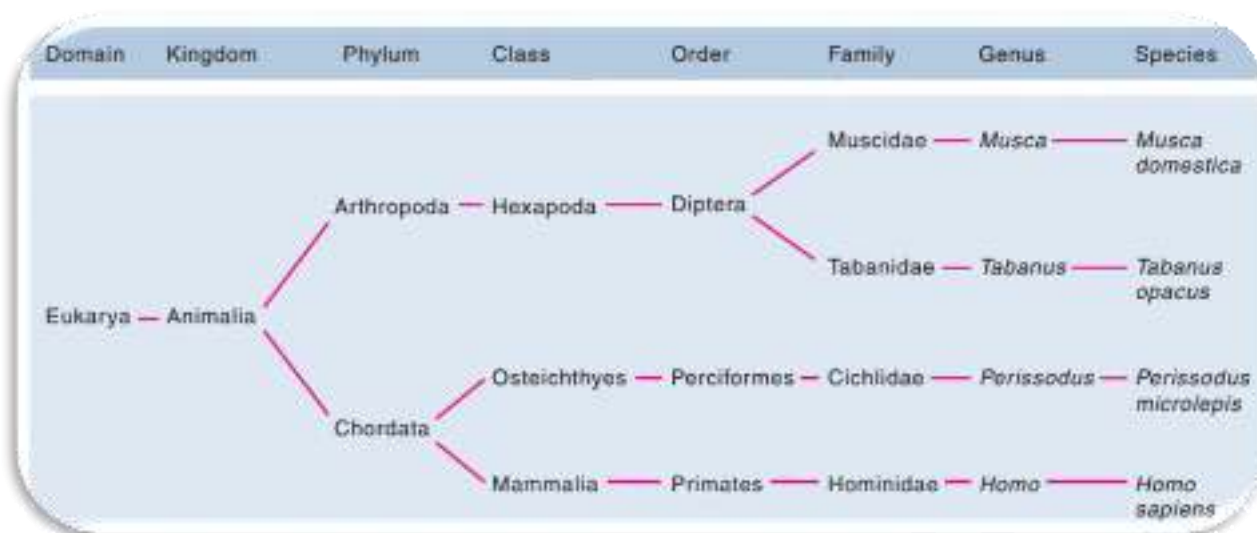


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LESSON 11

WORLD RESOURCES

Resource is any kind or stock or material that can be used effectively. **Natural Resources** are the resources which exist in nature without the involvement of mankind. They include all the valuable characteristics of nature. Magnetic gravitational force, sunlight, atmosphere, water, plants, animals etc. are important natural resources.

Natural resource can be divided into two main types: Renewable resources and Non-renewable resources.

Renewable resources are those resources which are constantly available. After using they are reasonably replaced or recovered e.g., water, sunlight, air and biomass. **Non-Renewable Resources** are those which once exhausted are no more available. They are not replaced or recovered e.g., oil, gas and minerals

Threats to Resource

Human overpopulation is a major threat to natural resources. Although modern technology is helping to produce more and more food but extensive use of minerals and oil reserves will exhaust these resources. Although biodiversity is a renewable resource but different animals and

plants living on this earth are at the risk of extinction because of overexploitation and destruction of their natural habitat.

Different strategies can be used to protect the resources. Conservation is one of the important methods to save natural resources. Resources may be conserved by increasing efficiencies of resource utilization, using alternative resources and recycling of materials. A control on population will have direct impact on resource conservation.

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LESSON 13

POPULATION OF THE WORLD

In 70,000BC about 1000 to 10,000 people were living on earth while the current population of the World is more than 7.7 billion. Most of the population is living in less developed countries. The number of people in less developed countries will increase in future. This will further increase the disparity between rich and poor nations.

Growth rate is the number of person increasing annually. The current population growth rate is 1.07% (means 82 million more people every year). The population growth rate was maximum in 1960's. Since then it is decreasing. An overview of growth rate and population of world is evident from the following table.

Table: Human population growth rate of the world. The growth rate shows that world population will be stabilized in 2100 while at that time the total population will be 10.9 billion.

Time span	Population growth rate
1960's	2%
2018-2019	1.07%
2023	<1%
2052	<0.5%
2076	<0.25%
2100	0.09%

LESSON 14

THE SCIENTIFIC METHOD

Scientific method is a series of steps followed by scientists to answer a specific natural problem. It is based on facts and measurable evidences. The main steps of scientific method are given in the flowchart.

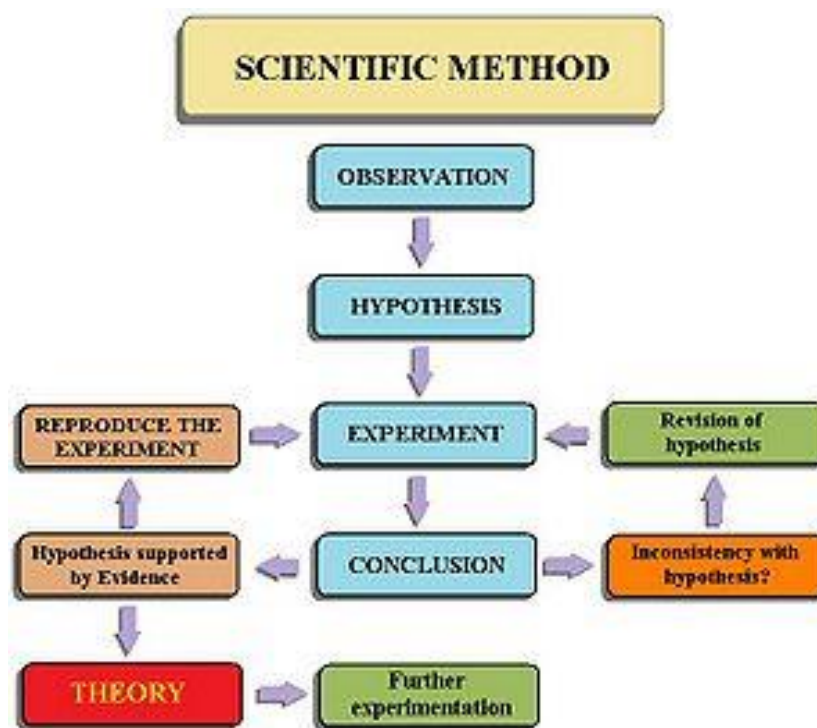


Fig: Flowchart of scientific method. Investigation of scientific problems usually involves different steps in a sequence.

a. Observations

Observation is the collection of information about a particular problem. Observations are the authority in science. Man uses his five senses to collect information and take the help of scientific instrument when required. For example, thermometer is used for accurate measurement of temperature while microscope is used to observe very small objects. The information obtained from observations is called **data**. Data is of two types: quantitative data and qualitative data. Quantitative data has numerical value like height, weight and temperature while qualitative data do not have numerical value like odor, shape and colour.

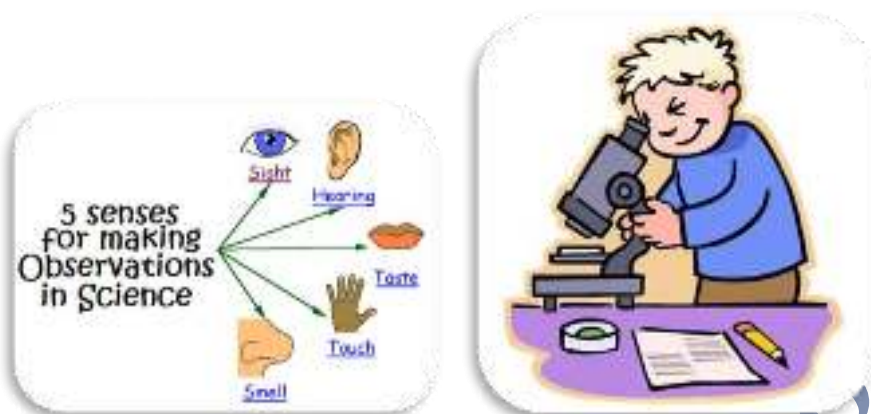


Fig: Observation is the collecting information using senses and specific instruments.

LESSON 15

b. Hypothesis

On the basis data collected through observation and their previous knowledge scientists give a reasonable explanation to the natural question that is called a hypothesis. A hypothesis may base on deductive reasoning or inductive reasoning. A **deductive reasoning** hypothesis is that conclude something from general information while the **Inductive reasoning** hypothesis given some general conclusion from very specific information.

c. Experiment

A hypothesis is tested by experiments. An experiment has three set of variables. An **independent variable** is parameter being tested in the experiment. A **dependent variable** is the parameter used to determine the outcome of an experiment while a **control variable** is that which can influence the results so it is kept constant. For example, an experiment was set to measure the effect of day light length on reproductive readiness of mice. Here, daylight length is independent variable, frequency of mating is dependent variable while temperature is a control variable. All experiment contain at least two groups *i.e.*, experimental group and control group. A control group is kept at same conditions with independent variable omitted. Control group is used for comparison.

Any difference between control and experimental group is the result of experiment. Regardless of the outcomes of the experiment further experiments are needed and the results must be shared with other scientists.

LESSON 16

d. Theory

When a hypothesis confirmed by repeated experiments and other related hypothesis support then it is converted to a theory. "A theory is a tested and widely accepted model that helps to explain and predict natural facts and which is based on observations, experiments and reason". It is generalized term very different from commonly known things. The major criteria of theory are: Observable, repeatable and predictive/ Explanatory. A theory is always provisional and may be modified in future. Example: Theory of evolution

LESSON 17

e. Scientific Law

A scientific law is a statement based on repeated experimental observations that describes some aspect of the nature. It is applied under certain conditions. Scientific law is represented by certain statements and formulas. Experimental results can be predicted by formula. A theory becomes law when the experiments agree with the theory and no contradictory opinion is arises. The law has universal acceptance and cannot be challenged unless solid experimental evidences given. Law of segregation, Law of independent assortment and Hardy-Weinberg law are the examples of scientific law.

LESSON 18

EXPERIMENTAL VERSUS EVOLUTIONARY SCIENCES

When we study about living organisms many question arise in our mind. e.g., How cells divide? Why specific number of chromosomes in each species? How genetic information encode proteins? Why some animals live together while others solitary?

All these questions may be divided into two categories: Proximate causes and Ultimate causes. **Proximate cause** is an event immediately responsible for causing some observed result. Normally related to functioning of biological system for a particular time. E.g., metabolic and physiological functions. **Ultimate causes** are those reasons which have produced system and its characteristic through evolutionary time. It also called the real reason. E.g., Evolutionary forces that caused birds to acquire migratory behavior.

Biological science that addresses the questions of proximate causes is called **experimental science**. It proceeds through experiments. E.g., process of maintaining body temperature, process of cell division.

Biological science that addresses the questions of ultimate causes is called **evolutionary science**. It proceeds through comparative methods E.g., comparison of hemoglobin structure of human and fish.

LESSON 19

ORIGIN OF LIFE

Life evolved about 4.0 billion year ago. According to theory of chemical evolution simple molecules were first converted into monomers of carbohydrates, proteins, lipids and nucleic acids. These monomers later joined to form polymers. All these polymers were suspended in oceans giving up a soup like consistency. Polymers later arranged to form a primitive type of cell called Protocell. This was a simple self replicating system. It was a simple bacteria like primary heterotroph organism. As food availability became limited, natural selection acted upon these simple cells and self replicating systems were more successful. Cells began to evolve and genetic code was established and protein synthesis mechanism was developed. Fossil record shows that life was existing about 3.8 billion years ago. Eukaryotes (membrane bounded nucleus and organelles) evolved about 1.5 billion years ago.

The debate arise that what was the controlling center of these protocells? There are two hypotheses. The first called RNA world hypothesis says that initially RNA was having main role in the cell. RNA molecules were working as enzyme as well as genetic material. The other hypothesis says that it was protein which was having dominant role in controlling cell.

LESSON 20

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LESSON 21

CHEMISTRY OF LIFE

Elements is a species of atom having the same number of protons in their atomic nuclei. About 25 elements make living organisms. A **Compound** is formed by atoms of two or more elements. The smallest entity of matter which can exist independently is called a molecule. Atoms in a molecule are held together by chemical bonding. Mainly there are three types of bonds: covalent bonds, hydrogen bonds and ionic bonds.

Acids, Bases and Buffers

Acids are those molecules which can donate H^+ (proton) or accept electron. E.g., amino acids, fatty acids and hydrochloric acid. **Bases** are those which release OH^- or donate electrons or accept proton H^+ . E.g., nitrogen bases. Buffer is the solution which resists the change in pH. It is able to neutralize the small amount of acids or base. Buffers stabilize the internal environment of cell (pH 7.35- 7.45). e.g., Carbonic acid- bicarbonate system.

LESSON 22

THE MOLECULES OF LIFE: BIOMOLECULES

Biomolecules are the molecules produced by cell or living organisms. They make all forms of life. Large biomolecules include proteins, glycogen and starch. Small biomolecules include monosaccharides, amino acids and intermediates of different metabolic pathways. Chemically they consist of carbon, hydrogen, oxygen, nitrogen, sulfur and phosphorus. Biomolecules have specific structures. Atoms in biomolecules are held together mainly by covalent interaction. Others include hydrogen bonding, ionic bonding and van der Waal forces.

Functions of Biomolecules

Biomolecules perform following important functions in living organisms:

- i. Basic building blocks of living organisms
- ii. Source of energy
- iii. Performing biochemical reactions
- iv. Storing genetic information
- v. Maintaining homeostasis

Types of Biomolecules

There are four mainly four classes of biomolecules i.e.,

- Carbohydrates
- Proteins
- Lipids
- Nucleic acids

LESSON 23

CARBOHYDRATES: Chemical Composition and Occurrence

Carbohydrates are polyhydroxy aldehydes, ketones or complex molecules giving aldehyde or ketone on hydrolysis. They are the most abundant biomolecules on earth and important part of diet in most parts of the world. Chemically they are made up of C, H and O. However N, S, P may also present in their derivatives. General formula of carbohydrates is $(CH_2O)_n$. Carbohydrates are also called hydrated carbons as the ratio between hydrogen and oxygen is same as in water(2:1).

Carbohydrates are abundantly present in bakery items (bread, cakes, pastries etc.), dairy products (milk, yogurt, ice cream), Vegetables, fruits, cereals (wheat, rice, corn), legumes, candies, soft drinks and desserts. Meat also contain some amount of carbohydrates. Carbohydrates are a main source of our daily energy needs. We obtain 60-65% of energy from carbohydrates. About 225-325 gram per day carbohydrates are required to a normal healthy person.

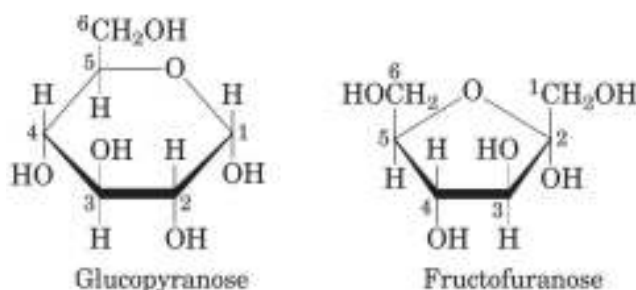
LESSON 24

a. Monosaccharides

Monosaccharides are the simplest carbohydrates which cannot be further hydrolyzed into simpler carbohydrates. E.g., glucose. They are sweet in taste, readily soluble in water, crystalline at room temperature and are reducing sugars. Monosaccharides normally range from 3-7 carbons.

Monosaccharide name	No. of carbon atoms
Triose	3C
Tetrose	4C
Pentose	5C
Hexose	6C
Heptose	7C

Mono saccharides with aldehyde groups are called aldoses while those with ketonic group are called ketoses. Carbon atoms form linear chains while those with four or more carbon form a ring structure in aqueous environment. Monosaccharides with five corner ring is called Furanoses while those with six corner ring are called pyranoses.



Monosaccharides are important source of energy in our body. They have large number of C-H bonds which release energy during cellular respiration. Glucose is the major source of energy in our body. It is most important source of energy for all organisms. Fructose and Galactose also provide energy. Monosaccharides combine together to form oligosaccharides and polysaccharide of animals.

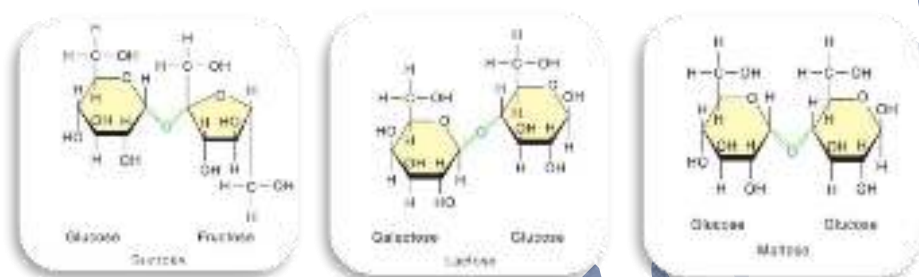
LESSON 25

b. Disaccharides

Disaccharides are the most common type of oligosaccharides. Two monosaccharide subunits combine to form a disaccharide. They are linked to each other through glycosidic bond. Disaccharides are soluble in water, less sweet in taste and crystalline solids. Maltose and lactose are reducing disaccharides while sucrose is an example of non-reducing disaccharide. Molecules

with same molecular formula but different structural formula are called isomers. All disaccharides are isomers of each other. Their molecular formula is $C_{12}H_{22}O_{11}$.

Disaccharides are important sugar which provide energy to our body. Sucrose is obtained from sugar cane and sugar beet. Lactose is present in milk sugar while maltose is present in sweet potatoes, candies. Disaccharides are broken down by intestinal enzymes into monosaccharides.



LESSON 26

c. Polysaccharides

When many monosaccharides join together through glycosidic bond, they form a polysaccharide. Polysaccharides are not sweet in taste, very little soluble in water molecules non-reducing with general formula $C_x(H_2O)_y$ or $(C_6H_{10}O_5)_n$. Common Polysaccharides include glycogen, starch, cellulose and chitin. Some polysaccharides work as fuel storage such as glycogen and starch while others such as chitin and cellulose are structurally important.

LESSON 27

Carbohydrates as Energy Source and Structural Support

Carbohydrates are a main source of our daily energy needs. We obtain 60-65% of energy from carbohydrates. About 225-325 gram per day carbohydrates are required to a normal healthy person. Glucose is the most important source of energy for all organisms. Disaccharides are broken down by intestinal enzymes into monosaccharides. Among polysaccharides starch and glycogen are broken down into glucose molecules. Some animals also digest cellulose and obtain glucose.

Carbohydrates also provide structural support. Chitin forms the exoskeleton of different arthropods. e.g. insects and crustaceans. Cellulose provides strength to cell wall of plants. Glycocalyx make a whorl outer to cell membrane which makes recognition sites and protects the cell. The extracellular material which hold the cells together contains carbohydrates.

LESSON 28

LIPIDS: Chemical composition and occurrence

It is a diverse group of biomolecules with are water insoluble and readily soluble in organic solvent. Like carbohydrates lipids are mainly made up of C, H and O. However, N, S, P also present in some derivative forms. Lipids contain much smaller amount of oxygen than carbohydrates and highest number of C-H bonds. That's why they give more than double amount of energy as compared to carbohydrates and proteins. Lipids are present in dairy items (milk, cheese, butter, cream, yogurt, margarine etc.), Meat, fish eggs, dry fruits (peanut, almond, walnut etc.), Cooking oils and fried foods.

Lipids are not only the richest source of energy but they are the important component of all cellular membranes. Many hormones and vitamins are derived from lipids. They are also involved in protection, insulation and cell signaling.

LESSON 29-30

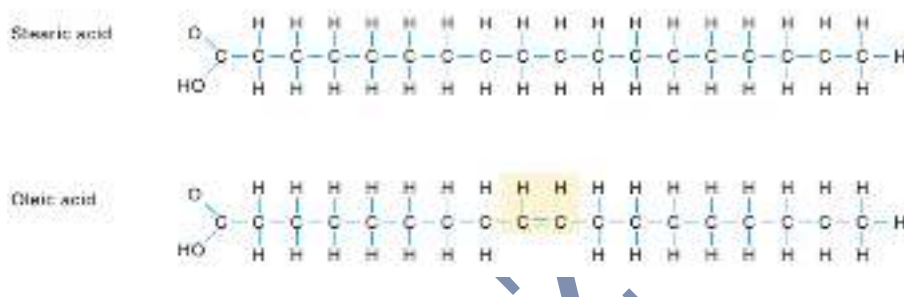
Fatty Acids

Fatty acids are long chain hydrocarbons bonded to carboxylic (-COOH) group. They have maximum number of C-H bonds. Oxygen is present only in the form of COOH group. Animals mostly have even number fatty acids and their size varies from 4-36 carbons while most common are 14-20 carbons. Fatty acids having single covalent bond between all carbons are called saturated fatty acids while those having one or more double bonds are called unsaturated fatty acids. Saturated solidify at room temperature while unsaturated are liquid at room temperature. Melting point of fatty acids increase with increase in number of carbon atoms while solubility decreases with increase in carbon chain size. Melting point also decrease with addition of double bonds.

Table: Some common fatty acids found in nature

Fatty acid	Melting point	Occurrence
Palmitic acid	62.9°C	Animals, plants and

(16C, saturated)		microorganisms
Stearic acids (18C, saturated)	69.6°C	Animal fat
Arachidic Acid (20C, saturated)	76.5°C	Peanut and corn oil
Palmitoleic acid (16C, unsaturated)	1°C	Olive oil
Oleic acid (18C, unsaturated)	13.4°C	Human adipose tissues



LESSON 31

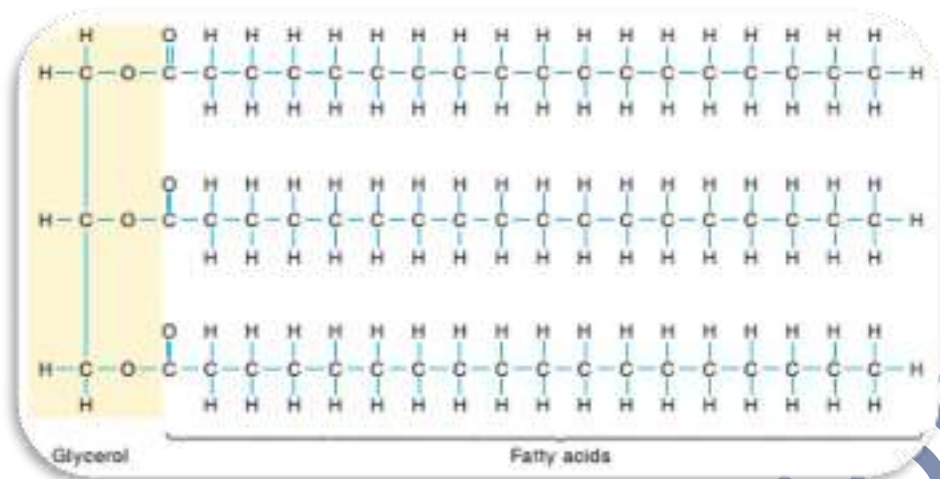
Fig. Examples of saturated and unsaturated fatty acid

Types of Lipids

Lipids are of different types. Triglycerides, Phospholipids and steroids are important types of lipids.

a. Triglycerides (FATS and OILS)

Triglycerides are the simplest type of lipids. They are also called neutral fats or triacylglycerol. Triglycerides have a glycerol backbone and one fatty acids attached to each of three carbons of glycerol through ester linkage. The fatty acids found in triglycerides have mostly 16-20 carbon backbone. Simple triacylglycerol have only one type of fatty acids while mixed triacylglycerol have two or three different types of fatty acids. Triglycerides are stored in adipocytes or fat cells and provide energy to body. They are also present beneath the skin and work as insulator against heat loss. Triacylglycerol solid at room temperature are called **fats** and contain all three saturated fatty acids e.g., animal fats. Whereas triacylglycerol liquid at room temperature are called **oils**. They contains unsaturated fatty acids e.g., Plants oils.



LESSON 32

b. Phospholipids

Phospholipids are the molecules in which two fatty acids and a phosphate group along with a nitrogen base are attached to glycerol backbone. They have a polar head of phosphate and nitrogen base while the nonpolar tail has fatty acids. Due to hydrophilic head and hydrophobic tail they form lipid bilayer of membranous structures of animals.

There are of four main types of phospholipids i.e., phosphatidylethanolamine, phosphatidylcholine, phosphatidylserine and phosphatidylinositol.

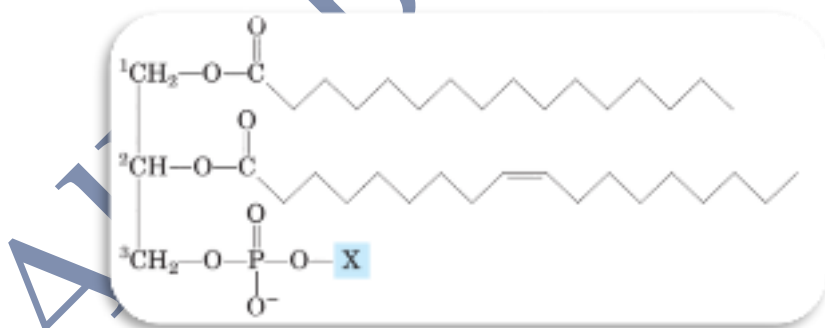
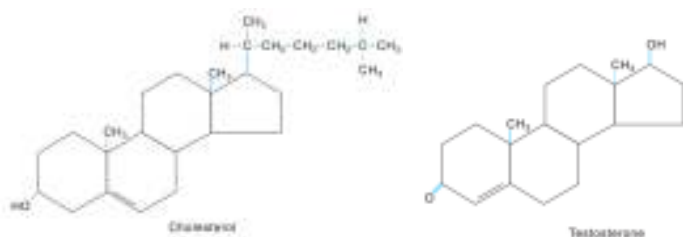


Fig: General structure of phospholipids.(x represents nitrogen bases)

LESSON 33

c. Steroids

Steroids are naturally occurring lipids which contain four fused carbon rings. Three 6-sided and one 5-sided rings make steroid nucleus of 17 carbons. Important steroids in animals are cholesterol, aldosterone, testosterone, estrogen and vitamin D. Cholesterol is found in cell membrane, aldosterone is released by adrenal glands while testosterone and estrogen are the hormones of testes and ovaries, respectively.



LESSON 34-35

PROTEINS

Proteins are the biomolecules having one or more chains of amino acids. Chemically they are made up of carbon, hydrogen, oxygen and nitrogen. Sulfur is also present in proteins. Animals have thousands of different types of proteins. They have both structural and functional role. Important roles of proteins in our body are:

- Making all the body structures of animals. e.g., bones, muscles, visceral organs, hair and nails.
- Antibiotics and Antibodies to fight and protect against diseases
- Transportation of gases and other molecules.
- Most of the enzymes are protein in nature which catalyze biochemical reactions.
- All types of movements in living organisms are due to proteins. i.e., locomotion, heart beat and breathing process
- Many hormones, neurotransmitters and intracellular messengers are protein in nature.
- Proteins also provide energy when their amino acids are degraded by deamination process.
- Important dietary sources of proteins include dairy products (milk, yogurt and cheese), meat, poultry, fish, egg, seeds, nuts, beans and legumes.

LESSON 36

Amino Acids

The building blocks of proteins are amino acids. About 20 types of amino acids are present in proteins. Chemically amino acids may be polar, non-polar, acidic, basic or aromatic. Nature of R group dictate the chemical properties of proteins.

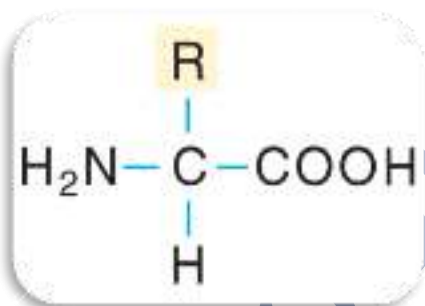


Fig. general structure of amino acids. All amino acids differ with respect to R group.

LESSON 37

1. Secondary Structure

It is the local folding of polypeptide chain. Secondary structure is formed by repeating pattern of hydrogen bonds between amino acids. There are two major types of secondary structures:

- a. Alpha helix
- b. Beta sheets

a. Alpha Helix

α -helix is helical arrangement of polypeptide chain. In majority of proteins it is right handed. In α -helix, amino hydrogen of one amino acid makes hydrogen bond with carboxylic oxygen of fourth amino acid.

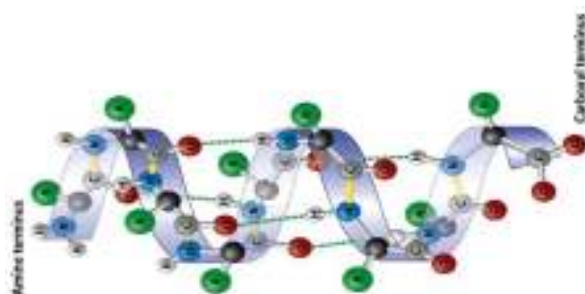


Fig. alpha helix of polypeptide chain

b. β -pleated Sheets

Polypeptide chain is also arranged in the form of sheets called β -pleated sheets. These sheets arrange in parallel or antiparallel form. Sheets are attached together through hydrogen bonds between amino hydrogen of one β -sheet and carboxylic oxygen in the other sheet.

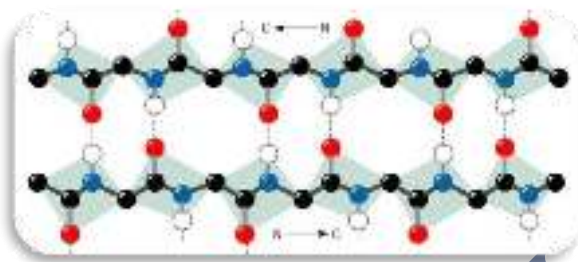


Fig. β -pleated sheets of polypeptide chain

c. β -turns and random coil

β -turn are the bends between two β -sheets. Sometimes polypeptide chain do not attain any regular shape and it is called random coil.

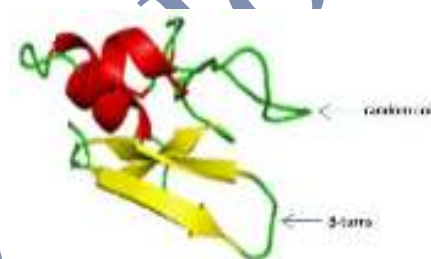


Fig. β -turns and random

LESSON 38

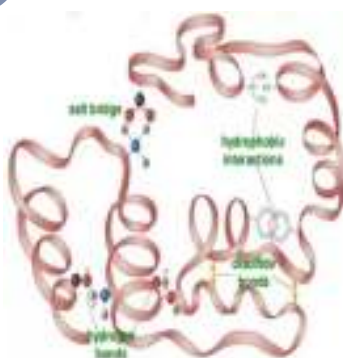
2. Tertiary Structure

Overall folding of a polypeptide chain into a 3D form is called tertiary structure. Main forces involved in formation of tertiary structure are hydrogen bond, ionic bond, hydrophobic interaction and disulfide bond. Myoglobin and salivary amylase have tertiary structures.

LESSON 39

3. Quaternary Structure

When two or more polypeptide quaternary structure. Main structure are hydrogen bond, and sometime covalent bond. structures include hemoglobin,



chains fold together they form a forces involved in quaternary ionic bond, van der Waal forces. Proteins with quaternary pepsin and keratin.

Fig. Tertiary structure and the bonds involved

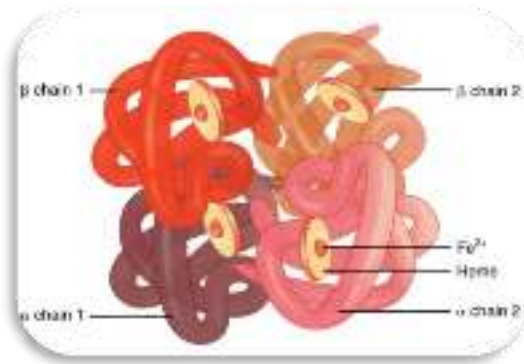


Fig. Quaternary structure of hemoglobin

Fibrous and globular protein

Fibrous proteins have long fibers. They are water insoluble and provide structural support to animals. Keratin (in nails, hair, skin), collagen (in bones, cartilage, tendons) and silk fibroin in silk are examples of fibrous proteins.

Globular proteins have compact globular structure. They are water soluble and have functional role. All enzymes, hemoglobin and myoglobin are examples of globular proteins.

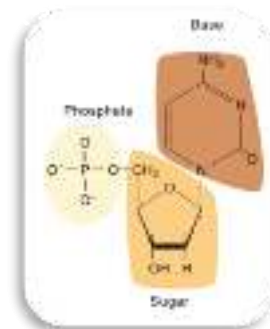
LESSON 40

NUCLEOTIDES AND NUCLEIC ACIDS

NUCLEOTIDES: Chemical composition and occurrence

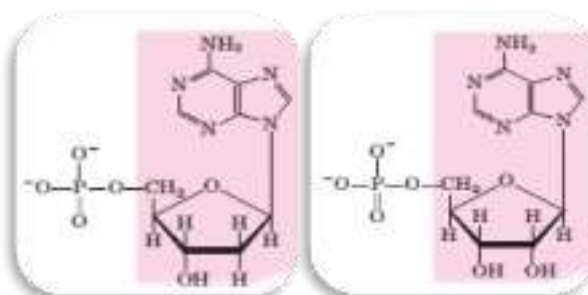
Nucleotides are important biomolecules essential to life. They are building blocks of nucleic acids (DNA and RNA). They also perform different cellular activities. Nucleotides are made up of following three components:

- 1) Five carbon/pentose sugar/ (ribose, deoxyribose)
- 2) Phosphate group
- 3) Nitrogen containing base (adenine, guanine, cytosine, thymine/Uracil)



Types of nucleotides

Nucleotides making DNA molecules are called deoxyribonucleotides while nucleotides making RNA molecules are ribonucleotides.



Deoxyribonucleotides Ribonucleotides

On the basis of nitrogen bases there are following types of nucleotides:

Deoxyribonucleotides		Ribonucleotides	
Deoxyadenosine triphosphate	dATP	Adenosine triphosphate	ATP
Deoxyguanosine triphosphate	dGTP	Guanosine triphosphate	GTP
Deoxycytidine triphosphate	dCTP	Cytidine triphosphate	CTP
Deoxythymidine triphosphate	dTTP	Uridine triphosphate	UTP

LESSON 41

Role of nucleotide into cell

Nucleotides are the building blocks of DNA and RNA molecules. They are the coenzymes of different enzymes e.g., NAD and NADP. Some nucleotides like ATP and GTP work as energy currency of the cell. cAMP work as chemical messenger within the cell.

LESSON 42

DNA

DNA is made up of deoxyribonucleotides. It is double helical structure where adenine pairs with thymine (A=T) and guanine pairs with cytosine (G=C). DNA is the hereditary material of the cell and also transfers the hereditary information to the next generation.

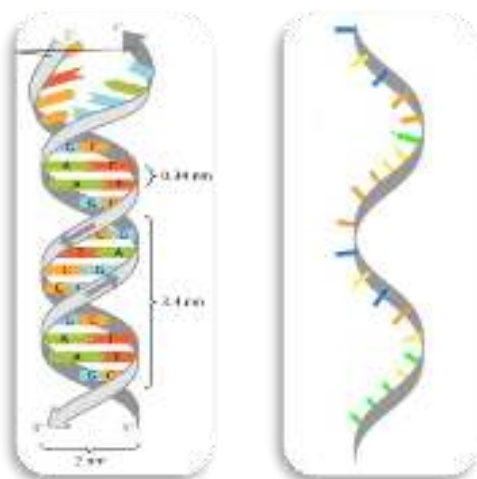


Fig. Structure of DNA and RNA

LESSON 43

RNA

RNA is made up of four types of ribonucleotides (ATP, GTP, CTP, UTP). It is single stranded polynucleotide chain. There are three types of RNA: rRNA, tRNA and mRNA. rRNA is part of ribosomes, tRNA is involved in translation process while mRNA copies information from DNA for protein synthesis. RNA is also the genetic material of many viruses.

LESSON 44

STRUCTURAL HIERARCHY IN MULTICELLULAR ANIMALS

“A hierarchy is an organizational structure in which items are ranked according to levels of importance”. The living organisms have following structural hierarchy.

i. Atoms

Atom is first level of structural hierarchy. It is the smallest unit of matter.

ii. Molecules

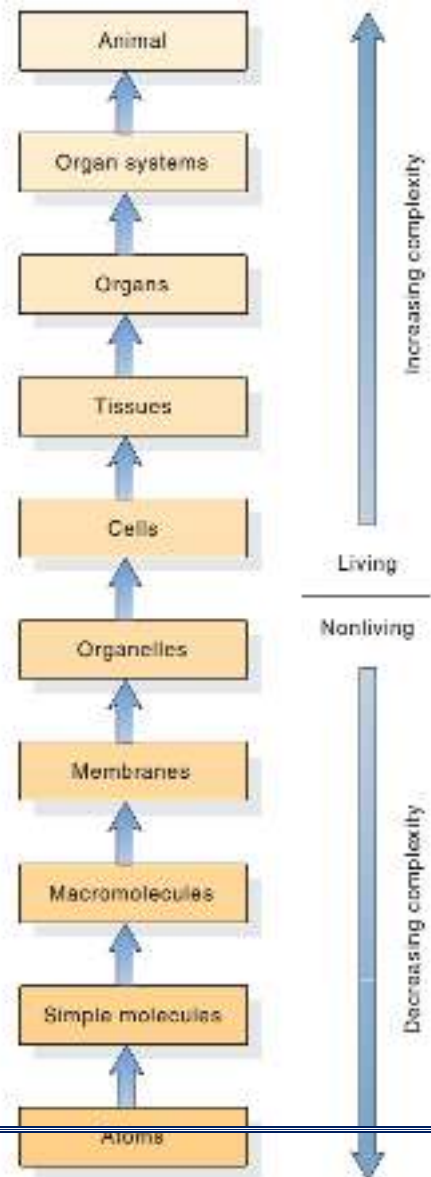
Atoms combine together to form molecules. Molecules exist independently and take part in a chemical reactions. Small size molecules are called micromolecules (H_2O , CO_2) while large size molecules are called macromolecules (DNA and proteins).

iii. Organelles

Organelle is the small cellular structure performing specific function in the cell. Some are membrane bounded (Vacuole, Golgi bodies) while some are without membrane (ribosome).

iv. Cells

Cell is the structural and functional unit of life. It means all living organisms are made up of cells and all functions of



living organisms are also performed by the cell. Cells are two basic types: Prokaryotic cell (without nucleus) and Eukaryotic cell (have true nucleus).

v. Tissues

Tissue is a group of cells performing similar functions. Animals have different types of tissues e.g., cardiac tissues, epithelial tissues and endocrine tissues.

vi. Organs

Organ a part of body which performs specific function. Stomach, intestine and heart are the examples of organs.

vii. System

Different organs performing related functions form a system. It system is designated to perform specific function. Major systems in our body include respiratory system, digestive system and circulatory system.

viii. Organism

Systems make an organism or individual. An organism has individual existence. It performs all the activities of life.

LESSON 45

WHAT IS A CELL?

Cell is the smallest independent unit of life. Cell is the structural and functional unit of life. Cells can grow, divide and synthesize biomolecules. All cellular activities like secretion, absorption and transportation are performed by the cell. Unicellular organisms are made up of only one cell while multicellular organisms have few to trillions of cells.

Cells are of two basic types: Prokaryotic cells and Eukaryotic cell.

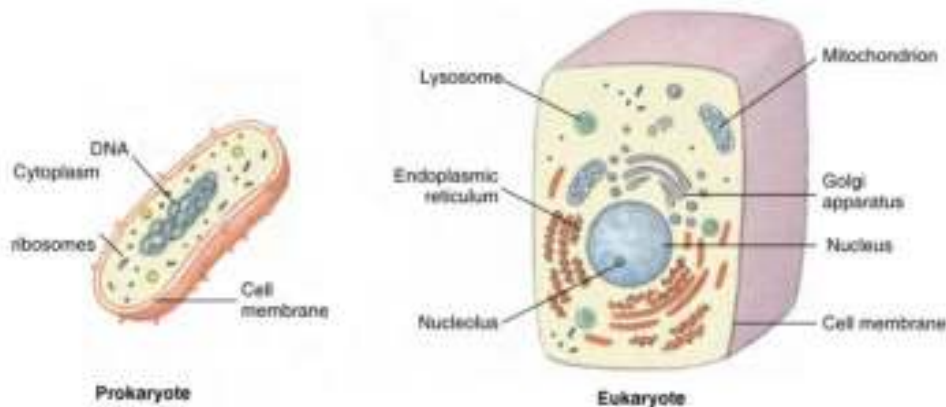
LESSON 46

Prokaryotic Cell

Prokaryote is a combination of two Greek word “pro” means before and “Karyon” means nucleus. Prokaryotic cells are those which do not have a membrane bounded nucleus. They also have no other membrane bounded organelles as well. Organisms with prokaryotic cells are called prokaryotes. E.g., bacteria and cyanobacteria.

Eukaryotic Cell

Eukaryote is a combination of two Greek word “eu” means true and “Karyon” means nucleus. Eukaryotic cells are those which have a membrane bounded nucleus. They also have other membrane bounded organelles. Organisms with eukaryotic cells are called eukaryotes. E.g., animal and plant cells.



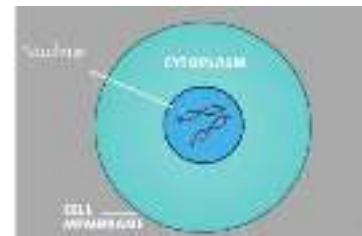
LESSON 47

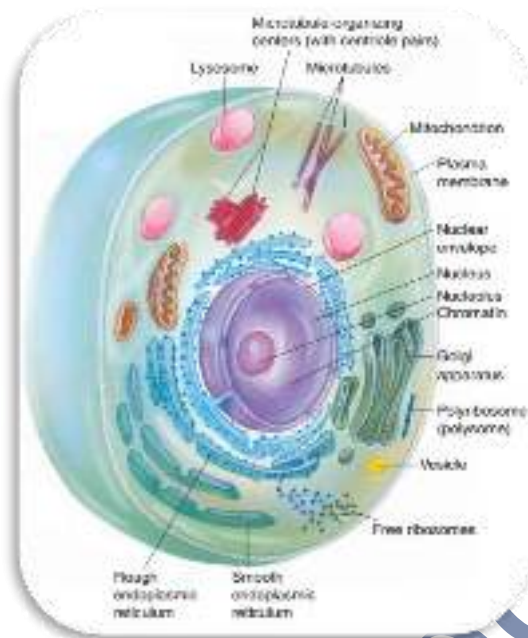
General Features of Eukaryotic Cell

There are three main components of eukaryotic cells:

1. Plasma membrane
2. Cytoplasm
3. Nucleus

Membrane bounded organelles, cytoskeleton and linear chromosomes are important features of eukaryotic cells. Presence of different organelles is also called compartmentalization. Each organelle performing specific job. For example Lysosome performs digestion, mitochondria produces energy and Golgi apparatus is involved in cell secretion.





LESSON 48

Why Most Cell are Small?

Average size of Ostrich egg is 15 x 13 cm while neurons of human and elephant are about 1m and 4 m, respectively. However, most of the cells are very small and range 5-150 μ m. Why cells are so small? This is because an increase in cell size increases volume enormously. The increase in volume causes two major problems. Firstly, by increasing size the ratio between volume of nucleus to volume of cytoplasm decreases. As a result nucleus will lose its control on very large cytoplasm. Secondly, cell volume increases much more than its surface area. This will result in reduced gases exchange, uptake of nutrients and removal of wastes.

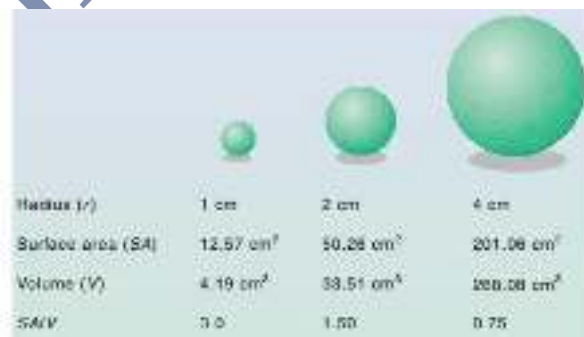


Fig. The increase in volume causes a decrease in surface area to volume ratio (SA/V).

LESSON 49

CELL MEMBRANE

Composition

Cell/plasma membrane is the outer most boundary of a cell. It also makes the boundaries of membranous organelles. Chemically cell membrane is made up of phospholipids, cholesterol, proteins and carbohydrates.

Phospholipids form lipid bilayer. They have polar heads and nonpolar tails. Polar heads are oriented outward and to cytoplasm while tails are present between two head layers. **Cholesterol** is present in plasma membrane of eukaryotes only. Cholesterol is embedded interior of membrane. It makes cell membrane stable and less permeable to water. Membrane **proteins** are individual molecules present inner or outer surface (peripheral proteins) or embedded in the membrane (intrinsic proteins). Outer proteins are attachment site for carbohydrates while proteins on cytoplasmic side are attachment site for cytoskeleton. Some membrane proteins transport materials into and out of cell. **Carbohydrates** make less than 1% of the cell. They combine with proteins to form glycoproteins and with lipids to form glycolipids. Carbohydrates, proteins and lipids at the surface of cell membrane form cell coat called **glycocalyx**. Glycocalyx is involved in cell recognition and determination of cell behavior.

LESSON 50-51

Structure of Cell Membranes

Cell membrane separates the cell from external environment. All material move across the cell membranes. There were two models about structure of cell membrane: a). Unit membrane model
b). Fluid mosaic model

a) Unit membrane model

According to unit membrane model cell membrane has four layers. Two lipid layers are present in the center and two outer protein layers. It means lipids are sandwiched between two protein layers. This model was however, unable to explain the movement of molecules across cell membrane.

b) Fluid mosaic Model

In 1972, S. Jonathen Sanger and Garth Nicolson presented fluid mosaic model of membranes. According to this model plasma membrane is fluid in nature where lipids form bilayer and proteins are embedded in a mosaic pattern. Lipids form bilayer due to hydrophobic tails. Phospholipids molecules form a sea in which protein molecules are floating like icebergs or ships. Being fluid the membrane is in a constant state of shifting and changing. However membrane maintain a uniform structure. Due to fluid nature membrane is not locked for transportation of materials.

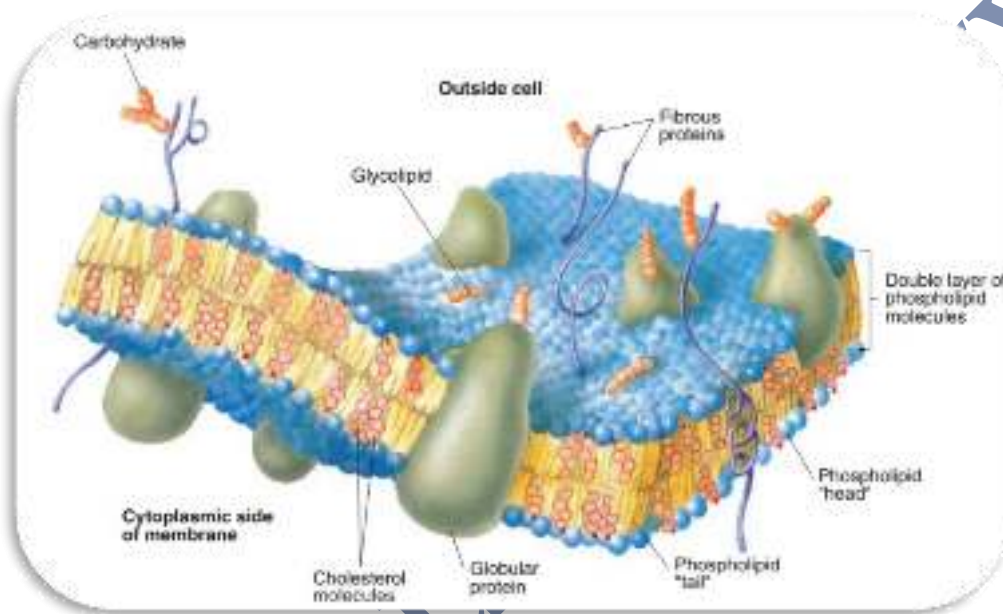


Fig: Fluid mosaic model of cell membrane

LESSON 52

Functions of Cell Membranes

Some of the important functions performed by cell membrane are:

1. It separates the cells from one another and from external environment.
2. It separates various cellular organelles from general cellular environment. This property is called compartmentalization.
3. It regulates the transport of materials into and out of the cell. It also controls the movement of materials between different organelles.
4. Different Chemical reactions take place on the surface of cell membranes.
5. Cell membranes contain different types of molecules which serve as identification markers of different cells. i.e., antigens
6. It maintains the internal environment of cell (cellular homeostasis).

LESSON 53

MOVEMENTS ACROSS CELL MEMBRANES

1. Simple Diffusion

“Movement of molecules from an area of high concentration to the area of low concentration is called simple diffusion”. Diffusion is a passive transport of molecules. *i.e.*, no energy is required for this process. It is a random movement of molecules. Diffusion accounts for movement of molecules for short distance.

- a) Movement of O_2 from lungs into blood stream
- b) Movement of CO_2 from tissues into tissue fluid

LESSON 54

2. Facilitated Diffusion

“Movement of molecules from an area of high concentration to the area of low concentration with the help of membrane proteins is called facilitated diffusion.” There are two types of these proteins: a) Channels b) Carrier

Like simple diffusion, facilitated diffusion is also a passive transport method. Large size molecules and polar or charge bearing molecules are transported across cell membrane by this method. Glucose transporter, Na^+ channels and K^+ channels transport glucose, Na^+ and K^+ through facilitated diffusion mechanism.

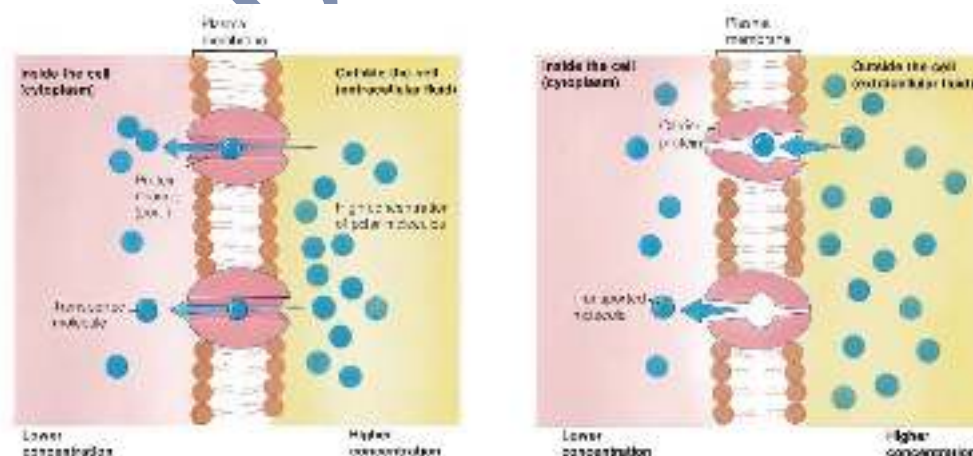


Fig: Facilitated diffusion

LESSON 55

3. Osmosis

“It is the movement of water molecules across a selectively permeable membrane from an area of higher concentration to the area of lower concentration”. The minimum pressure required to prevent the inward flow of its pure solvent across a semipermeable membrane is called **osmotic pressure**. The concentrated solution surrounded by dilute environment is called **hyperosmotic**. e.g., a cell placed in pure water, cell is hyperosmotic with reference to surroundings. If the solution has same concentration of solute with reference to surroundings, it is called **isosmotic**. e.g. if a cell is placed in normal salt concentration medium, the cell is isosmotic with reference to surroundings. The solution with lower concentration of solute than surroundings is called **hypo osmotic**. e.g., when a cell is surrounded by concentrated environment, the cell is hypo osmotic with reference to external environment.

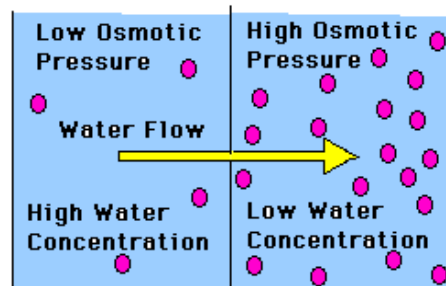


Fig. osmotic pressure is high where water molecules are in low concentration

Osmosis maintains ionic balance and osmotic equilibrium. Minerals and nutrients are uptaken by the process of osmosis.

LESSON 56

4. Filtration

“Filtration is a process that forces small molecules across selectively permeable cell membrane using hydrostatic pressure”. It is the pressure exerted by fluid at any point within the fluid or on the walls. Hydrostatic pressure increases with increasing depth and it acts in all directions. E.g., Filtration also takes place in glomerulus of nephron in kidney which is first step of urine formation.

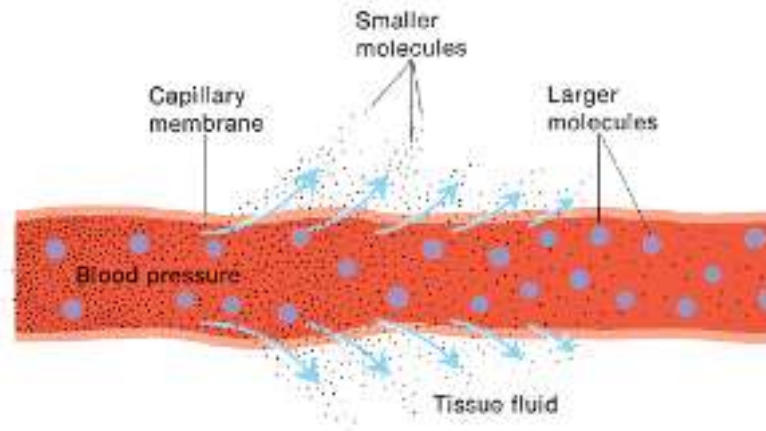
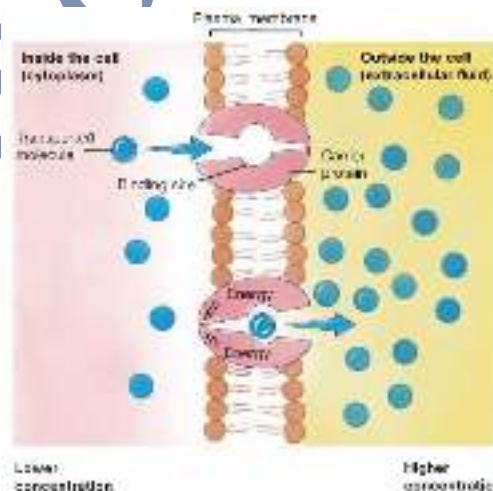


Fig. Filtration across capillary walls

LESSON 57

5. Active Transport

“Movement of molecules from a selectively permeable membrane against concentration gradient is called active transport”. It is the movement of molecules from low concentration to high concentration with the expenditure of energy (ATP). Like passive transport carrier protein are involved. These proteins are also called pumps because they work from low to high concentration. e.g., sodium/potassium pump which helps to maintain K^+ and Na^+ gradient in nerve cells. Ca^{2+} is kept hundreds of times low concentration in cytosol than endoplasmic reticulum.



LESSON 58

6. Endocytosis

“The bulk movement of molecules into the cell is called endocytosis. There are three forms of endocytosis:

- Pinocytosis
- Phagocytosis
- Receptor mediated endocytosis

a. Pinocytosis

It is the uptake of liquid from extracellular environment. Liquid is up taken in the form of vesicle. A small solid dissolved into the liquid is also taken into the cell.



Fig. Pinocytosis

b. Phagocytosis

It is the uptake of solid materials by the cell. Cell membrane invaginates to take solid material in the form of a vesicle. Within cell this vesicle combines with lysosome to form **phagolysosome** for digestion.

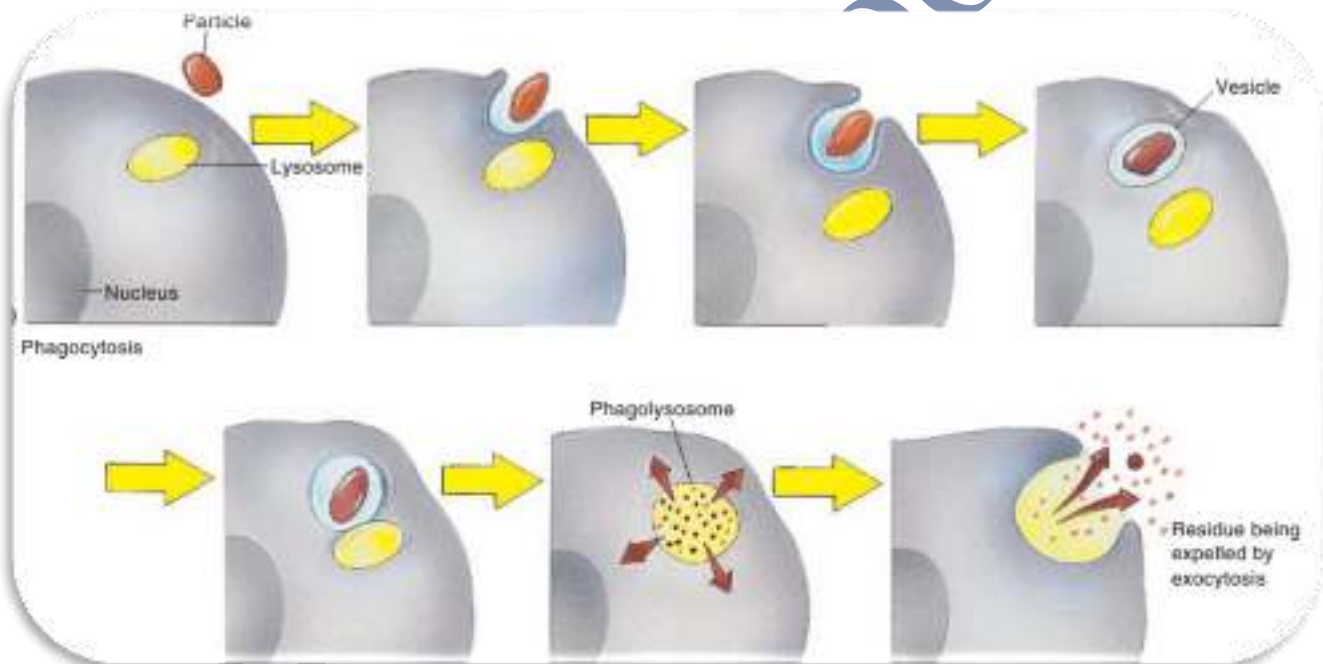


Fig. Phagocytosis by an animal cells

c. Receptor

It is the uptake of molecules when they bind with specific receptor on cell membrane. After this membrane invaginates and vesicle formation occurs. e.g., transport of cholesterol across cell membrane.

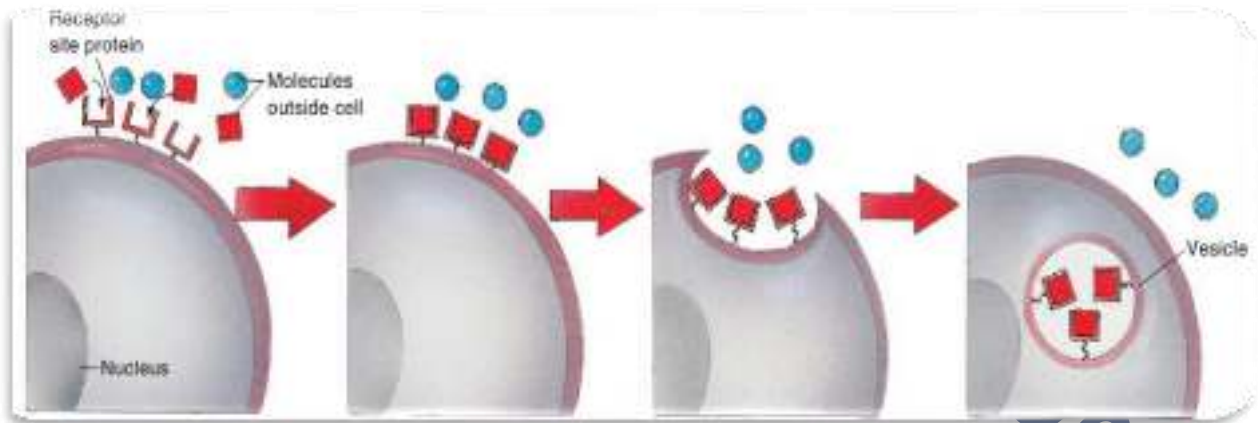


Fig. Receptor mediated endocytosis

LESSON 59

7. Exocytosis

“It is the process by which cellular material are packed up into vesicles and transported out of cell”. This is opposite to endocytosis. Different proteins which have to be transported out of cell are brought to cell surface via exocytosis. E.g., release of extracellular enzymes and removal of undigested food by amoeba and paramecium.

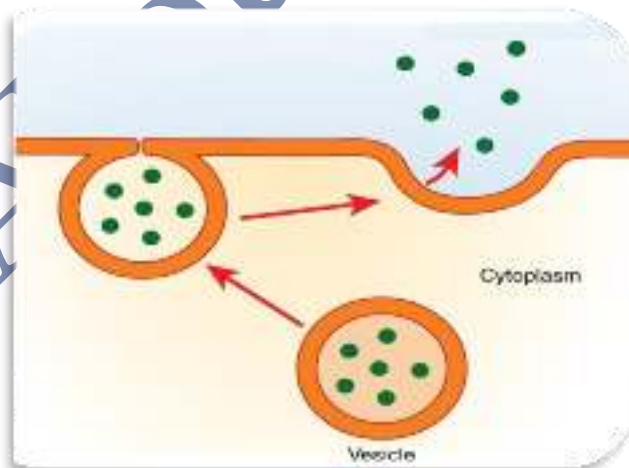


Fig. Exocytosis

Exocytosis adds new fragments to cell membrane. This is the compensation of membrane lost during endocytosis.

LESSON 60

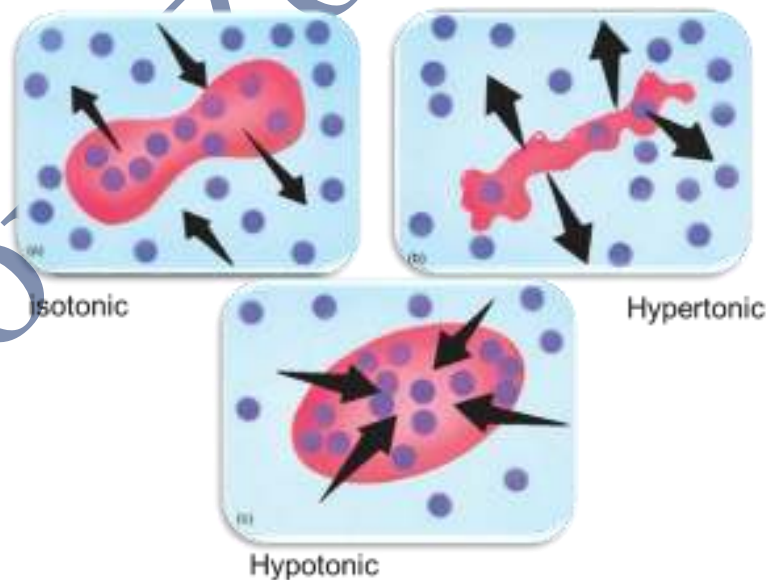
TONICITY

“It is the relative concentration of solutes dissolved in solution inside and outside the cell”. Water molecules move into and out of cell due to difference in tonicity. A may be present in three different types of solutions.

- a. **Isotonic Solution:** When solute concentration is same outside and inside of the cells. Water molecules move inside and out of the cell at same rate.
- b. **Hypertonic Solution:** When solute concentration is higher outside the cells than inside. Water molecules move out and the cell shrinks. This condition is called crenation.
- c. **Hypotonic Solution:** When solute concentration is lower outside the cell than inside. Water molecules move into the cell which causes the cell to swell and burst.

Fig. General structure of an animal

Cell



LESSON 61

CYTOPLASM AND ITS FUNCTIONS

Cytoplasm is the portion of cell present between nucleus and plasma membrane. **Ectoplasm** is the clear, outer layer of cytoplasm which is immediately below the plasma membrane. While the inner, dense portion of cytoplasm is called **endoplasm**. Cytoplasm has semi-fluid portion called **cytosol** while membrane bounded and non-membranous structures are called **organelles**. Organelles of cytoplasm perform different functions such as protein synthesis, digestion, ATP synthesis etc. Cytoplasm has the storage of molecules required for different cellular activities.

The important cellular structures are: ribosomes, endoplasmic reticulum, lysosomes, Golgi apparatus, mitochondria, vacuoles, cytoskeleton, cilia and flagella.

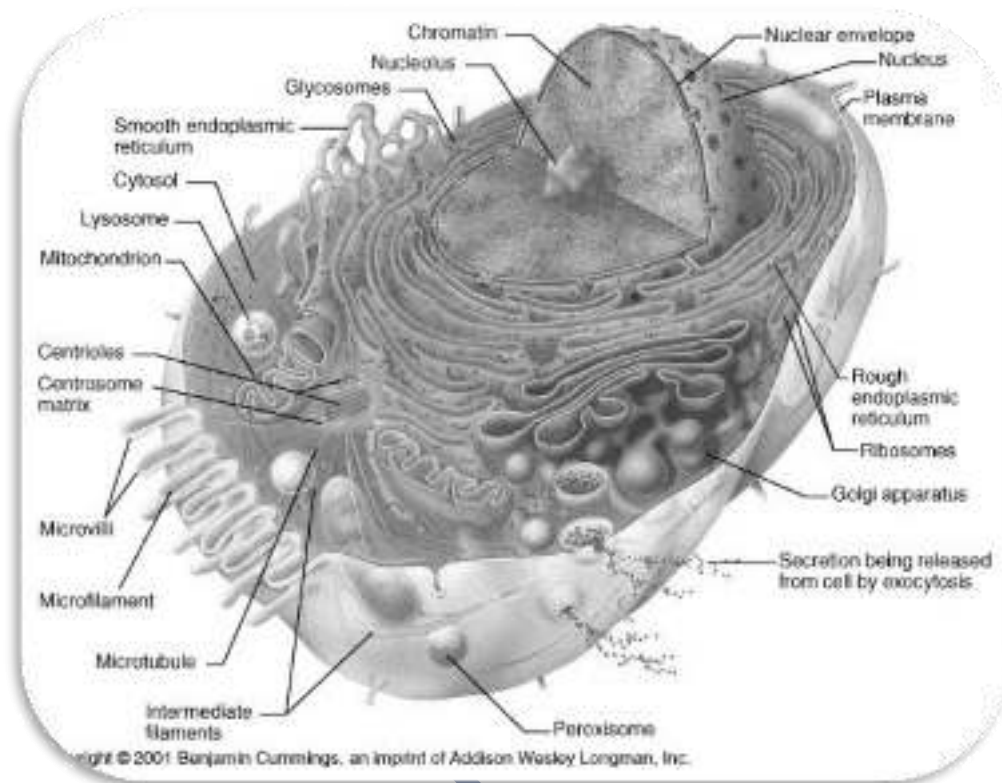


Fig. General structure of an animal cell

LESSON 62

1. Ribosomes

Ribosome is the non-membranous structure of cytoplasm involve in protein synthesis. Prokaryotes like bacteria have small size ribosome (70S) while eukaryotes have large size ribosome (80S). Ribosome consists of two subunits: small ribosomal subunit and large ribosomal subunit. Chemically ribosomes are made up of equal amount of rRNA and proteins. They may be free or attached with endoplasmic reticulum. Ribosome get attached with mRNA and synthesize protein molecule. Sometimes many ribosomes are attached to single mRNA and the resulting structure is called **polysome**.

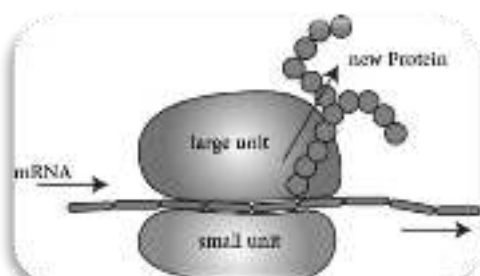


Fig. A single ribosome during

protein synthesis

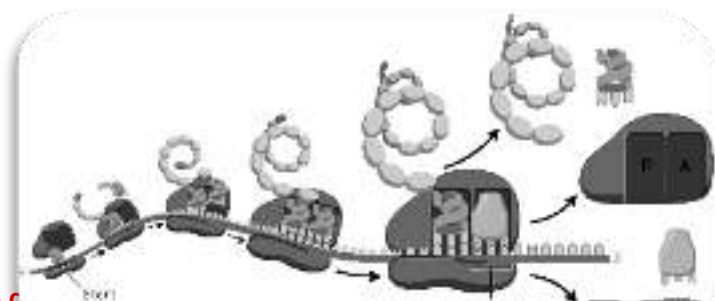
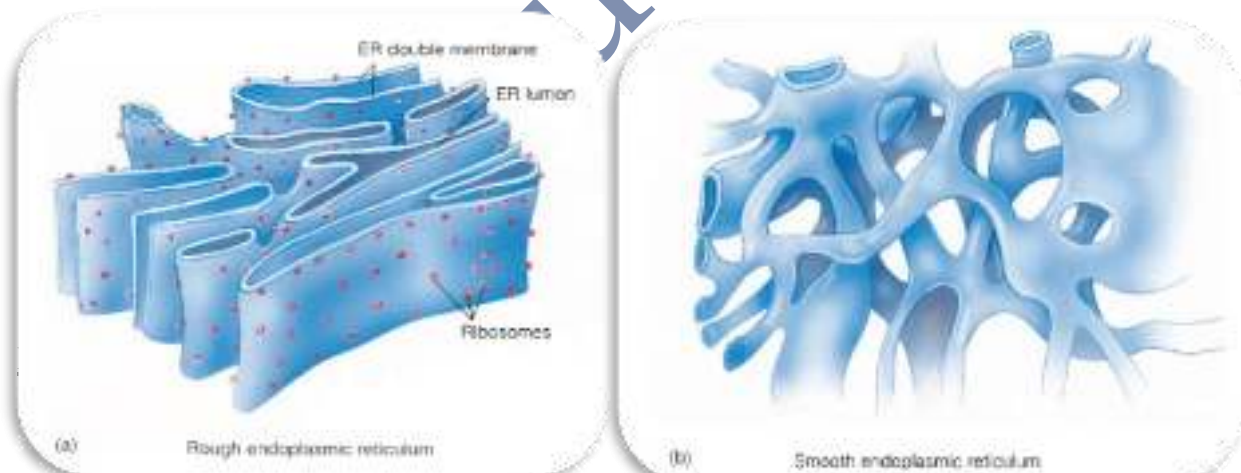


Fig. A polysome

LESSON 63-64

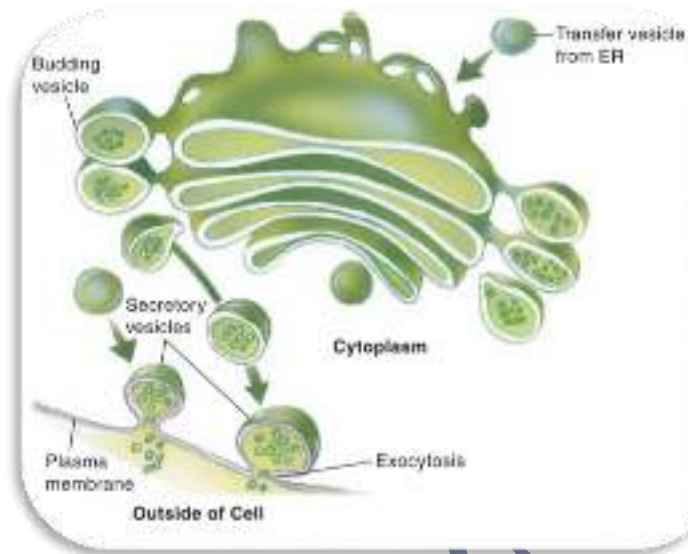
2. Endoplasmic Reticulum

Endoplasmic reticulum (ER) is a complex network of membrane bounded sheets, sacs and tubules present throughout the cytoplasm. At one side attached with outer membrane of nucleus while on other side attached with plasma membrane. Tubules of endoplasmic reticulum are called cisternae. There are two types of endoplasmic reticulum: Rough endoplasmic reticulum (RER) and Smooth endoplasmic reticulum (SER). Endoplasmic Reticulum with attached ribosomes on their surface are called **rough endoplasmic reticulum (RER)**. Presence of ribosomes give them rough appearance. While endoplasmic reticulum without ribosomes on their surface are called **smooth endoplasmic reticulum**. Due to absence of ribosomes on their surface they appear smooth. Important functions of ER are: mechanical support, material circulation, storage of enzymes, proteins and calcium, lipid production, detoxification of organic molecules and calcium storage.



It is a collection of membranes within cytoplasm involve in cell secretion and intracellular transport. Golgi apparatus is also called Golgi complex. It was first reported by Camilo Golgi in 1898. Golgi Apparatus is composed of 3-7 cisternae and some golgi vesicles. The side of golgi apparatus towards nucleus is called forming face while the side away from golgi apparatus is called maturing face. Golgi complex is involved in sorting, packing and secretion of proteins and lipids. Proteins are concentrated, chemically modified and sorted for different destinations. It is most abundant in cell involve in secretion.

Proteins are synthesized in the lumen of endoplasmic reticulum from where they are sealed off in small packets called **transfer vesicles** and send to Golgi apparatus. After modifications in Golgi apparatus proteins are packed into small sacs called **secretory vesicles** and move towards cell membranes for cells secretions



LESSON 66

4. Lysosomes

Lysosomes are single membrane bounded organelles which contain hydrolytic enzymes for intracellular digestion. They digest carbohydrates, lipids, proteins and nucleic acids. They can selectively digest and recycle their own cytoplasm or organelles. Lysosomes contain acid hydrolases which digest food under acidic conditions. A phagocytic food vacuole and lysosome fuse to form phagosome. In phagosome the ingested is digested and absorbed. Undigested food is excreted out by the process of exocytosis.

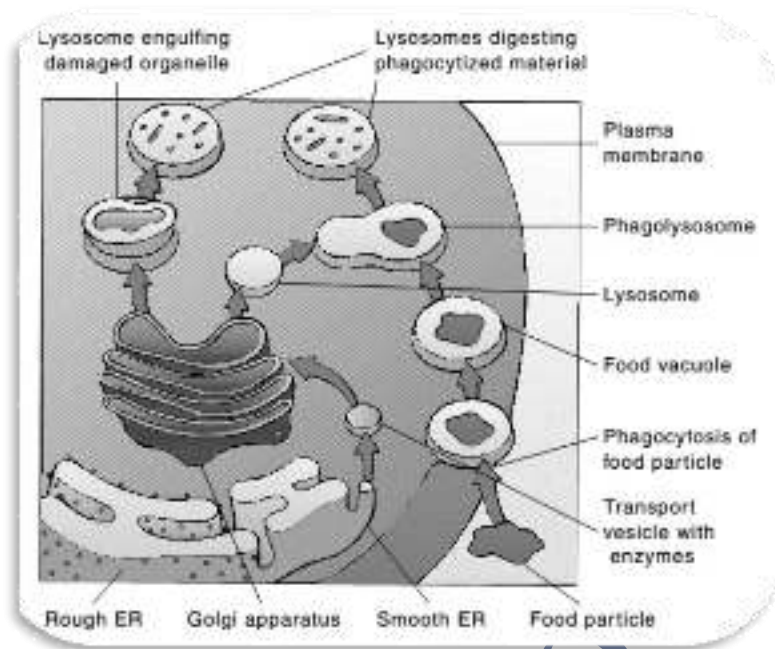


Fig. formation and function of lysosome

LESSON 67

5. Mitochondria

- Mitochondria are double membrane bounded organelles of cell involve in energy production. They are spherical to elongate in shape. Their outer membrane is flat while inner membrane is folded and forms finger like projections called cristae. Matrix is present between cristae. Matrix contain ribosomes, circular DNA, and other materials.

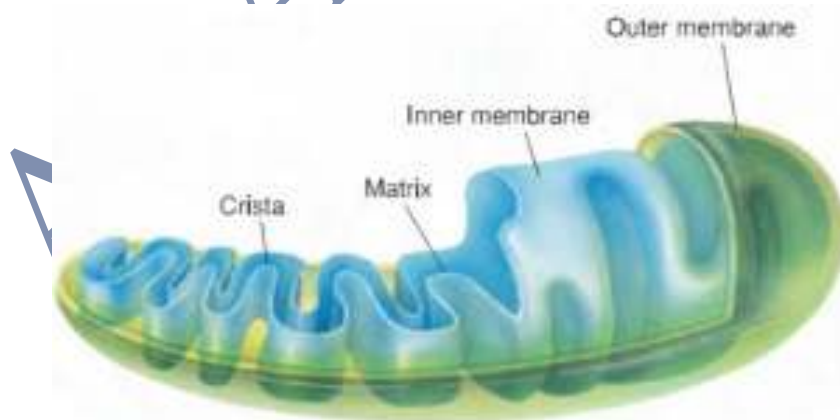


Fig. Inner structure of mitochondria

Mitochondria are “Power house” or “power generators” of the cell. Processes of ATP synthesis, Krebs cycle, electron transport chain and fatty acid oxidation take place in mitochondria. The number of mitochondria vary according to energy requirements of cells.

LESSON 68

6. Vacuole

Vacuoles are single membrane bounded organelles mainly involve in storage of water and salts in the cell. They vary in shape and number. Animal cells contain more than one small vacuoles. Membrane of vacuole is specialized in transportation of water and salts. Contractile vacuule in protozoa and sponges remove waste water from the cell while food vacuole is involved in digestion of food.

LESSON 69-70

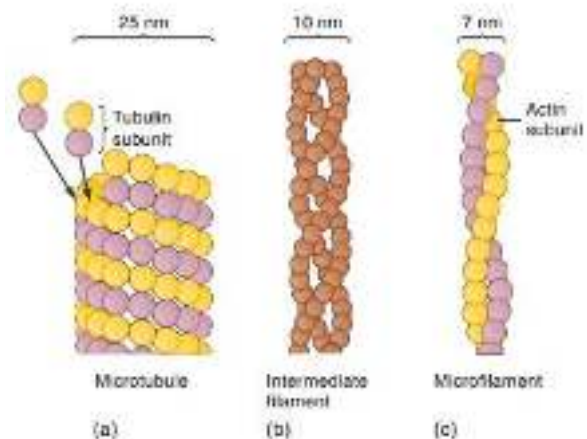
7. Cytoskeleton

It is the network of protein fibers extending throughout the cytoplasm present in eukaryotic cells only. It provides mechanical support and connects various cellular organelles. Cytoskeletal is made up of three types of fibers: Microtubules, Intermediate filaments and Microfilament.

Microtubules are hollow, slender, cylindrical structures. They are largest cytoskeletal elements. Each microtubule is about 25nm in diameter and made up of tubulin protein. Microtubules help in movement of organelles and chromosomes. They are part of transport system (e.g., secretory vesicle movement) in the cell and are involved in overall shape changes of cell during specialization. Microtubules make different structures like mitotic apparatus, cilia, flagella and centrioles.

Intermediate filaments are heterogeneous group of cytoskeletal fibers. They are made up of more than 70 different types of proteins. They are of intermediate size (10nm diameter). Intermediate filaments help to maintain cell shape, maintain spatial arrangement of organelles and promote mechanical activities in cytoplasm.

Microfilament are the smallest cytoskeletal fibers with 7nm diameter. They are made up of actin subunits. Microfilaments in muscle are highly developed and called as myofibrils. Main functions



of microfilaments are muscle contraction, mechanical support in non-muscle cells and contractile movements of cell (E.g., amoeboid movement)

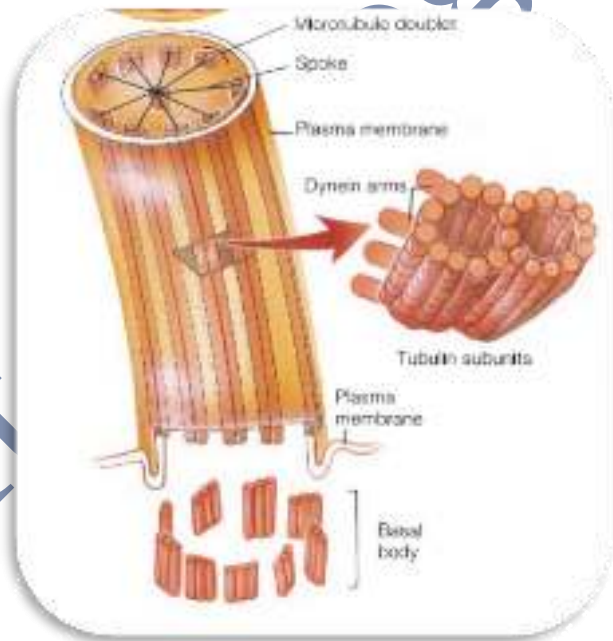
LESSON 71-72

8. Cilia and Flagella

Cilia and flagella are motile appendages present on the surface of some cells. **Cilia** are 5 to 20 times smaller than flagella and present on cells of trachea, fallopian tubes, protozoa and invertebrate larva. In trachea they push mucus and dust particles toward mouth, in fallopian tubes they move egg towards uterus and in protozoa and invertebrate larvae they are responsible for locomotion. **Flagella** are present on flagellated protozoans, bacteria and Gametes of algae, fungi, plants and animals. They are mainly involved in locomotion and have sensory role.

Both cilia and flagella are structurally same. Cell membrane forms continuous outer membrane. Material inside the membrane is called matrix. The central microtubule structure of cilia and flagella is called **axoneme** or axial filament. Axoneme has nine pairs of microtubules arranged in a circle and two central tubules. This is 9+2 pattern. Dynein arms project towards neighboring doublet. Nine pairs are connected with central tubules through **radial spokes**.

A microtubules structure present at the base of cilia and flagella is called basal body. It is made up of nine triplets of microtubules and no central pair of microtubules.



LESSON 73

9. Centrioles

Centriole is a cylindrical organelle present near to nucleus and involved in cell division process. Nine triplets of microtubules. They radiate from the center like spokes of wheel. There is pair of centrioles in the cell. Both are present right angle to each other. Centriole duplicate before cell

division. During cell division they form mitotic apparatus and help chromosomes to get separate. They are also involved in the formation of cilia and flagella.



Fig. A pair of centriole is perpendicular to each other.

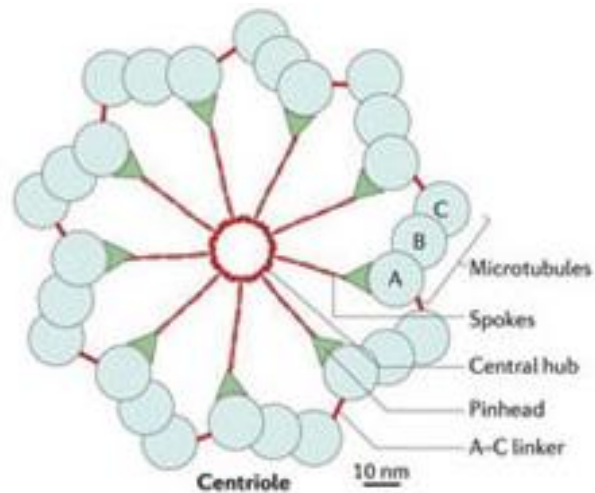


Fig. internal structure of centriole

LESSON 74

10. Microtubule Organizing Center

Microtubule organizing centers (MTOC) are the structures from where microtubules emerge. When observed under electron microscope, microtubules appear to originate from single point. Centrosome and basal body are two MTOC in the cell. **Centrosome** is a complex region present close to nucleus. It has two main components: centriole and pericentriolar material. Microtubule formation takes place in two steps. A small proportion of microtubules is initially formed slowly. This is called nucleation. In second step microtubules length increase. It is a faster step. Microtubule nucleation starts at centrosome and radiate out into all cytoplasm. **Basal Bodies** are the MTOC for cilia and flagella. Basal bodies are structurally identical to centrioles.

LESSON 75

NUCLEUS

Nucleus is double membrane bounded organelle of cell which contain DNA and is main controlling center of eukaryotic cell. Nucleus Controls all activities of cells, stores genetic information and transfer it to next generation. Cells may be uninucleate (one nucleus), binucleate (two nuclei) or multinucleate (many nuclei). Important components of nucleus are: Nuclear envelope, chromatin material, nucleolus and nucleoplasm.

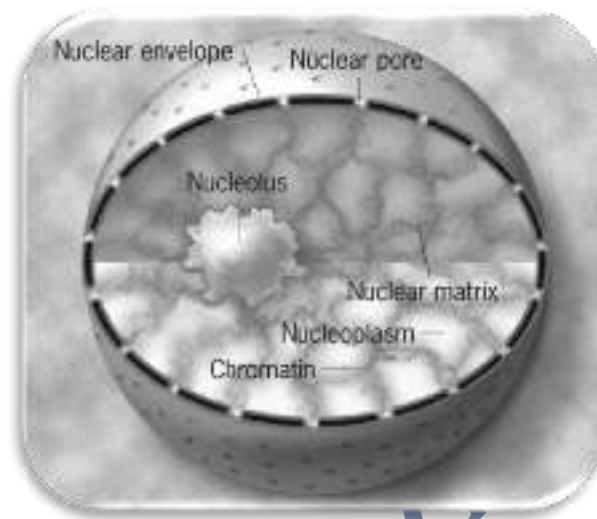


Fig. The nucleus

LESSON 76

Nuclear Envelope: Nuclear pore is a double membrane structure that separates nucleus from cytoplasm. Both outer and inner nuclear membranes are separate from each other. They are directly connected at the nuclear pores. Outer nuclear membrane is in continuation with endoplasmic reticulum. Nuclear envelope bears **nuclear pores**. The number of nuclear pores vary from few to many thousands (3000 in egg). Nuclear pores is composed of globular and filamentous proteins. It controls the transport of materials between nucleus and cytoplasm.

LESSON 77

Nucleoplasm: Nucleoplasm is the soluble portion of nucleus enclosed in nuclear envelope. It is composed of ground substance of nucleus *i.e.*, nucleotides, RNA molecules, proteins, and enzymes for DNA replication and Transcription. Nucleoplasm is the site for DNA replication, Transcription and RNA processing.

LESSON 78

Nucleolus: Nucleolus is non-membrane bounded structure in nucleus of non dividing cells. There are two or three nucleoli in most cells. Some cell may have thousands (e.g. amphibian egg). Nucleolus contain two regions the outer granular region and inner fibrillar region. Nucleolus is the site for rRNA synthesis and assembly of ribosomes.

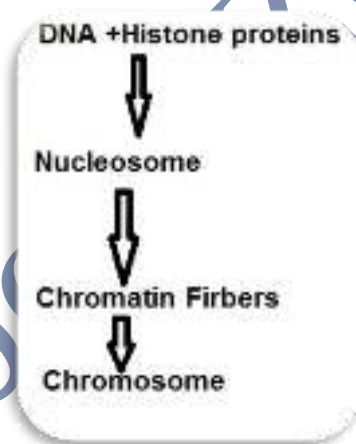
LESSON 79

Chromosomes and Chromatin Material: All animals have DNA as genetic material. Different segments of DNA encode specific proteins and polypeptides. The part of DNA which encode specific protein or polypeptide chain is called a gene. Genes also encode tRNA and rRNA molecules. DNA is packed along with histone protein and form a network. This network of genetic material is called **chromatin material**. At the time of cell division chromatin material condenses and attain the form of **chromosome**. Every species of animals have fixed number of chromosomes in their body.

LESSON 80

TISSUES

A tissue is an aggregate of cells performing common function. They are specialized for specific functions. Cells of single type of cells are called **simple tissues** while those which are made up of more than one types of cells are called **compound tissues**. Animal Tissues are classified into four major classes: epithelial tissues, connective tissues, muscle tissues and nervous tissues.



performing common specific functions. Cells of single type of cells are called **simple tissues** while those which are made up of more than one types of cells are called **compound tissues**. Animal

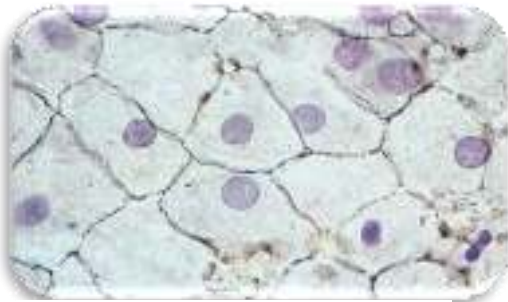
LESSON 81-82

A. Epithelial Tissues

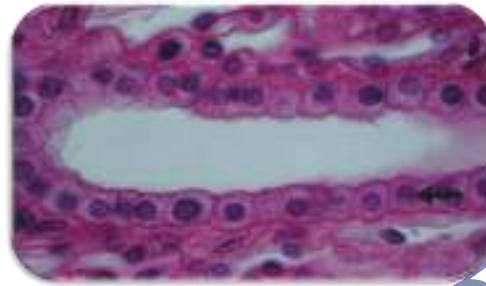
They are renewable sheets of cells covering different body parts or line the tubular portions. They form outer layer of our skin, visceral organ like heart, kidneys and lining of tubular portions such as digestive system. Epithelial tissue is separated from underlying tissues by basement membrane. The shape, size and arrangement of epithelial tissues is directly related to their function. Important functions of epithelial tissues are absorption (Intestine lining),

Transport (capillaries, kidney tubules), Excretion (sweat glands), Protection (skin), sensory function (taste buds, hearing) and secretion (exocrine glands).

Epithelial tissues are classified on the basis of shape and number of layers. **Squamous epithelial tissues** are single layered, tightly packed, flatten disk shaped located in lungs air sacs, linings of heart, blood vessels and lymphatic vessels and kidney glomeruli. They are involved in smooth flow, diffusion and filtration process. **Cuboidal epithelial tissues** are tightly packed and cube shaped. They are located in kidney tubules, ducts, small glands and surface of ovaries. They are involved in secretion and absorption. **Columnar epithelial tissue** are single layer of elongated cells. They line digestive tract, gallbladder and excretory ducts of some glands. They are involved in absorption and enzyme secretion. **Pseudostratified ciliated columnar epithelial tissue** have tuft of cilia on columnar cell. Cells appear stratified due to multilayers of nuclei. They are located in lines of bronchi, uterine tubes and some region of uterus. They propels mucus and reproductive cells by the action of cilia. **Stratified squamous epithelium tissue** contains many layers of cells. They form keratinized surface of skin, lines of esophagus, mouth and vagina. Their main function is protection from abrasive damage.



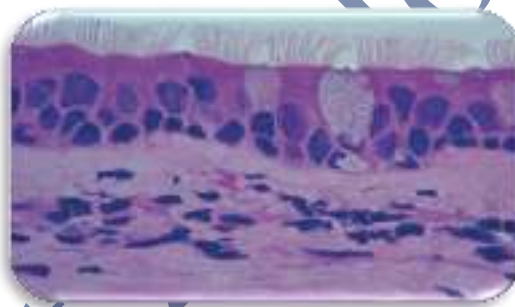
Squamous epithelium



Cuboidal epithelium



Columnar epithelium



Pseudostratified columnar epithelium



Stratified squamous epithelium

LESSON 83-84

B. Connective Tissues

These are diverse types of tissues which serve both supportive and binding function. They are wide spread in animal body and have relatively few cells and much more extracellular fibers and

matrix. Matrix may be in liquid or solid form. There are two general types of tissues: Loose connective tissues and hard connective tissues.

Loose connective tissues are strong flexible fibers of collagen which are interwoven with elastic fibers. They are located in epithelia of skin and throughout body. They wrap and cushion organs. In **fibrous connective tissues** collagen fibers densely packed, parallel. They are located in dermis of skin; submucosa of digestive tract; fibrous capsule of organ and joints. Their major function is to provide structural strength.

There are following types of connective tissues on the basis of structure and function:

- i. Adipose tissue
- ii. Cartilage
- iii. Bone
- iv. Blood

i. Adipose Tissues

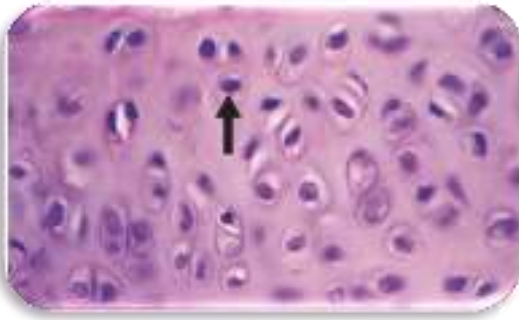
These are fat storing tissues. Large lipid droplets in adipose cells push nucleus to one side. They are present around kidneys, under skin, in bones, breast and abdomen. Their main function is fuel storing, insulation, support and protection.

ii. Cartilage

This is a hard and flexible tissue. In cartilage, chondrocytes cells are present in lacunae surrounded by matrix. Matrix and collagen fiber provide strength and elasticity. Cartilage is present in external ear, epiglottis, bone ends, disks of joints and complete skeleton of sharks. Their main function is to support, Shock absorber and shape the organs/body with flexibility.

iii. Bone Tissues

Bone cells (osteocytes) are present in lacunae. They are heavily impregnated with calcium phosphate making bones hard and strong. They make over all structure of body, provide protection, act as lever system for muscle movement, store calcium and provide a site for blood cells formation.



Cartilage



Bone

iv. Blood

It is a fluid form of connective tissues. Blood is composed of plasma with suspended RBCs, WBCs and platelets. Blood plays an important role in transportation of gases, nutrients, hormones, minerals, vitamins and wastes within the body.

MODULE 85

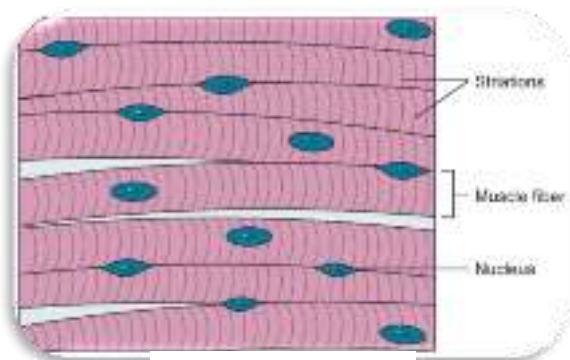
C. Muscle Tissues

These are the tissues having ability to contract and relax thus responsible for movement and locomotion in animals. There are three different types of connective tissues:

- i. Skeletal muscles
- ii. Smooth muscles
- iii. Cardiac muscles

i. Skeletal Muscles

These are the muscle tissues attached to the skeleton bones. Skeletal muscles cells (muscle fibers) are long, cylindrical, striated and contain many peripheral nuclei. They involve in voluntary movements (movement of finger, hands, arms, head, legs and back) and locomotion (*i.e.*, walking, running and flying). They are found in both vertebrates and invertebrates.



Skeletal muscles

LESSON 86

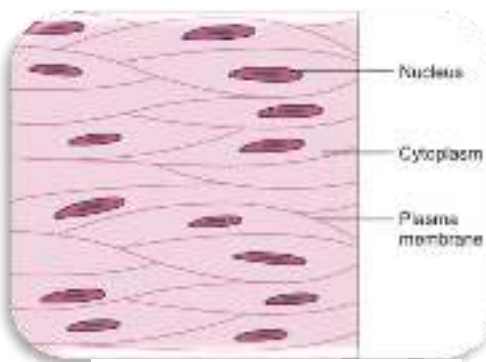
ii. Smooth Muscles

These are the muscle tissues making most of the internal organs especially hollow organs. Smooth muscles cells are spindle shaped, non-striated and contain single nucleus. They are involuntary muscles and have main role in movements of food through digestive system, urination and uterine contraction during birth. They are arranged together to form sheets. Smooth muscles are found in both vertebrates and invertebrates.

LESSON 87

iii. Cardiac Muscles

These are the specialized vertebrates only. Cardiac striated, contain single nucleus through intercalated discs. involuntary muscles. They body and transport wastes. Average heart beat times/min or 100,000 times/day. In beats for about 2.5 billion times.



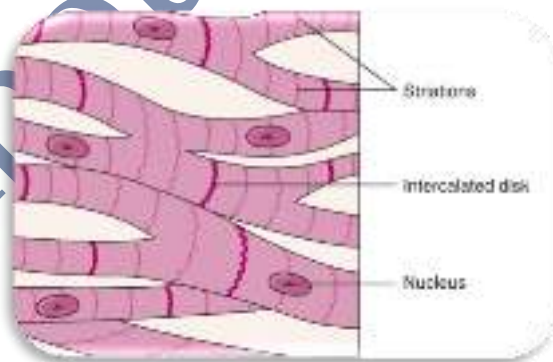
Skeletal muscles

tissues of heart found in cells are branched, nucleus and connected Cardiac muscles are circulate the blood in nutrients, gases and for human is 72 the life of 70 years heart

LESSON 88

D. Nervous Tissues

These are the specialized responsible for coordinating the body activities. They are spinal cord and nerves. are made up of neurons, peripheral glial cells.



Cardiac muscles

tissues and controlling found in brain, Nervous tissues neuroglia and Neuroglia protects

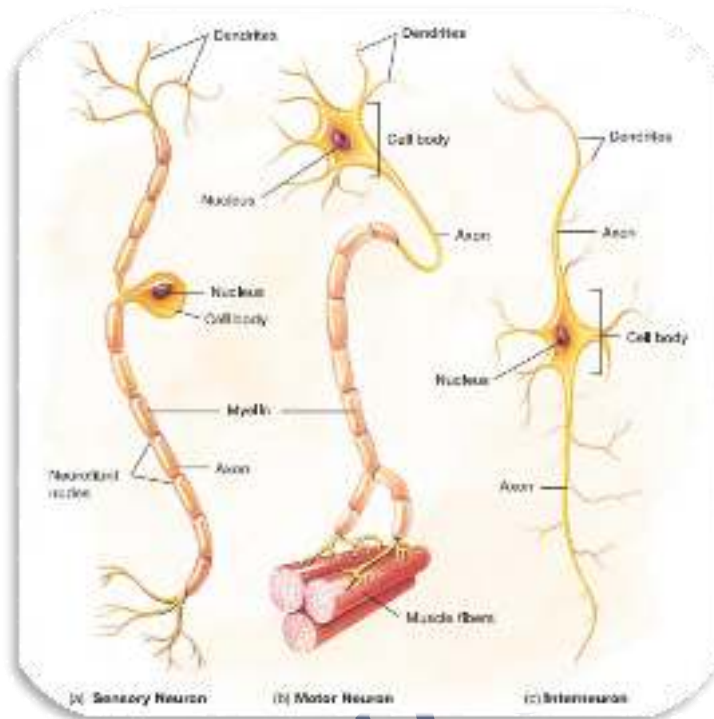
and nourish CNS neurons while peripheral glial cell protect and nourish peripheral neurons. The Neurons transmit electrical signals to other neurons, muscles and glands. A neuron has three main parts dendrite, cell body and axon. On the basis of functions there are three types of neurons:

Sensory neuron transfer information from receptors to central nervous system. **Motor neurons** transfer information from CNS to effectors and **Inter neurons** are present in brain and spinal cord.

LESSON 89

Organ

Organ is a part of adapted to perform function. Organ is different types of tissues work in a way to perform function. Heart, liver, kidney and some examples of animals.



animal body specific made up of tissues. These coordinated specific stomach, Lungs are organs in

LESSON 90

Organ System

Organ system is a association between different organs to complete a process. An organs system is composed of different organs having related functions. For example digestive system is made up of different organs: esophagus, stomach, small intestine, large intestine, pancreas and liver. Eleven organ systems make a human

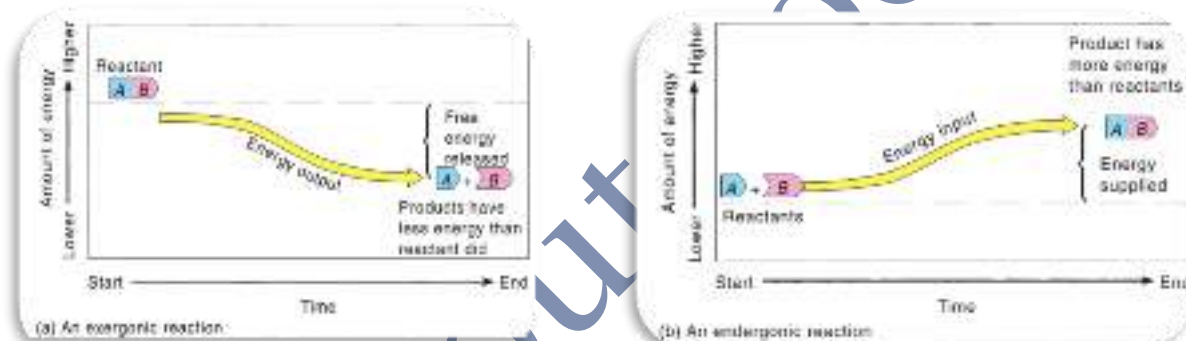
- 1) Integumentary system
- 2) Muscular system
- 3) Skeletal system
- 4) Digestive system
- 5) Circulatory system
- 6) Respiratory system
- 7) Endocrine system
- 8) Reproductive system
- 9) Nervous system
- 10) Lymphatic system
- 11) Urinary system

LESSON 91

ENERGY

The ability to do work is called energy while work is transfer of energy. e.g., photosynthesis in plants transform solar energy into chemical energy. Energy exists in two basic states: **Kinetic energy** and **Potential energy**. Energy stored in chemical bonds of biomolecules is called potential energy. Energy has many forms e.g., heat energy, sound energy and electromagnetic energy.

Reactions in which energy is released are called **exergonic reactions** while reactions in which energy is absorbed are called **endergonic reactions**. The usable energy is called **free energy**. It is the available energy to do work. The SI unit of energy is joule while mostly it is measured in calories. Energy required to raise the temperature of 1g of water through 1°C is called a calorie.



LESSON 92

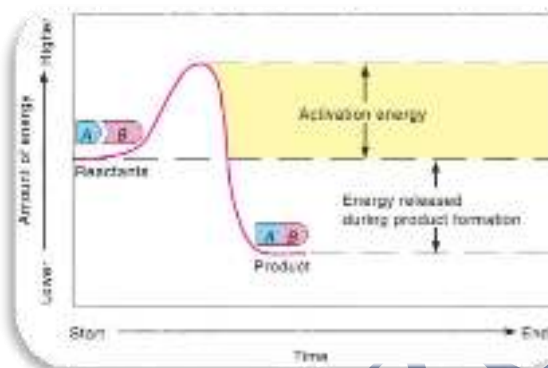
Laws of Energy Transformation

Branch of science which deals with relationship between heat and other forms of energy is called thermodynamics. In this we measure the energy change during a biochemical reaction. There are two laws of thermodynamics. According to **first law of thermodynamics**, "Energy can neither be created nor destroyed, however it can be transformed from one form to another form". e.g., electrical energy used for heat production; we eat food and do work (chemical to kinetic energy). According to **second law of thermodynamics**, "All objects in the universe tend to become disordered and the total amount of disorder in universe is continuously increasing. Things tend to become more stable by acquiring low energy state (disordered). The measure of degree of disorganization is called **entropy**. For example, when natural gas burns to give heat energy, some of it cooks food, other released into environment. Unusable energy is increasing entropy.

LESSON 93

Activation Energy

The amount of energy required to start a chemical reaction is called activation energy. This is the energy barrier between reactants and products. The top hill of the energy barrier is called transition state. In exergonic reactions, the reactants are at high energy state while in case of endergonic reactions, reactants are at low energy state. None of the reactions occur spontaneously. The amount of reactants converted into products in a given time is called **reaction rate**. Reaction rate does not depend upon how much energy is released. It depends upon activation energy. Catalysts such as enzymes increase reaction rate by lowering activation



energy.

LESSON 94

ENZYMES

Enzymes are molecules which catalyze biochemical reactions. They increase reaction rate enormously. Their catalytic power is much more than chemical catalysts. Life is a series of chemical reactions catalyzed by enzymes. Metabolism proceeds because enzymes channel molecules through specific chemical pathways. Without enzymes the biochemical reaction will be too slow to continue life. Enzymes are very selective for their substrate. They catalyze specific chemical reactions.

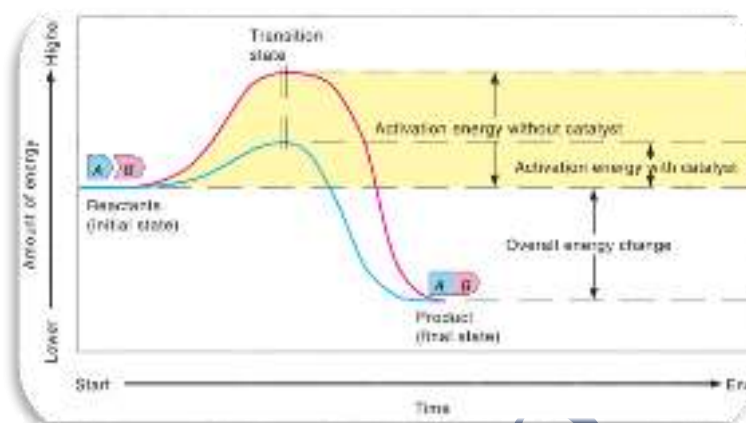
LESSON 95

Enzymes Structure

Most of the enzymes are protein in nature. They are globular proteins may present as soluble molecules or a part of membrane. An enzyme may be composed of single polypeptide or more than one polypeptide chains (multisubunit). Few RNA molecules in nature work as enzymes are called **ribozymes**.

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Enzymes contain special pocket or cleft called active site where substrate bind and catalytic activity is performed. Active site has two parts: Binding domain and Catalytic domain. When a substrate binds to an enzyme it induces a change in shape of enzyme called induce fit. When product is released, enzymes resume its initial shape. Active site have optimized environment for converting a substrate into product.



LESSON 96

Enzymes Function

Catalytic activity starts with binding of substrate to enzyme which forms enzyme substrate complex (ES complex). Different types of bonding like covalent bonding, hydrogen bonding etc. are involved in binding. Mostly it is a weak non-covalent interaction between enzyme and substrate. The weak interactions during binding release energy called **binding energy**. Binding energy is one of the major source of energy which lower activation energy. It also make reaction more specific. Enzymes do not change the nature of product. They simply increase reaction rate.

LESSON 97

Factors Affecting Enzyme Activity

The conditions that alter the three dimensional structure of enzyme will effect the enzyme activity. Mainly there are two factors: Temperature and pH

a. Temperature

The temperature at which enzyme activity is maximum is called optimum temperature. Proteins and nucleic acids maintain their 3D structure by hydrogen bonding. At low temperature enzyme lose their flexibility and their activity is reduced. High temperature easily disrupt this bonding and enzymes will denature. This will stop their activity. Birds and mammals enzymes work best between 35 to 40°C.

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b. pH

Enzymes are more sensitive to pH than temperature. Change in pH causes ionization of enzymes. The pH at which enzyme activity is maximum is called optimum pH. Normally optimum pH of enzymes is according to the environment where they are present.

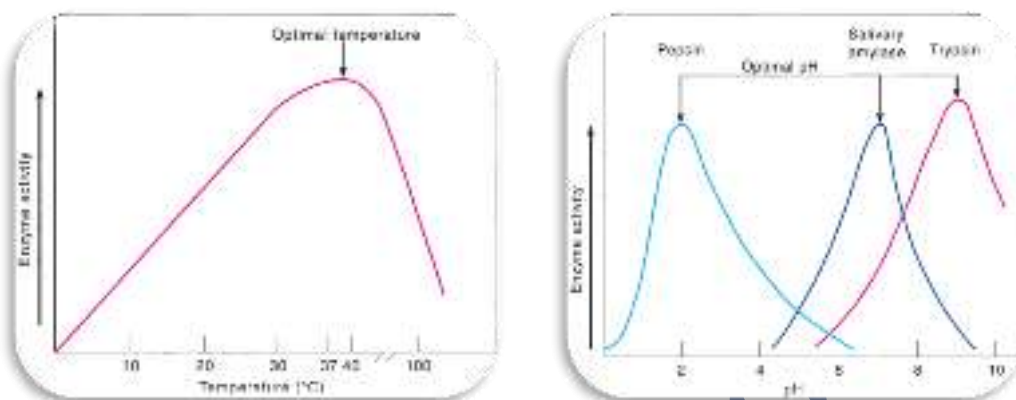


Fig. Effect of temperature and pH on enzyme activity

LESSON 98-99

Cofactors and Coenzymes

Some enzymes require one or more metal ions for their activity called **cofactors**. e.g., Ca^{2+} , Mg^{2+} , Mn^{2+} , Cu^{2+} and Zn^{2+} . Zn is the cofactor of more than 70 enzymes. Cofactors have following three roles:

- Activate active site
- Changing in shape of enzyme to bind with substrate
- Temporarily bonds between enzyme and substrate in ES complex

The non-protein organic molecules require for enzyme activity is called **coenzyme**. e.g., vitamins (niacin, riboflavin); nucleotides (NAD^+ , FAD). They normally transfer electrons or temporary carriers of functional group. An enzyme without its cofactor or coenzyme is called **apoenzyme**. Apoenzyme is catalytically inactive. An enzyme with its attached cofactor or coenzyme is called **holoenzyme**. Holoenzyme is catalytically active. When cofactor of coenzyme is tightly bound, it is called a **prosthetic group**.

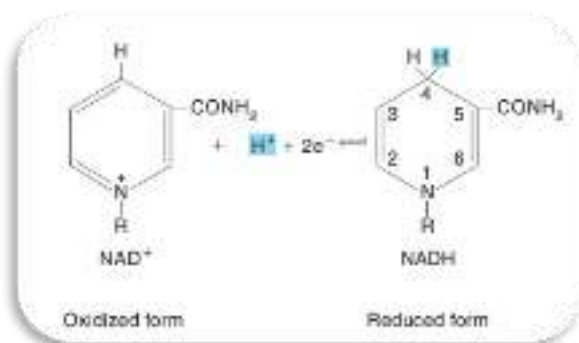


Fig. NAD^+ is one of the most important coenzyme in the cell

LESSON 100

ATP: The Energy Currency of Cell

ATP is the major currency of the cell. Energy needed for different processes in living organisms is provided in the form of ATP. As ATP is used by all type of cells, it must have appeared in early life history. Ability of ATP to store energy lie in its structure. ATP has three subunits: adenine, ribose and three phosphate groups. Energy is property of entire molecule. The covalent bonds connecting phosphate group are high energy bonds. Hydrolysis of one phosphate group of ATP releases 7.3kcal. It is very unstable molecule and survives for a short time only. So, it can neither stored for long time in the cell nor transported from one cell to another cell.

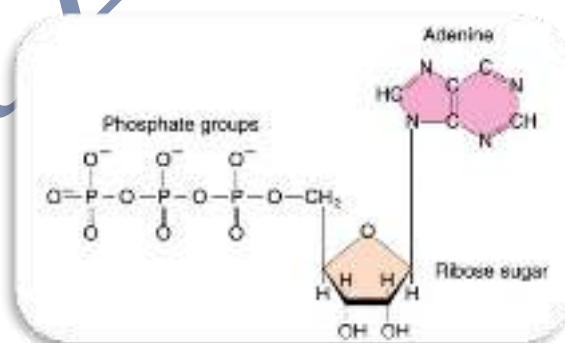


Fig. structure of ATP molecule

LESSON 101

HOW CELLS HARVEST ENERGY?

Animals synthesize ATP from energy stored in C-H bonds of nutrient or stored materials. Animals make ATP in their cells by two method:

- Substrate level phosphorylation
- Chemiosmosis

a. Substrate Level Phosphorylation

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In substrate level phosphorylation, ATP is synthesized by transferring P_i from a substrate molecule to ADP with the help of enzyme. The phosphate group (P_i) of substrate breaks more easily than ATP. These reactions are strongly exergonic. e.g., ATP synthesis during glycolysis. It is one of the most fundamental in all ATP synthesis reactions.

LESSON 102

b. Chemiosmosis

Chemiosmosis is the synthesis of ATP by flow of H^+ across the membrane. In animals H^+ flow from outside of inner mitochondrial membrane to inside and ATP is synthesized. A proton gradient is required for chemiosmosis. Concentration of H^+ should be higher outside the membrane. When protons move from higher concentration to lower concentration, ATP is produced.

Proton gradient is generated when high energy electron move through electron transport chain. Hydrogen ions (protons) are pumped outside the inner mitochondrial membrane. When these hydrogen ions comeback, ATP synthetase use their potential energy to synthesize ATP.

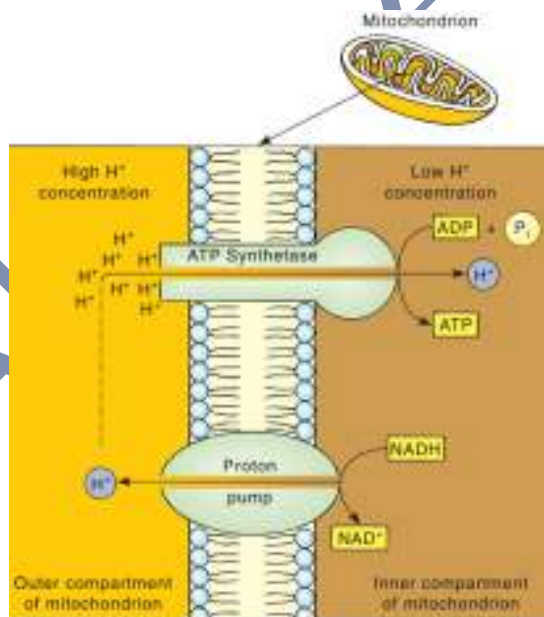


Fig. ATP synthesis by chemiosmosis

LESSON 103

METABOLISM

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All chemical reactions in living organisms are collectively known as metabolism. In a cell metabolism is used to harvest energy from biomolecules, synthesis of biomolecules and remove the toxic wastes. Metabolism is of two main types: catabolism and anabolism.

a. Catabolism

The type of metabolism in which complex molecules are broken down into simple molecules. e.g., digestion and respiration. Catabolism is important for harvesting energy and synthesis other molecules.

b. Anabolism

The type of metabolism in which simple molecules combine to form complex molecules. e.g., synthesis of glycogen, lipids and proteins.

LESSON 104

GLYCOLYSIS

Evolutionary perspective

The breakdown of glucose into pyruvate through a series of chemical reactions is called glycolysis. Glycolysis is the combination of two Greek words: *glykys*, “sugar” and *lysis*, breakdown. It is the universal pathway of glucose metabolism present in all organisms from bacteria to human. Glycolysis is older than aerobic respiration. By this method harvest energy in the absence of oxygen. During early life history organisms/cells with glycolysis were at advantage than organisms having no glycolysis. Later when animals got more efficient methods to harvest energy, glycolysis was retained as stepping stone. Glycolysis is the sole source of metabolic energy in erythrocytes, renal medulla, brain and sperms. Many anaerobes are entirely dependent on glycolysis.

LESSON 105-106

Glycolysis takes place in cytoplasm. There are total 10 steps of glycolysis. First five steps constitute **preparatory phase**. Two ATP are required in this phase. Reactions of step 6 to 10 constitute **payoff phase**. Total 4 ATPs are produced during this phase. Net output of glycolysis is 2ATPs. Two NADH are also yielded during this process.

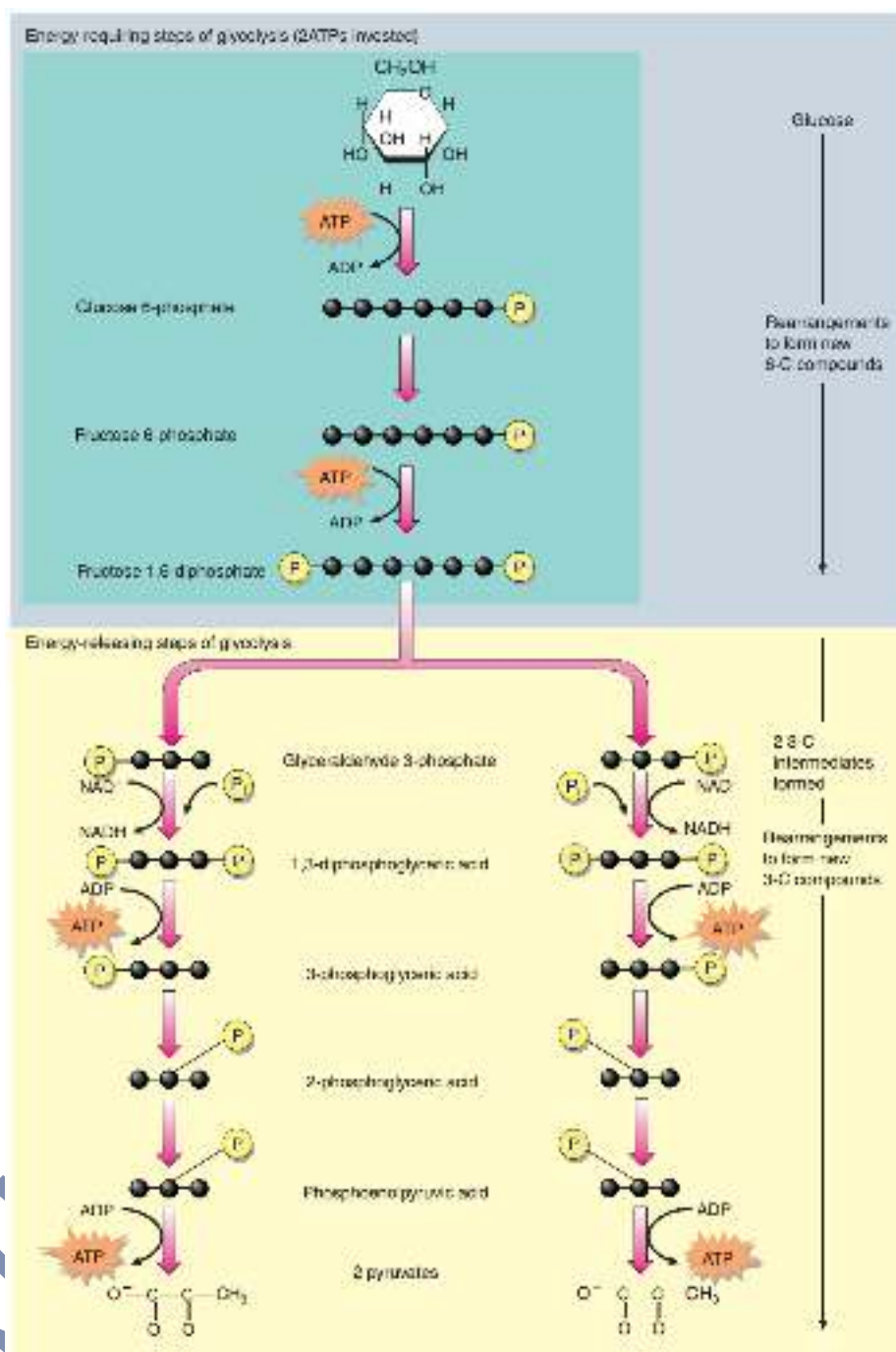


Fig. Reactions of glycolysis. (Ref. Miller and Harley, Zoology)

LESSON 108

Nature of Electron Transfer: Structure of NADH and FADH₂

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Energy of organic molecules is trapped in chemical bonds. This energy transferred through electrons. In energy transfer the molecule which donates electrons is **oxidized** (loss of e^-) and the molecule which accepts electrons is **reduced** (gain of e^-). Overall it is oxidation-reduction reaction or **redox reaction**. Different types of electron carriers include metal ions, nucleotides and proteins. Two most important electron carriers are: NADH and $FADH_2$.



LESSON 109-110

KREBS CYCLE

It is a series of chemical reactions in which acetyl-CoA is oxidized to CO_2 yielding ATP and high energy electrons. It was first discovered by Hans Krebs in 1930's. In eukaryotes Krebs cycle takes place in mitochondria. Carbons skeleton of organic molecules is completely oxidized during Krebs cycle. Before entering into Krebs cycle pyruvate is oxidized to acetyl-coA. In each Krebs cycle 3 molecules of NAD^+ are reduced to NADH, one FAD is reduced to $FADH_2$ and one molecule of GTP (ATP equivalent) is also formed.

In first step acetyl-CoA reacts with oxaloacetate to form Citric acid. Citric acid contain three carboxylic ($COOH$) groups. Due to this reason Krebs cycle is also called as citric acid cycle or Tricarboxylic acid cycle (TCA). Different molecules present at different steps of Krebs cycle (citric acid, alpha ketoglutaric acid, succinic acid, malic acid, and oxaloacetic acid) are called intermediates while molecules which are released during Krebs cycle are byproducts (CO_2 , NADH and $FADH_2$).

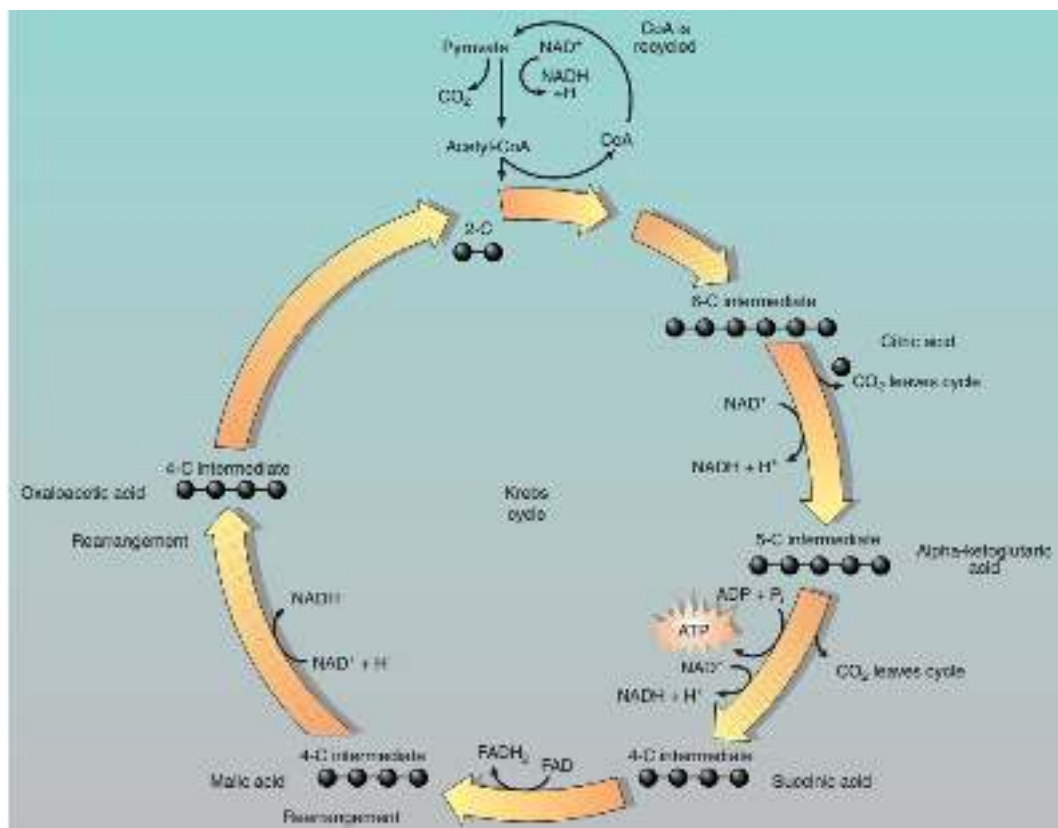


Fig. The Krebs cycle (ref. Miller and Harly, Zoology)

LESSON 111-112

ELECTRON TRANSPORT CHAIN

It is an organized set of electron carriers and enzymes with enhanced oxidation reduction reactions which extract the energy of electrons. Different molecules of electron transport chain make redox centers. Electron accepted from NADH and FADH₂ are passed through redox center. Energy harvested from these electrons is used to move H⁺ across inner mitochondrial membrane to intermembrane space. Electron transport chain is located in inner mitochondrial membrane. Accept electrons from. Major components of electron transport chain are NADH dehydrogenase, flavoproteins (FAD, FMN), ubiquinone (Coenzyme Q), cytochromes and Fe-S proteins. At any given time the electrons will be accepted from one donor: either from FADH₂ or NADH. Later these electrons are given to O₂ which combines with H⁺ to form water molecules.

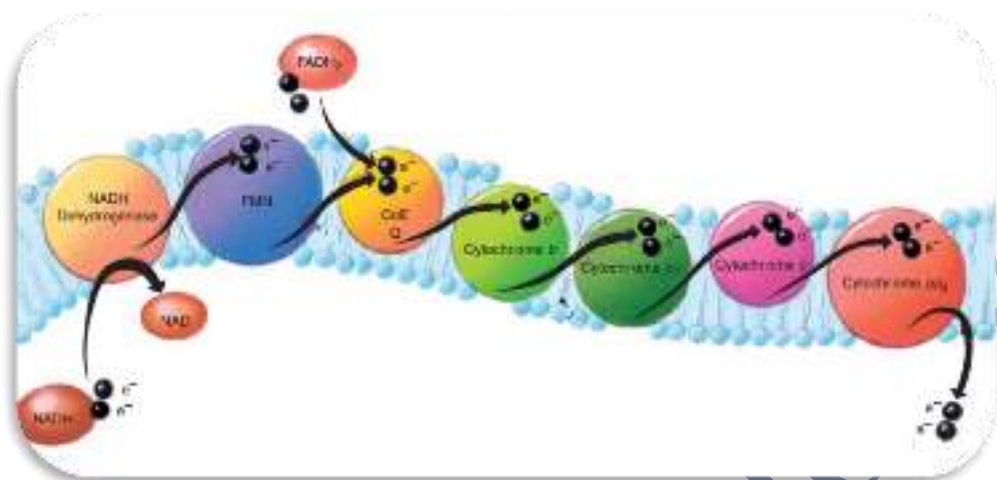


Fig. Arrangement of components of electron transport chain

LESSON 115-116

METABOLISM OF FATS

Fats are important part of our diet. They are the basic part of cellular membranes and important source of energy to our body. Fats provide more than double amount of energy as compared to carbohydrates and proteins. The recommended amount of energy for our daily life is 30%. Some organs such as liver, heart and skeletal muscles meet half of energy requirement from fats while fats are sole source of energy in hibernating animals. Fats are actually triacylglycerides in which three fatty acids are attached with one glycerol molecule.

Fat digestion occurs in small intestine. Liver bile Emulsify the fat droplets while lipase completely digested the fats. Fats are absorbed in small intestine and converted into triglycerides again. Fats are transported in the body as chylomicron. Chylomicron are formed by the combination of fats, cholesterol and proteins. Fats are stored in adipose tissues and skeletal muscles.

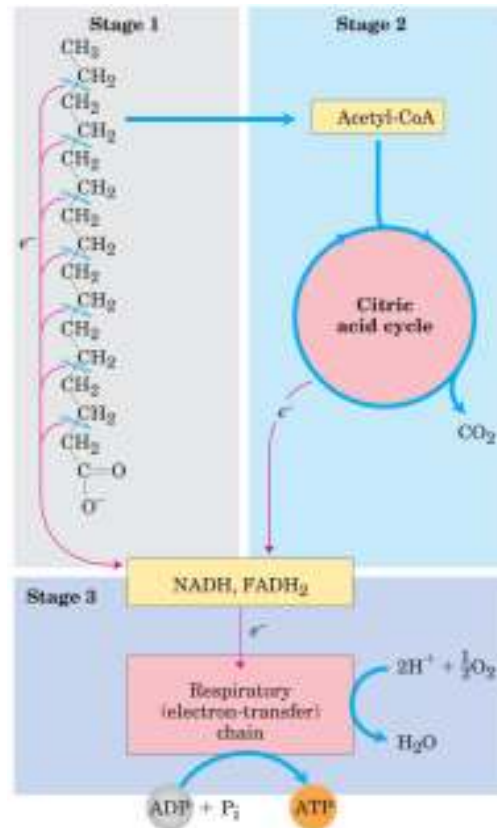


Fig. Fatty acids are oxidized to acetyl CoA, NADH and FADH₂. Acetyl CoA enters Krebs cycle while NADH and FADH₂ enter into electron transport chain

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When required fats are hydrolyzed by enzymes into glycerol and fatty acids. Glycerol is converted to glyceraldehyde-3-phosphate which enters into glycolysis. Fatty acids oxidation mainly occurs in mitochondria while small amount is also oxidized in endoplasmic reticulum and peroxisome. Breakdown of fatty acids yields acetyl CoA, NADH and FADH₂. Acetyl CoA in Krebs cycle forms NADH and FADH₂ which enter into electron transport chain for ATP production.

One gram of fats give 2.5 times more energy than 1g of carbohydrates and protein. This is because they contain much more C-H bonds as compared to carbohydrates and lipids.

LESSON 117-118

METABOLISM OF PROTEINS

Proteins are one the most important biomolecules for living organisms. They have both structural and functional role in our body. Important protein molecules include muscle fibers, bones, enzymes, hormones, antibodies, membrane transporters, lens proteins of eyes, hair, nails, feathers and spider web.

Proteins are digested in stomach and small intestine. Amino acids are final product of protein digestion which are absorbed in small intestine. They reach to cells through blood circulation and are used for protein synthesis. Excessive amino acids are degraded mainly in liver and skeletal muscles. Amino acid breakdown also occurs during starvation.

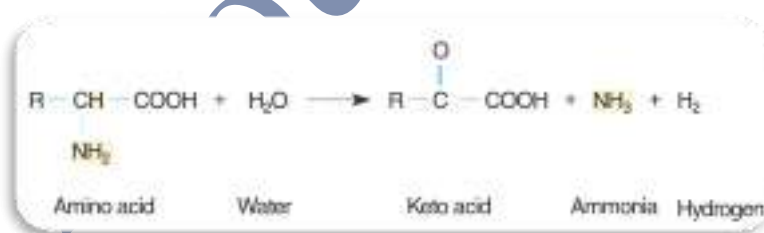


Fig. Amino acids catabolism

Amino acids break down to Keto acid after deamination. Keto acids are funneled to Krebs cycle to yield ATP. One gram of proteins give approximately 4kcal energy which is approximately equal to glucose. Ammonia is formed during deamination of amino acid. In aquatic organisms ammonia is released from moist surfaces. For release of ammonia large amount of water is required. In land animals ammonia is converted to urea that is excreted through urinary system while animals with acute shortage of water, release uric acid.

LESSON 119-120

CONTROL OF METABOLISM

Cells are very efficient and do not waste energy. If some molecule is in excess, its synthesis is switched off. The most common method for control of metabolism. In this method the product inhibits enzyme that catalyzes the key step. In anabolism cells expend energy for biomolecules synthesis. Anabolism is mainly controlled by regulating the enzyme activity at strategic points. For example, phosphofructokinase has receptor sites for ATP, ADP, AMP, citric acids. By controlling the activity of this enzyme cell regulates its entire metabolic process. ATP and citric acid inhibit phosphofructokinase in glycolysis. When a cell has sufficient ATP, its glycolysis is stopped by inhibition of phosphofructokinase. When ATP level is decreased in a cell and the level of ADP and AMP increase. This activates phosphofructokinase, as a result glycolysis is stimulated. When cell has enough citric acids produced in Krebs cycle. Citric acid in cytoplasm inhibits phosphofructokinase. At low concentration of citric acid glycolysis accelerates.

LESSON 121

METABOLIC POOL

All the substances of metabolism constitute metabolic pool. It is actually reservoir of molecules upon which enzymes act. These include substrates, products and reaction intermediates. All catabolic and anabolic reaction in cell use metabolic pool.

An open system is in which compound may enter or leave the biochemical pathway at various steps. Almost all the biochemical pathways in living organisms are open system. Metabolic intermediates of glycolysis and Krebs cycle may be withdrawn or put into by other metabolic pathways.

LESSON 122

REPRODUCTION AND ITS IMPORTANCE

REPRODUCTION

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With the passage of time animals get aged, new animals should take their place. Reproduction is the process of producing new individuals. It is the basic feature of all forms of life. It is essential for existence of species and also for continuity of life on earth. Capability to reproduce is called reproductive potential. All the animals have great reproductive potential. If resource are unlimited a single species of fishes may fill the all oceans.

Animals reproduce by two basic means: Asexual reproduction and sexual reproduction

LESSON 123

A. Asexual Reproduction:

It is the type of reproduction in which offspring are produced without fertilization of gametes. In asexual reproduction the basic method of cell division is mitosis which involves no genetic recombination. So, the animals produced by asexual reproduction are identical to their parents and siblings. Asexual reproduction is common the common method of reproduction in protozoa (Amoeba, paramecium and euglena) and lower invertebrates (hydra, jellyfish, and flatworms). Asexual reproduction is correlated with ability to regenerate.

Early organisms used to reproduce by asexual method. This was the only method of reproduction in first 2 billion years of life. During this time life evolved slowly because of less genetic diversity.

Followings are the common method of asexual reproduction in animals:

- a. Fission
- b. Budding
- c. Fragmentation
- d. Parthenogenesis

LESSON 124

a. Fission

Fission (Lenten word *fissio*, the act of splitting) is a type of asexual reproduction in which one organisms splits into two or more organisms. There are two basic types of fission: Binary fission and multiple fission. The process in which one organism divides into two organisms is called **binary fission**. Both are approximately equal size. Binary fission may be asymmetrical, transverse and longitudinal. Asymmetric organisms like amoeba may divide into two from any

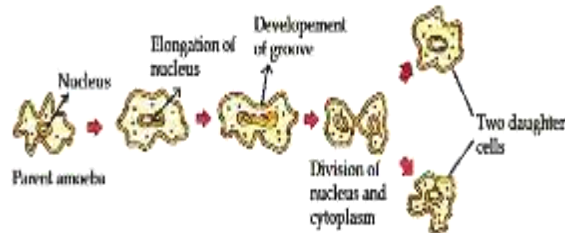


Fig. asymmetrical fission in amoeba



Fig. Longitudinal fission in planarian

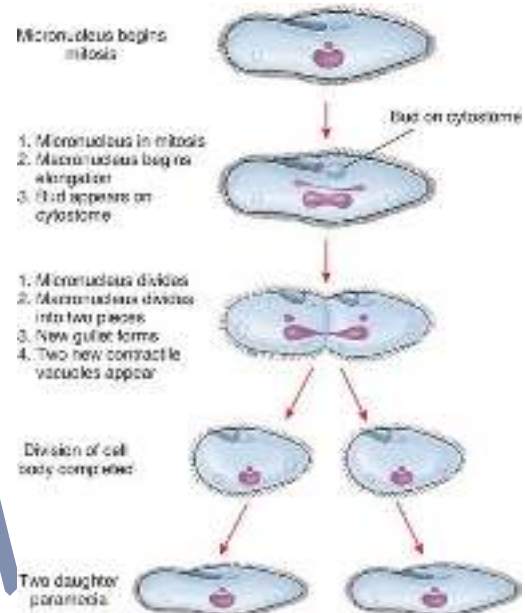


Fig. Transverse fission in paramecium

side, such fission is called asymmetric fission. When a line of cleave transversely divide an organism into two is called transverse fission. e.g., binary fission in paramecium. When an organism is divided longitudinally into two daughter organisms, this is called longitudinal fission. e.g., binary fission in planaria and euglena.

Multiple fission is a number of successive divisions of nucleus followed by cytoplasmic division in which one cell divides into many cells. e.g., amoeba, tapeworm. Amoeba form cyst under unfavorable conditions and form new amoebae by multiple fission.

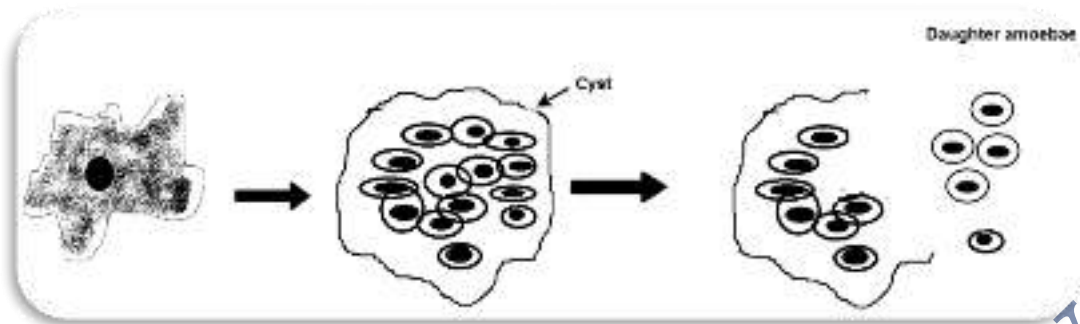


Fig. Multiple fission in amoeba.

LESSON 125

b. Budding

Asexual reproduction in which an outgrowth appears on the body of animal which grows into complete organism. e.g., hydra, obelia and sponges. In budding, a group of cells rapidly divides and form a small outgrowth called bud. This bud increases rapidly and form a complete organism. The bud may get detach from the parent or sometimes it may remain attached with the parental organism and form a closely associated group of individuals called a **colony**. Members of a colony belong to same species. In sponges internal buds are produced which are called as **gemmules**. Gemmule is a collection of cells surrounded by body wall. When parent dies, each gemmule gives rise to a new individual.



Fig. Budding in hydra

LESSON 126

c. Fragmentation

Fragmentation is the process of asexual reproduction in which an animal breaks into two or more pieces and each piece is capable of growing into a new organism. Fragmentation is common in different groups of animals including cnidarians, Platyhelminthes and echinoderms

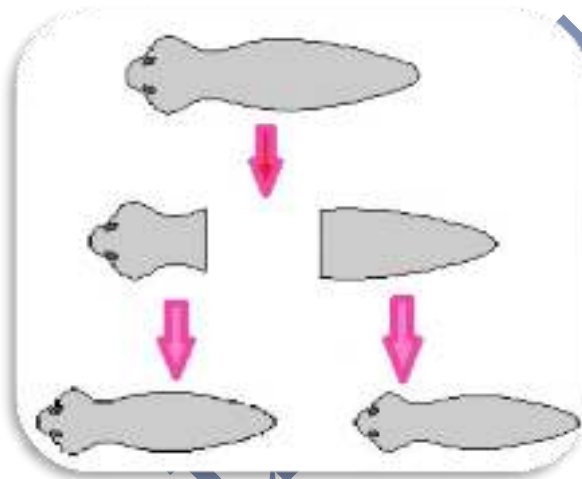


Fig. Fragmentation in planaria

LESSON 127-128

d. Parthenogenesis

The process of production of an organism from an unfertilized egg. There are many patterns of parthenogenesis. Parthenogenesis is a spontaneous activation of a mature egg, followed by normal egg divisions and subsequent embryonic development. In some species, the only way of reproduction is parthenogenesis. In others, those eggs which could not fertilize undergo parthenogenesis to produce new organism. In parthenogenesis genetic material is only shared by the female. Parthenogenesis is very common in wasps, bees and ants. It is essential for social



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Fig. New Mexico Whiptail lizard population has only females

organization of these insets. Parthenogenesis have been observed in some lizards and snakes. New Mexico Whiptail lizard are exclusively females. Their population contain no male members. Eggs of this lizard are spontaneously activated and produce a female young one. Parthenogenesis has two common forms: Meiotic parthenogenesis and ameiotic parthenogenesis.

In **ameiotic Parthenogenesis** eggs are diploid. They are produced without meiosis. Young ones are the clones of their parents. This method is common in flatworm, rotifers, crustaceans and some insects. In **meiotic Parthenogenesis** eggs are produced by the meiosis process. Haploid egg starts development and diploid number restored by chromosomal duplication. However, some insects remain haploid and no chromosomal duplication occurs. In some cases, egg may be activated by sperm to start parthenogenesis. Here sperm will not fertilize egg, just activates. In others eggs are activated spontaneously.

Parthenogenesis is advantageous: 1) When population consists of only females. 2) When environment is very stable. 3) For social organization of colonies of bees, wasps, ants (for males)

The disadvantage of parthenogenesis are: 1) Less genetic variability. 2) Little chances for organisms to shift gene combination in changing environment.

LESSON 129

Advantages of Asexual Reproduction

- 1) Species survival: Asexual reproduction is specially the beneficial to those species have one sex only.
- 2) Minimal energy requirements: Only one sex is involved so less amount of energy is required.
- 3) Positive genetic combinations passed on to next generation: Because there is no genetic recombination, the good traits acquired of an organism are transmitted to next generation
- 4) Rapid Increase in Population: Under stable conditions animals reproduce asexually causing a rapid increase in population

LESSON 130

Disadvantages of Asexual Reproduction

- 1) Low genetic variability: No genetic recombination. Very little variations and population is genetically same.

- 2) Susceptibility against diseases: As population is genetically same, so equally susceptible to disease or changing environmental conditions. This may result in the death of whole population at once.
- 3) All mutations pass on to next generation: Most of the mutations are detrimental. In Asexual reproduction all mutations are passed on to next generation

LESSON 131

B. Sexual Reproduction

It the types of reproduction in which new offspring are produced by the fusion of gametes. In sexual reproduction normally two sexes are involved. Offspring get one set of chromosomes from male and other from females. This results in new genetic combinations. Gametes produced by male are called sperms while gametes produced by female are called eggs. Sperms are produced in testes while eggs are produced in ovaries. Both gametes are haploid and produced by the process of meiosis. The process of sperms production is called **spermatogenesis** while the process of eggs production is called **oogenesis**.

LESSON 132

Internal and external fertilization

The process of fusion of gametes is called fertilization. The process in which fusion of gametes occurs outside the body of animals is called external fertilization. Normally, it occurs in water. Female releases many eggs in the water, the process is called broadcast spawning. Male spray sperms on the released eggs. So, fertilization occur in water and the development is also outside the body of female i.e., external. In case of **Internal Fertilization**, fusion of gametes occurs inside the body of animals. In mating process male introduces sperms into female body, sperms are motile they approach to female gametes within the body of female. Many sperms are packed into a ball like structure called **spermatophore**. Which a accepted by female. Sperms are protected in spermatophore and there is minimal loss of sperms.

Species with external fertilization produced large number of gametes while few gametes are produced in case of internal fertilization.

LESSON 133-134

Hermaphroditism

It is the condition in which both male and female sex organs are present in the same animal. E.g., earthworm, mangrove killifish and hamlet fish. Hermaphroditism is more beneficial to sessile

animals. Hermaphrodites are also called monoecious (Greek. *Monos*, single and *oikos*, house). Monoecious means one room for two sexes. Some undergo self-fertilization, but mostly cross fertilization is the rule. Two animals come close to each other, both donate and receive sperms. Sequential hermaphroditism is a special type of hermaphrodites.

Sequential hermaphrodites have one sex in first phase of life and opposite sex in other phase of life. Means if animal is male in first phase of life, it will be female in second half of life. Those sequential hermaphrodites which are female in first phase of life and male in second phase of life called **protogynous** (female first) e.g., wrasses. Those animals which are male in first phase of life and female in second phase of life are called **protandrous** e.g., clown fish.

LESSON 135

Bisexual reproduction

It is the type of reproduction in which two separate individuals are involved. They are also called **dioecious** (Gr. *Di*, two and *oikos*, room). Most of the animals have bisexual reproduction method. One benefit of this is that the offspring have new gene combination and new genotypes appear. Sexual dimorphism is the condition in which both male and female are phenotypically different. The difference is mainly in secondary sex characters, size, colour and weight. e.g., many of the males in birds are brightly coloured and larger in size.

LESSON 136

Sexual reproduction is considered as more advantageous than asexual reproduction. Important benefits of sexual reproduction are:

- 1) Genetic variability: Genetic recombination occurs in sexual reproduction which give rise to new combination of traits. This may help in changing environment or in case of disease.
- 2) Foundation for evolution: In sexual reproduction, variation appear in offspring which provide the foundation of evolution
- 3) Elimination of Deleterious Traits: Genetic recombination helps in elimination of deleterious traits.

Sexual reproduction also has certain disadvantages, some of which are as follows:

- 1) Asexual animals: sexual reproduction is not feasible for animal which rely on asexual means only, especially population with one sex only.
- 2) Adaptive genes combination dismantle: In sexual reproduction new genetic combination arise. This will upset the already established adaptive gene combination.
- 3) Wastage of energy: in sexual reproduction a large number of gametes are formed. Many of which are not fertilized. This will cause a significant loss of energy.

LESSON 137

Reproductive Strategies in Amphibians

Class Amphibia has three orders: order caudate, order gymnophiona and order anura. Order caudate and gymnophiona has internal fertilization while order anura has external fertilization. **Eggs** have no hard covering. Eggs may be given as single, clumps or strings. Majority of members of gymnophiona retain eggs within body while members of order anura lay eggs in water, moist soil and tree trunks. **Breeding** in temperate region is linked to temperature while in tropical region, it is linked to rainy season. **Courtship behaviour** helps to locate breeding sites, identify potential mates, prepare them for reproduction and ensures egg fertilization. Animals use olfactory, visual, vocalization and tactile cues for courtship behavior. **Development** includes aquatic larva or internal in case of gymnophiona.

LESSON 138

Reproductive Strategies in Reptiles and Birds

Reptiles and birds are dioecious. They have internal fertilization. Fertilization in the upper portion of oviduct. Sperm may be stored in seminal vesicles e.g., up to 4 years in some turtle and 6 years in some snakes. **Eggs** range from soft to hard shells. Eggs are desiccation resistant and contain enough amount of yolk. Reptiles and birds eggs are called amniotic eggs. Amniotic eggs have three extraembryonic membranes: amnion, chorion and allantois. **Breeding behavior** in reptiles includes copulation in winter during hibernacula and fertilization in spring while birds have breeding activity in spring. **Courtship Behaviour** in reptiles is very complex and function for sex recognition. Males actively seek out females. Birds show territorial behavior. Males attract females by sounds (wood pecker), dancing (cranes, peacocks). More than 90% monogamous (pair with single female). Polygamy occurs in species where young ones require less parental care. **Development** in reptiles and birds is mostly external (oviparity), fertilized eggs remain unattended while in some cases eggs are cared for humidity. Crocodile is a special case where young ones get post hatching care. In birds there is external development. Eggs are incubated and protected from predators. Young ones get extensive parental care.

LESSON 139

Reproductive Strategies in Mammals

Mammals are also dioecious. Eggs contain little amount of yolk except egg laying mammals. They have internal fertilization. Fertilization in the upper portion of oviduct. Some bats have delayed fertilization. Mammals also have complex **courtship behavior**. Males actively seek out females. Males show territorial behavior. Vocalization is very common among mammals. Mammals show **reproductive cycle**. They have definite time for egg maturation. Females

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undergo estrus cycle during which it is behaviorally and reproductively receptive to males. Some females undergo one estrus cycle during one year they are monoestrus, other have many estrus cycles and are known as polyestrus. **Development** in mammals is internal (viviparity) except monotremes (oviparous). In marsupial mammals fetus get nutrition from uterine milk, placenta is primitive and gestation period is short. In eutherian mammals embryo is implanted deeply, fetus get nutrition through placenta, gestation period 20 days to 19 months.

LESSON 140

Examples of Reproduction in Fishes and Amphibians

Thousands of eggs are fertilized in bony fishes. Many of them get fungal and bacterial infection. Many others are contaminated with silt. Still others eaten by predators. Bony fishes have little amount of yolk which can support development only for short time. That's why fishes have rapid development and hatchlings actively feed and they achieve maturity within short time. In some fishes embryos are cared properly. Sea horse and pipefish males carry embryo in their ventral pouches.

Amphibians mostly have external fertilization in water in few internal. Eggs are cared for aeration and infected eggs are removed from clutches. *Pipa* female carry eggs on back. *Rheobatrachus* females carry egg and tadpole in stomach. Amphibians contain little amount of yolk and longer time for development. That's why they have larval stage to complete development. During development they undergo metamorphosis.

LESSON 141

Examples of Reproduction in Reptiles and Birds

Reptiles are true terrestrial vertebrates. They have shelled eggs with extraembryonic membranes. Chorion and amnion give protection and provide aqueous environment. Allantois plays its role in gaseous exchange and to store excretory products. Reptiles contain large amount of yolk. Complete development takes place within shelled egg and there is no larval stage. Some snakes are ovoviviparous because they keep eggs within body and young ones are hatched out.

All birds except water fowl lack penis. They deposit semen against cloaca and fertilization is internal. Fertilization before shell formation. Hard shelled eggs are incubated by parents. There is more parental care and feeding than amphibians, reptiles and mammals.

LESSON 142

Examples of Reproduction in Mammals

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Among mammals monotremes (duckbilled platypus, spiny anteater) lay eggs. Duckbilled platypus lay eggs in nest/burrows while spiny anteater incubate eggs in ventral pouch. Marsupial mammals like koala and kangaroo keep the young one in ventral pouch (marsupium). They have short gestation period (8- 40 days) while feeding from mammary glands (suckling) is for 60 to 120 days. Most of the mammals are placental mammals (deer, lion, monkeys etc.). They have internal development and long gestation period. After birth young one is nourished through mammary glands. The longest gestation period is seen in elephants which lasts for 22 months.

LESSON 143

Reproductive Patterns in Animals

All invertebrates and vertebrates have one of the three reproductive patterns.

a. Oviparous

These are the animals which lay eggs and development takes place outside the body of animals. Fertilization may be internal or external. Majority of invertebrates and many vertebrates are oviparous.

b. Ovoviparous

These are the animals which retain eggs into the body but the young one gets all its food from yolk of egg. Both fertilization and development is internal. Many members of annelids, brachiopods, gastropods, fishes and reptiles.

c. Viviparous

These are the animals in which eggs develop into the body and the young one gets its

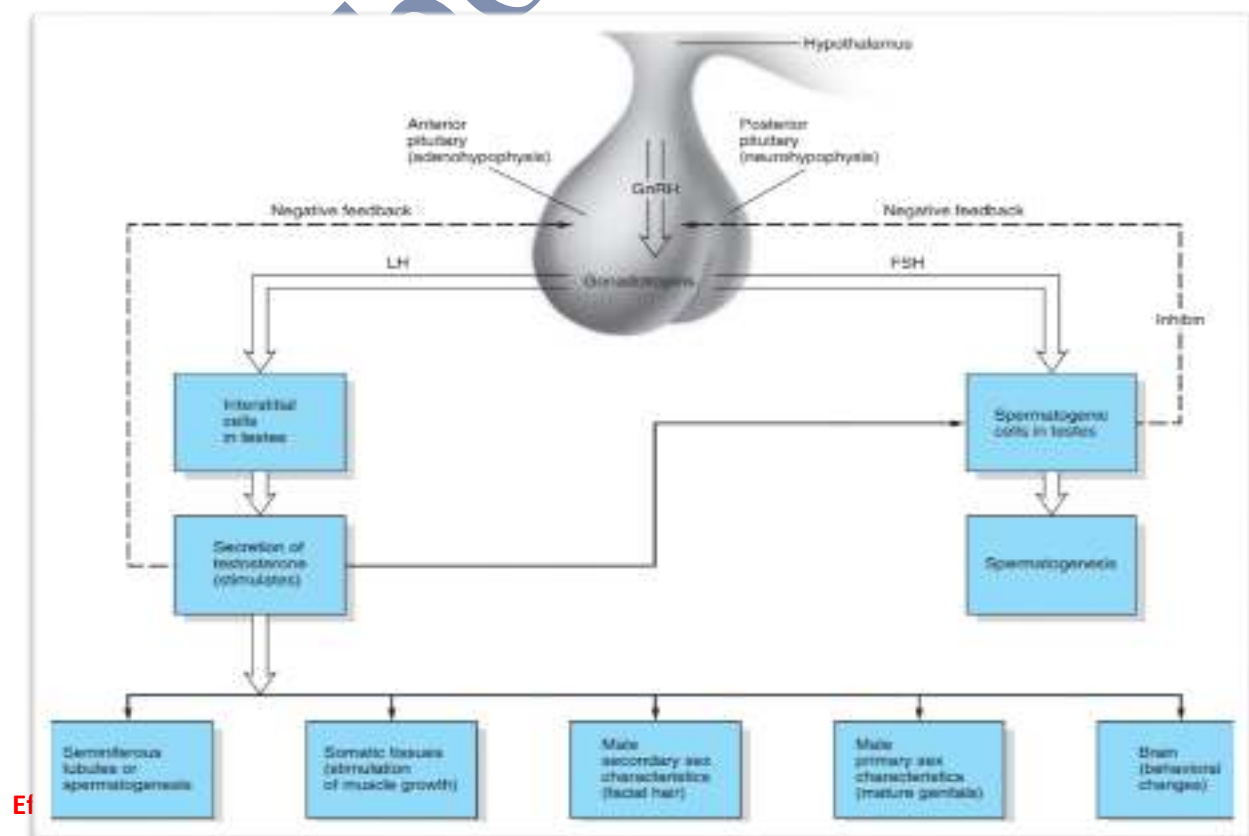


Fig. Hormonal control of male reproductive function

nourishment from mother. Both fertilization and development is internal. Scorpions, most mammals, elasmobranch fishes, few amphibians and reptiles are viviparous.

LESSON 144

INVERTEBRATE REPRODUCTIVE SYSTEM

Invertebrates may have a simple reproductive structure which release gametes into water for external fertilization. Other may have complex structures for internal fertilization. Some invertebrates like polychaetes have no permanent reproductive organs. Cells lining body cavity produce gametes which are released through coelomic or nephridial duct. Sometimes body wall may rupture. However most of the vertebrates have male and female reproductive organs.

Male reproductive system is meant for production and safe transfer of sperms. Male reproductive system has testes for sperm production. Sperm pass through sperm duct/vas deferens to seminal vesicle for storage. Then sperms are passed out through ejaculatory duct. Accessory glands add seminal fluid.

Female reproductive system has ovaries where egg or ova is produced. Mature eggs pass through oviduct to a common genital chamber, from where they enter into female bursa (vagina). Then eggs are stored in seminal receptacles. In some species, sperms from one mating are stored and used all the life.

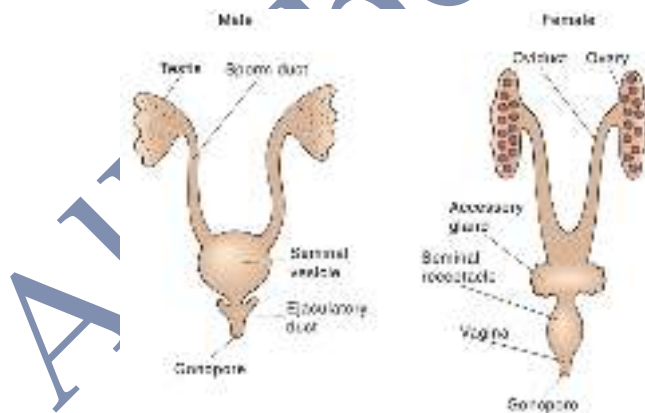


Fig. generalized structure of invertebrate reproductive system

LESSON 145

Human Male Reproductive System

Male reproductive system have two basic function: Production of sperms and Transfer of sperm to female reproductive tract. Important components of male reproductive system include scrotum, testes, rete testis, epididymis, duct deferens and ampulla. Seminal Vesicle. Male reproductive system consists of a pair of testes enclosed in a sac like structure called scrotum. Each testes has a large number of seminiferous tubules. These are the sites for sperm production. Seminiferous tubule join a network of tubules called rete testis. After that there is a dilated tubule called epididymis. Epididymis has three functions: 1) storage and maturation of sperms. 2) Smooth muscles that help to propel sperm during ejaculation and 3) Transfer sperms to duct deferens. Duct deferens transfer comes out of scrotum and passes through the lower part of abdominal wall via inguinal canal. Sometime this point is weakened and intestine part may protrude out. This condition is called inguinal hernia. Around urinary bladder duct deferens enlarges to form ampulla. Next to ampulla is called ejaculatory duct. After combining with urinary tube it moves in penis as urethra.

There are different glands present in reproductive system. Important glands are seminal vesicles, prostate gland and bulbourethral gland.

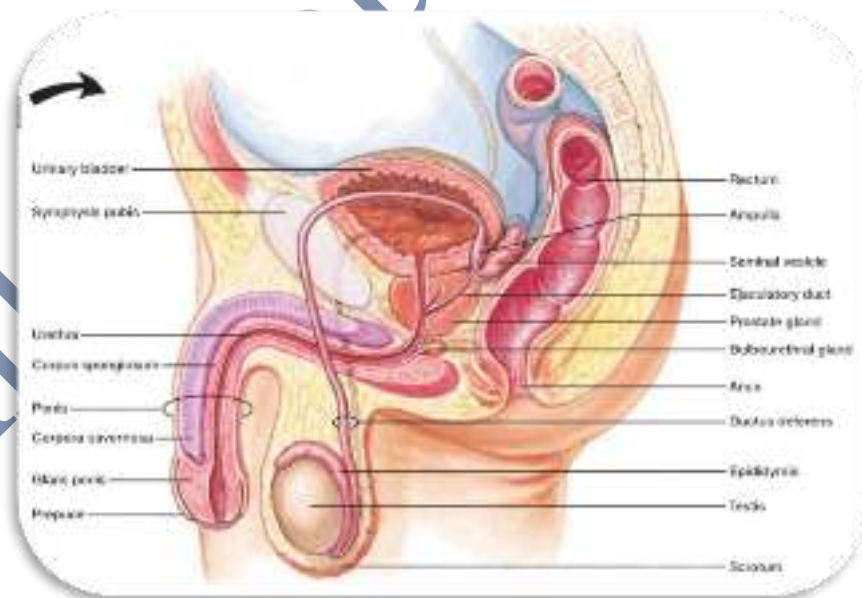


Fig. The human male reproductive system

LESSON 146

Production of Sperms in human

Sperm production occurs in the pair of testes. Testes are present in scrotum outside the body. This is because optimum temperature for sperm production and survival is 34°C . Each testis contain about 800 seminiferous tubules. Seminiferous tubules walls contain two types of cells: Spermatogenic cells and Sustentacular cells. There are clusters of interstitial cells between seminiferous tubules. Thousands of sperms are produced in each second in seminiferous tubules. The process of sperm production is called spermatogenesis. Spermatogenic cells are also called spermatogonia (singl. spermatogonium) are present in the wall of seminiferous tubules. A Spermatogonium increases in size and becomes primary spermatocyte. Meiosis-I results in two secondary spermatocytes. After meiosis-II four non-motile haploid spermatids are formed. Spermatid undergo morphological changes and are transformed into motile sperms. A mature sperm consists of head which contain haploid nucleus and acrosome cap having acrosin, midpiece which have mitochondria and tail that contains microtubules for whip like movements. Sustentacular cells provide nourishment to sperms and maintain fluid environment while

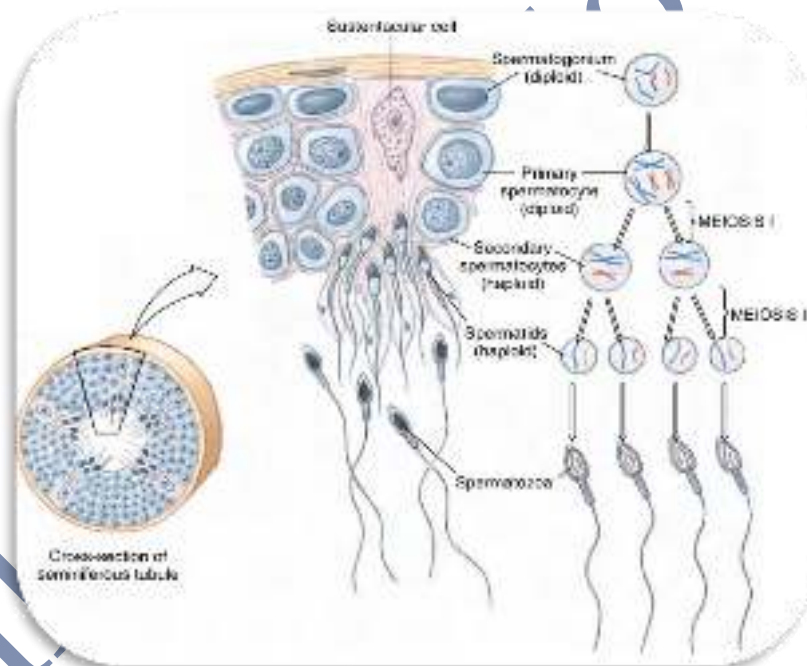


Fig. Spermatogenesis in seminiferous tubules of testis

interstitial cells release male sex hormone testosterone.

LESSON 147

Transport of sperms in Human

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Spermatogenic cells produce sperms while sustentacular cells secrete fluid for nourishment of sperms. Sperms from seminiferous tubules come into a network of called rete testis and then into epididymis where they are stored for some time. Muscular contraction propels sperm forward. Sperms through duct deferens are transported to ampulla where stored till ejaculation. Seminal vesicles secrete water, fructose, prostaglandins and Vitamin C. This is energy source for sperm motility and helps to neutralize pH of female reproductive tract. Prostate gland secretes water, enzymes, cholesterol, buffering salts and phospholipids. Bulbourethral glands secrete clear alkaline fluid that lubricates urethra to facilitate ejaculation. Fluid that results from the combination of sperms and glandular secretions is called semen. Average human ejaculation contains 3 to 4 ml of semen having 300-400 million sperms.

LESSON 148

Hormonal Control of Male Reproductive Function

Male sex hormones are collectively called androgens (e.g., Testosterones). The hormones which travel from brain and pituitary to testis and ovaries are called gonadotropins (e.g., FSH and LH). Testosterone is secreted by interstitial cells; it has a role in development of testis, prostate and secondary sex characteristics.

Low level of testosterone is detected by hypothalamus. Hypothalamus releases GnRH which effects the pituitary gland to release FSH and LH (ICSH). FSH stimulates spermatogenesis and LH stimulates the production of testosterone. Testosterone inhibits the secretion of LH while inhibin produced by sustentacular cells inhibits the secretion of FSH.

LESSON 149

HUMAN FEMALE REPRODUCTIVE SYSTEM

Reproductive role of human female is more complex. The main functions of human female reproductive system are egg production, to nourish, carry and protect developing embryo. Female also nurses the young one after birth.

Human female reproductive system consists of ovaries, uterine tubes, fimbriae and uterus, vagina, external genitalia and mammary glands. Ovaries produce eggs. They are also responsible for estrogen and progesterone production. Uterine tubes carry eggs from ovaries to uterus. Fimbriae are finger-like projections which receive the egg into uterine tube. Uterus is the place where embryo is implanted for development. Vagina receives sperms during sexual activity. External genitalia are important in sexual arousal and have a protective role while mammary glands are to feed the milk to newborn.

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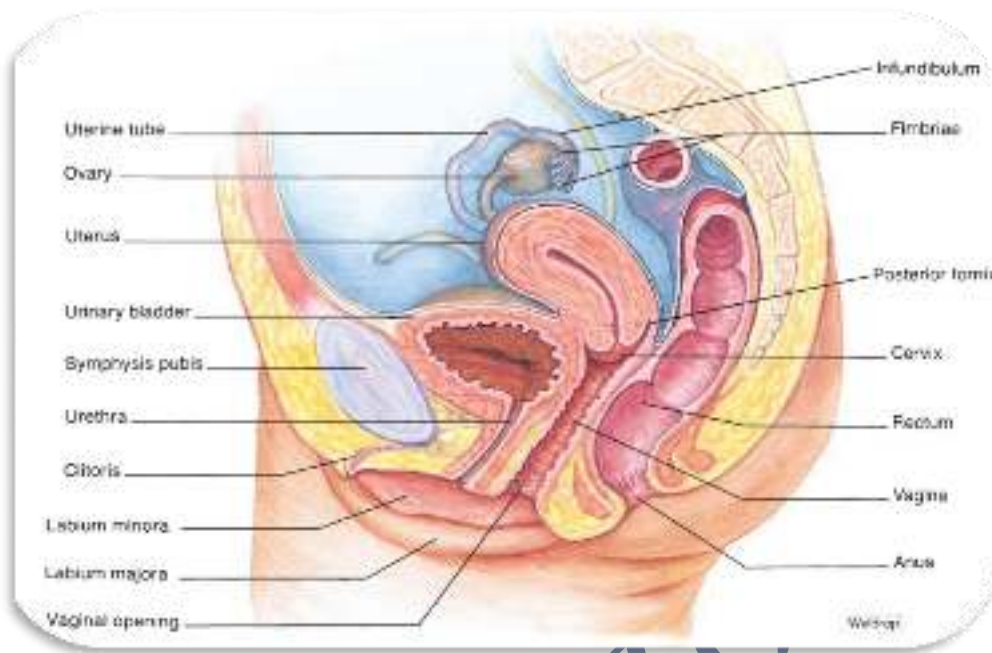


Fig. human female reproductive system

LESSON 150

MENSTRUAL CYCLE IN HUMAN

It is the monthly cycle of changes in ovaries and preparation of uterus for implantation of embryo. The cycle begins at puberty and stops at the age of 45 to 55 years.

1. **The Follicular Phase:** Hypothalamus releases GnRH which stimulate the release of FSH and LH from anterior pituitary gland. FSH starts the development of oocyte in the ovarian follicles.
 - i. **The Follicular Phase:** Developing follicle produces estrogen. Estrogen builds up and prepares uterus lining to become thicker (endometrium) for implantation of embryo.
 - ii. **Ovulation:** Elevated level of estrogen increases the release of LH from pituitary gland and inhibits FSH. LH cause the mature follicle to enlarge rapidly and release secondary oocyte. This process is ovulation.
 - iii. **The Luteal Phase:** Mature follicle after release of oocyte becomes corpus luteum. Corpus luteum secretes estrogen and progesterone. They complete the development of endometrium and maintain it for 10-14 days.

- iv. **Menstruation:** If the oocyte is not fertilized, corpus luteum disintegrates. Estrogen and progesterone production stops. As a result endometrium breaks and menstruation starts.

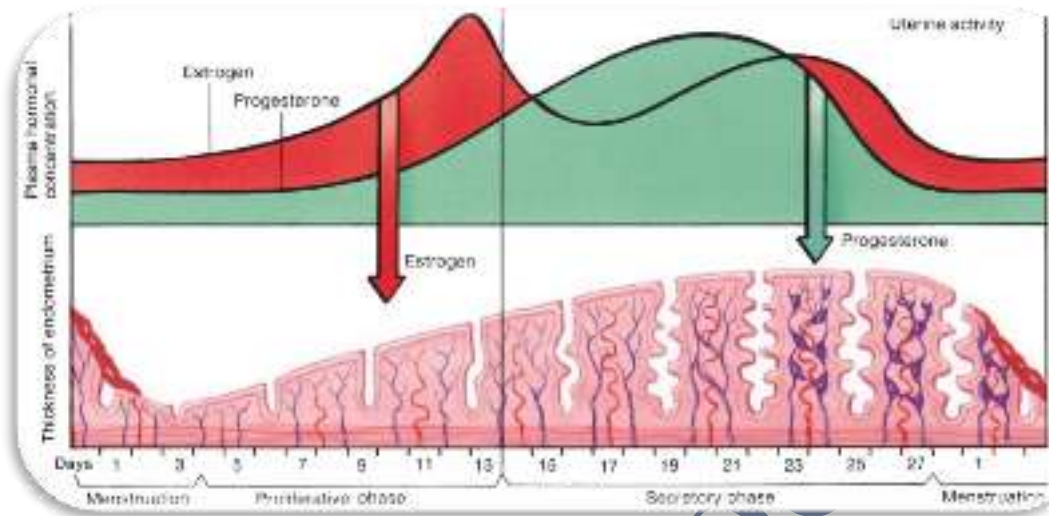


Fig. the human menstrual cycle

LESSON 151

Follicle development in human

An ovary consists of an inner medulla and outer cortex. Medulla has blood vessels and nerves while cortex has developing follicles. During first five months of development many small follicles are formed in the ovary of female fetus. These are called primordial follicles. At the time of puberty during each menstrual cycle some primordial follicles began to develop further and become primary follicles which then converted to secondary follicles and graafian follicle. Many follicle start development in each cycle but only one completes all the stages. The follicle

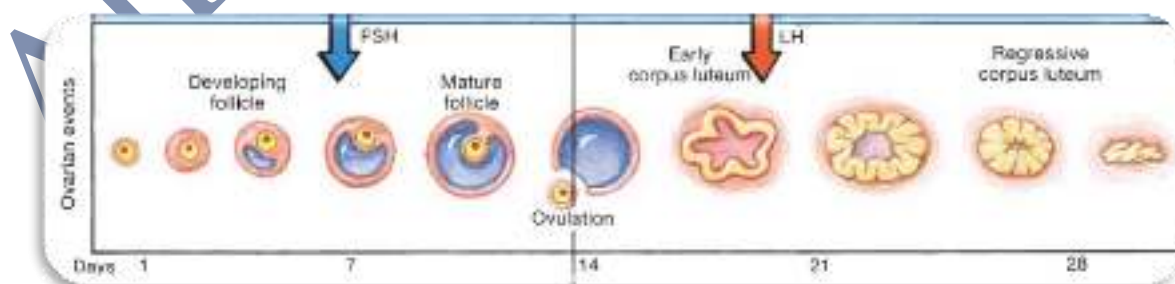


Fig. Different stages of follicle development

before release of egg is called graafian follicle. LH hormone causes the rupture of follicle to release egg. Graafian follicle after release of oocyte becomes corpus luteum which remain active

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for 10-14 days. If fertilization does not occur corpus luteum is converted to corpus albicans which ultimately disintegrates.

During each menstrual cycle several follicles start development but only one matures. Others disintegrate by the process atresia. In this process cells are disintegrated by apoptosis.

LESSON 152

Production and Transport of Egg in Human

Egg production starts in female while still at the developmental stages. A definite number of eggs development takes place in specific structures called follicles. Egg development is halted at early stage of meiosis-I. At puberty during menstrual cycle meiosis-I is completed and meiosis-II starts which is completed after fertilization.

Egg is released from ovary by the process of ovulation. LH cause the release of oocyte from ovary. Ovary is encircled by finger like ciliated fimbriae. The ciliary action and muscular contraction cause the entry of oocyte into fallopian tube also called uterine tube. Fertilization takes place in upper one third portion of uterine tube. Oocyte completes meiosis-II after fertilization. Fertilization should take place within 24 hour of ovulation.

Egg moves due to ciliated cells and muscular contraction of uterine wall. Egg takes about 5 days to reach to uterus. If fertilized, embryo implanted into uterus otherwise egg is released out.

LESSON 153

Hormonal Control of Female Reproductive Function

Low level of estrogen stimulate hypothalamus to release gonadotropin-releasing hormone (GnRH). GnRH acts on pituitary gland to release follicle stimulating hormone (FSH) and luteinizing hormone (LH). Both of these hormones act on ovary. FSH start the development of follicle. 15-20 follicles start development but only one matures. Ovary also starts to produce estrogen. Estrogen causes the thickness of endometrium of uterus

Higher level of estrogen triggers LH and inhibit FSH from pituitary gland. LH from pituitary causes the ripening of ovarian follicle and release of oocyte from follicle. LH also convert collapsed follicle into corpus luteum after ovulation. Corpus luteum secretes estrogen and progesterone. Estrogen and progesterone have two roles: they maintain endometrium for completing development and also inhibit LH and FSH. If no fertilization occur, FSH and estrogen level drops and new cycle is started.

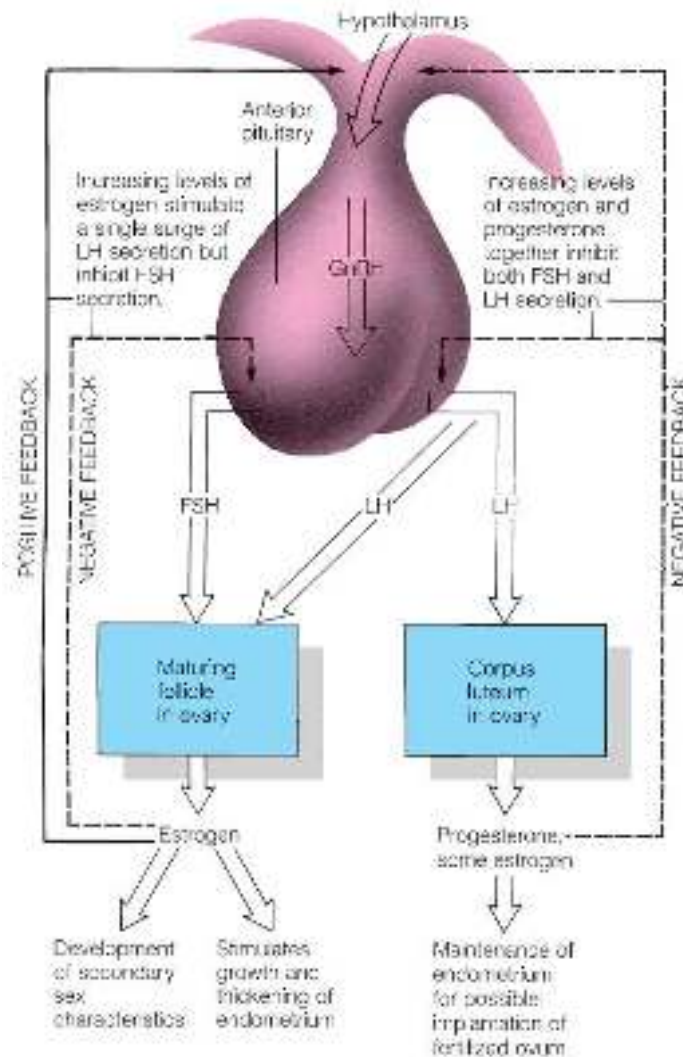


Fig. hormonal control of human female reproductive system.

LESSON 154

Historical Perspective of Embryology

Preformation theory: This theory says that gametes contain miniature version of all the element present in an adult. This means that every organ in a very small size is already present. Most biologist of 17th and 18th century believe in it.

Epigenesis theory gained popularity in mid-18th century. This theory says that embryo contain material from which embryo is gradually build. Much like a carpenter builds a building from nails, lumber and bricks.

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Birth of modern embryology: Modern embryology emerged with the proposed germ layer theory. Embryo form 2-3 layers from which different body parts are formed.

Development Biology: It the study by which animals and plants grow. Developmental biologists use the tools of molecular biology to investigate the genetic control of development.

LESSON 155

Gametogenesis

Gametogenesis is the process of formation of gametes. It is of two main types: spermatogenesis and oogenesis.

Spermatogenesis: The process of sperms production in male gonads through meiosis is called spermatogenesis. Spermatogenesis takes place in testes. In human the entire process of spermatogenesis and its transportation takes about 3 months. However, it is different in different animals.

Testes contain diploid stem cells. Sperm mother cell is called spermatogonium. It enlarges in its size and become primary spermatocyte. Primary spermatocyte undergo meiotic cell division. After meiosis-I two secondary spermatocytes are formed. Then meiosis-II results in four haploid spermatids. Spermatids do not undergo any further cell division. They undergo morphological changes to produce sperms. Spermatids are non-motile while sperms are motile cells.

LESSON 156

Oogenesis: The process of egg production in female gonads through meiosis is called oogenesis. Oogenesis takes place in ovaries. Egg formation and maturation takes place in follicles of ovary. Ovarian follicles contain oogonia. Oogonium increase its size and becomes primary oocyte which is a diploid cell with duplicated chromosome. Primary oocyte undergo meiotic cell division. After meiosis-I a secondary oocyte and a polar body is formed. Meiosis-II results in a haploid ootid and another polar body. Ootid undergo differentiation process to form ovum.

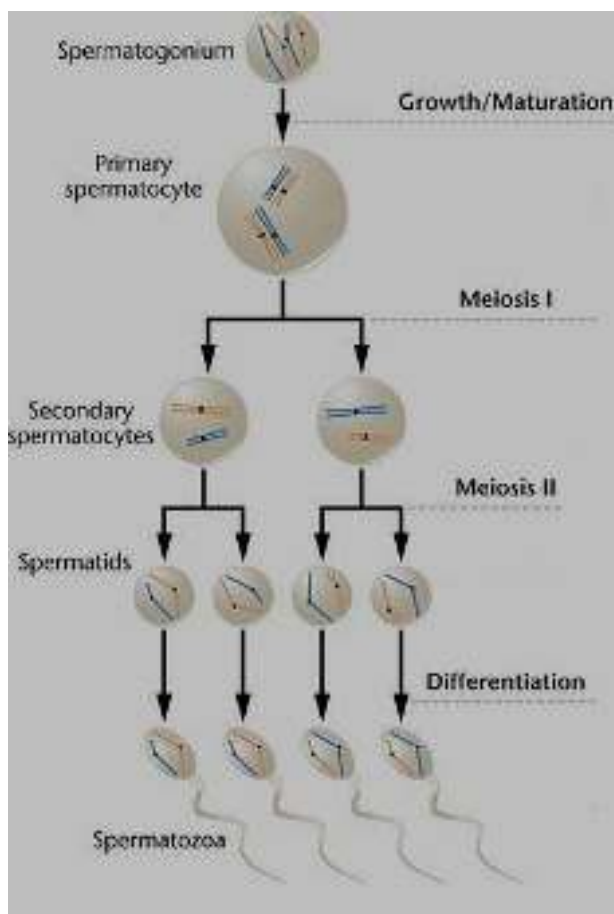


Fig. Spermatogenesis in animals

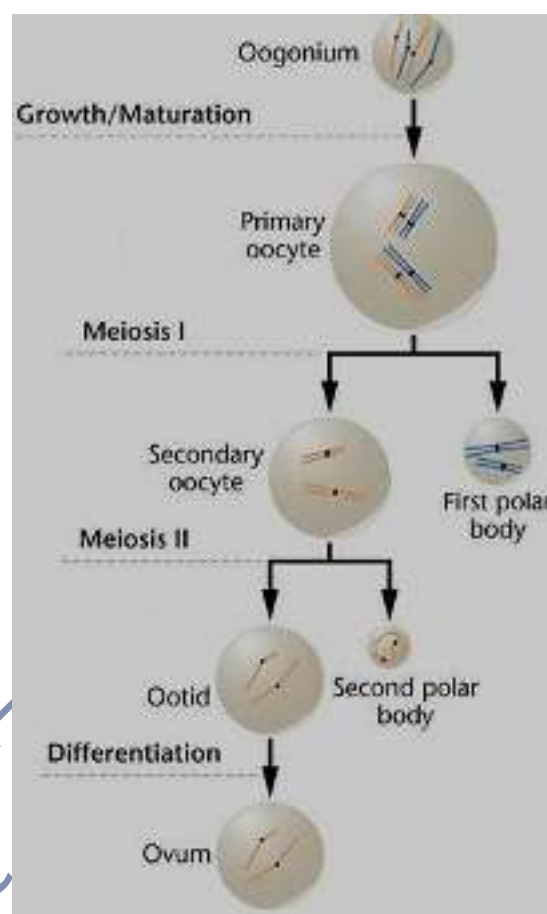


Fig. Oogenesis in animals

LESSON 157

TYPES OF EGGS

Eggs may be classified on the basis of amount of yolk or distribution of yolk.

Classification on the basis of amount of yolk: On the basis of amount of yolk eggs may be Alecithal, microlecithal, mesolecithal and macrolecithal. Eggs containing negligible amount of yolk are called Alecithal egg. e.g., placental mammals. Eggs containing very little amount of yolk are called microlecithal eggs. e.g., sea urchin, amphioxus and marsupial mammals. Eggs with moderate amount of yolk are called mesolecithal eggs. e.g., lung fish and amphibians. While eggs with large amount of yolk are called macrolecithal eggs. e.g., reptiles and birds.

Classification on the basis of distribution of yolk: Eggs may be classified on the basis of distribution of yolk. Eggs with equally distributed yolk are called homolecithal eggs. e.g., sea urchin and mammals. Eggs with yolk in the center and cytoplasm in periphery are called centrolecithal eggs. e.g., insects. Eggs in which yolk is present at one end while cytoplasm at other end are called telolecithal eggs. e.g., frogs, reptiles and birds. The region of egg containing

cytoplasm, its organelles and less amount of yolk is called animal pole while the region of egg containing more amount of yolk and less cytoplasm is called vegetal pole.

LESSON 158

FERTILIZATION

Fertilization is the process in which egg and sperms fuse to form a diploid zygote which is the first representative of next generation. Fertilization is of two types: external fertilization and internal Fertilization. External fertilization takes place outside the body mainly in water, while internal fertilization takes place within the body of animal. Fertilization may be via copulation, cloacal connection or via spermatophore.

The structure surrounding plasma membrane of egg is called vitelline membrane. It is made up of fibrous proteins and receptors needed for sperm binding. The sperm contain an acrosomal head. The acrosome have specific enzymes called lysins which dissolve egg membrane during fertilization.

Many sperms approach to egg but only one successful. In some species only nucleus of sperm fuses with egg. In others, mitochondria, centriole and flagella of sperm may get entry into egg.

Egg Activation: It is a series of biochemical changes in egg which ensure the completion of fertilization and initiate embryonic development. Normally many sperms approach to egg but only one sperm should fertilize the egg. For this, second fertilization is stopped by changes in plasma membrane and outer region of cytoplasm.

LESSON 159

Membrane and cortical events: As sperm contacts, **microvilli** from egg plasma membrane wrap around the sperm. Contraction of microfilaments causes the sperm to draw into the egg. Within milliseconds of sperm penetration, the **charges on plasma membrane** are changed. This makes plasma membrane unresponsive to other sperms. **Fertilization membrane** is formed by the discharge of granules of egg cortex. These granules are discharged between plasma membrane and vitelline layer. These granules loosen the contacts between plasma membrane and vitelline layer. Water molecules enter into the space and proteins of cortical granules thicken and strengthen the vitelline layer. Fertilization membrane formed within 1 to 2 minutes. After this, outer cytoplasm begins rotational and sliding movements. In amphibians, this rotation of cytoplasm results in the formation of **gray crescent** which is important in development.

LESSON 160

Metabolic and nuclear events: After fertilization ionic changes occur in cytoplasm causing an increase in **intracellular pH**. This triggers the developmental process in zygote. The zygote

starts the cleavage (cell division) process. For this, **DNA replication** starts as two copies of DNA are required for two daughter cells. Rate of **protein synthesis** is also boosted. This is because more and more proteins and enzymes are required for cell division and daughter cells. mRNA already present in the cell is activated to start protein synthesis. The mRNA in zygote used to protein synthesis is maternal in origin. Thus bulk of initial proteins is synthesized by maternal mRNA. This influence is called **maternal dominance**.

LESSON 161-162

CLEAVAGE AND ITS PATTERNS

Cleavage refers to cell divisions that occur during embryonic development. Initially all the cells of embryo divide at the same time this is called **synchrony**. As development proceeds, all cells don't divide simultaneously. This is called **asynchrony**. Eggs with evenly distributed yolk have cleavage pattern that result uniform size blastomeres. Egg with unevenly distributed yolk result in unequal size blastomeres. There are following important patterns of cleavage:

a. Holoblastic Cleavage

The pattern of cleavage in which egg is completely divided into two cells. Egg contain little or moderate amount of yolk. Cleavage in fertilized eggs of Amphibians, mammals, echinoderms, flatworms and nematodes.

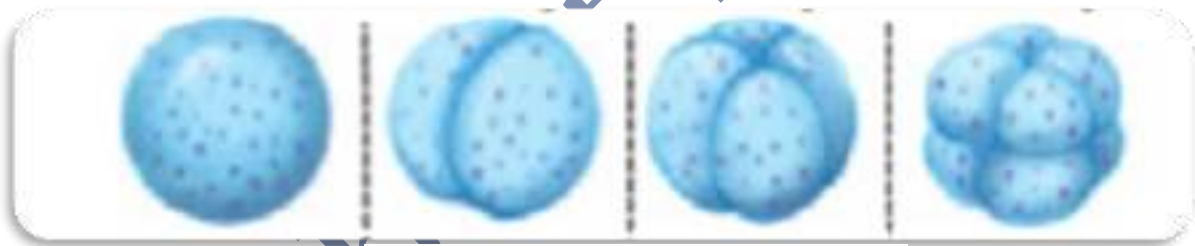


Fig. Holoblastic cleavage pattern

b. Meroblastic Cleavage

The pattern of cleavage in which egg is not completely divided into two cells. This is due to large amount of yolk. In these embryo development takes place around or on the top of yolk. e.g., cleavage in fertilized eggs of birds and reptiles.

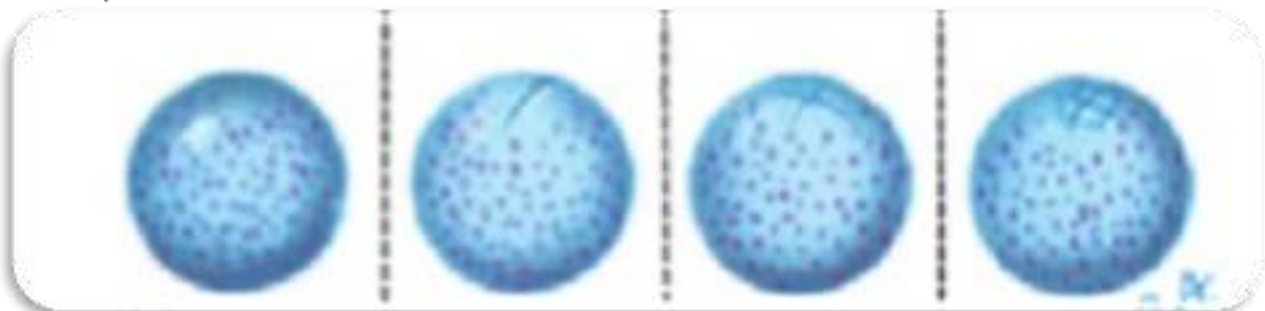


Fig. Meroblastic cleavage pattern

c. Spiral Cleavage

It is pattern in which cells of animal pole are not exactly laying above the vegetal pole cells. Cleavage takes place at oblique angle forming a spiral pattern. Example: protostomes cleavage

d. Radial Cleavage

It is pattern in which cells of animal pole are exactly laying above the vegetal pole cells. Upper tier of cells is exactly on the lower tier of cells. Example: deuterostomes cleavage

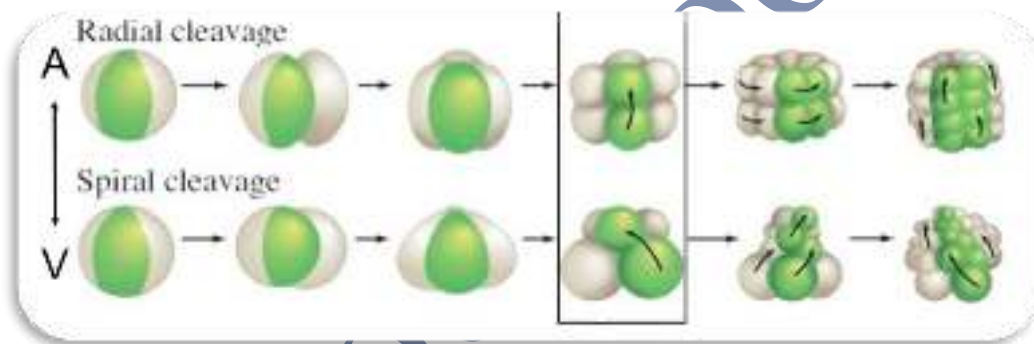


Fig. Radial and spiral cleavage pattern

LESSON 163

ECHINODERM EMBRYOLOGY

General Concepts

Echinoderms include starfish, sea cucumber, brittle star and sea urchin. Echinoderms are extensively studied group. This is because they are easily maintained in laboratory. Echinoderms lay eggs in water. In echinoderms fertilization is external and it takes place in water. Egg of echinoderm contain very little amount of yolk (microlecithal eggs).

LESSON 164

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Cleavage: Cleavage is holoblastic and completely divides into two. Cleavage lines pass in such a way that cells lie exactly one above the other. This type of cleavage is called radial cleavage. Radial cleavage is the characteristic of deuterostomes.

First two cleavage are from animal to vegetal pole (meridional) and perpendicular to each other. Third cleavage is equatorial and right angle to first two. It separates animal pole and vegetal pole. Fourth cleavage is medional. Initially division is equal, however, at sixteen cell stage division becomes unequal.

LESSON 165

Morulation and Blastulation: Cleavage results in a ball of cells called morula. Morula is a solid ball of cells without any cavity. At about 120 cell stage, a fluid filled cavity **blastocoel** is formed in the embryo. There is a single layer of cells around the blastocoel. Embryo at this stage is called blastula. At blastula stage embryo comes out of the fertilization membrane. At blastula stage cilia develop and embryo start swimming. At late blastula stage, some cells breakoff and position themselves within blastocoel. These cells are called primary mesenchyme and will form skeletal elements (spicules) of embryo. Late blastula is about 1000 cells of different size.

LESSON 166-167

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Gastrulation: Gastrulation is the process in which blastula is changed into gastrula. During this process primary germ layers are formed. Gastrulation begins at a point in vegetal half where cells start invagination. The point where invagination starts is blastopore. The invagination forms a new cavity in the embryo called **archenteron**. Archenteron gradually replaces blastocoel. Blastopore will form anus and archenteron is future gut of echinoderms. Some cells at the tip of developing archenteron get apart and form secondary mesenchyme cells. Secondary mesenchyme cells play a central role in pulling archenteron up to blastocoel wall. Initially embryo is round in shape. During gastrulation it begins to elongate and attains pyramidal shape (Prism) and ultimately form pluteus larva. The larvae have a preferred direction of movement. Pluteus larva swims freely and feeds on smaller plants and animal. It has bilateral symmetry,

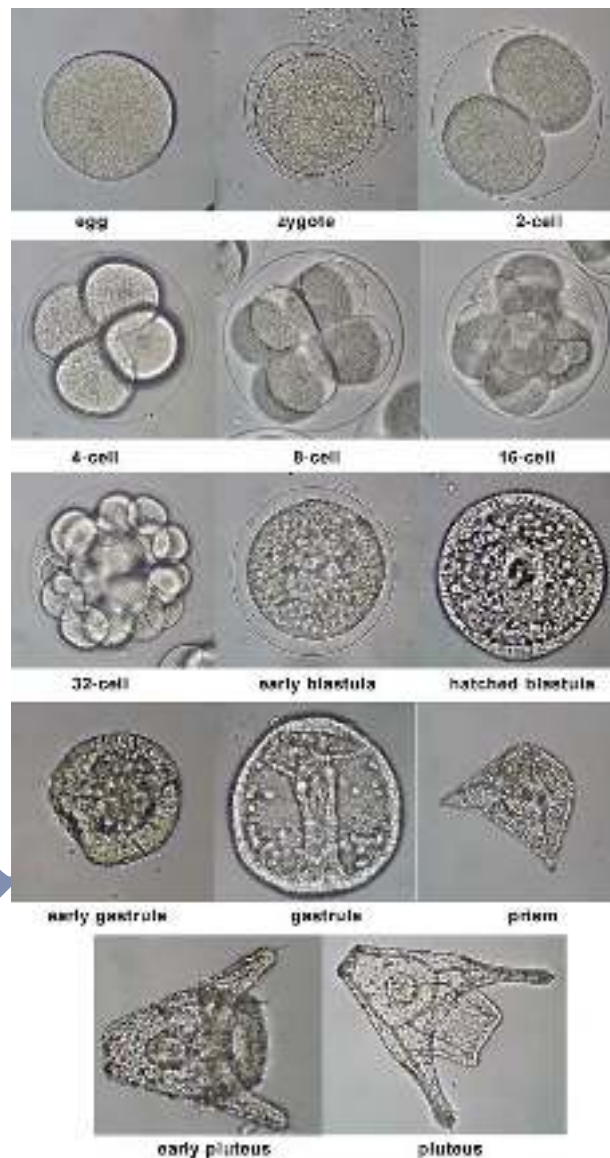


Fig. Echinoderm embryology

although adults have radial symmetry.

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LESSON 168

AMPHIBIAN EMBRYOLOGY

Most of the amphibians lay laid in water. Eggs are mesolecithal as they have moderate amount of yolk. The upper pigmented portion is called animal pole while the lower pole with large amount of yolk is called vegetal pole. Darkly pigmented animal pole on upper side camouflage from predators as it blends with bottom of water body. Light colour of vegetal pole blends with sky when viewed from below. Dark colour of animal pole also absorbs heat which promotes development. Fertilization takes place in water. Usually very little care by parents.

LESSON 169

Cleavage: Amphibians have mesolecithal eggs. Cleavage completely divide cell in two cells. Due to yolk at vegetal pole cleavage is slow. Size of cells at animal pole is smaller while larger at vegetal pole. First cleavage start from animal to vegetal pole. Cleavage at vegetal pole is slow due to large amount of yolk. It also divides gray crescent from middle. Second cleavage is perpendicular to the first and divides embryo into four. Third cleavage is equatorial and right angle to first two. Separate animal pole and vegetal pole. Fourth cleavage is meridional. Cleavage lines pass in such a way that cells lie exactly one above the other (radial cleavage). This radial cleavage is the characteristic of deuterostomes.

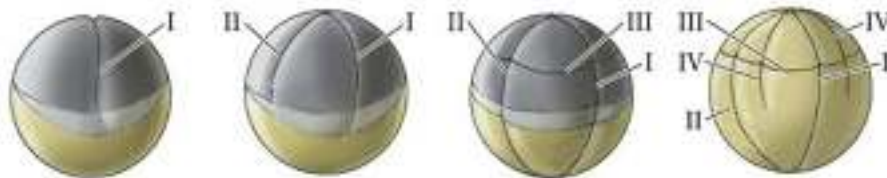


Fig. Cleavage in amphibians

LESSON 170

Morulation: Cleavage results a ball of cells called morula. Morula is a solid ball of cells without any cavity. Cell towards animal pole are smaller while larger at vegetal pole due to presence of yolk.

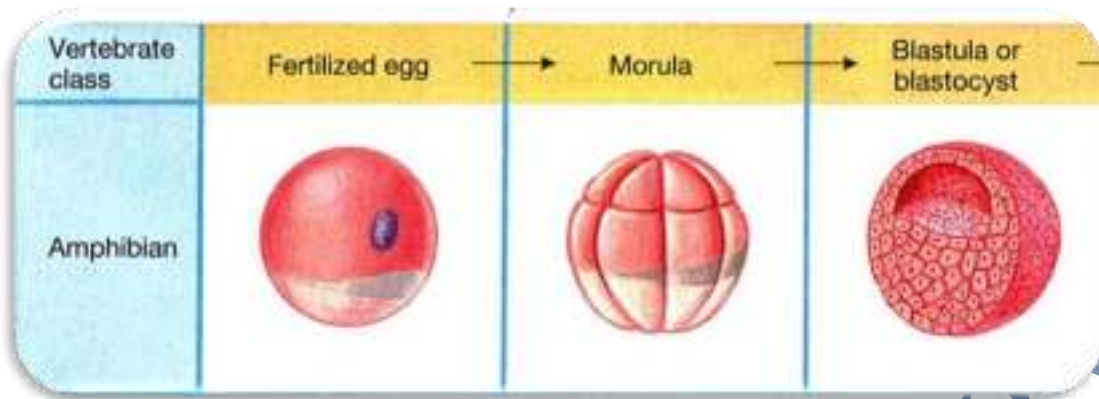


Fig. Morulation and blastulation

Blastulation: After morula formation, a fluid filled cavity **blastocoel** is formed in the embryo. Cell form multiple layers around the blastocoel. In amphibians blastocoel is formed towards animal pole due to yolk at vegetal pole

LESSON 171-172

Gastrulation: Gastrulation is the process during which cells arrange themselves into different layers called primary germ layers. Embryologist use dyes and carbon particles to mark different cells. Cells forming different structures are grouped on the surface of blastula. Later these migrate during gastrulation and form different structures. So these cells are named according to their future structure such as presumptive notochord, presumptive mesoderm and so on. Gastrulation begins with a slit like opening **blastopore** between gray crescent and ventral pole. Animal pole margin of blastopore is called its dorsal lip. Cells at the bottom of groove move anteriorly and groove spreads transversely. Cell at the surface begin to roll over the dorsal lip. This process is **involution**. Migrating cells spread across the slit like blastopore transversely and downward to the vegetal pole. Due to this migration one end of slit meets the other end. The ring like blastopore surrounds the yolk cells and they protrude out of the blastopore. This is called yolk plug. Later blastopore cells enclose yolk plug and blastopore is considered as closed.

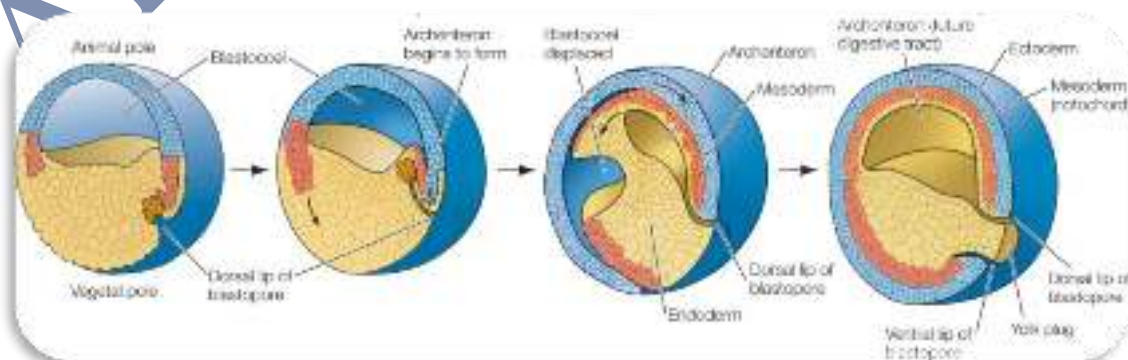


Fig. Gastrulation in amphibians.

Rolling over cells from blastopore form archenteron. Blastocoel becomes smaller and archenteron become larger. Archenteron is future gut and yolk cell make floor of gut. Some of the animal pole cell are rolling into the blastopore, they will form endoderm and mesoderm. The remaining animal pole cells are called ectoderm. These ectodermal cells migrate towards blastopore and spread over entire embryo. This is called **epiboly**. Some of the last cells rolling over the blastopore are presumptive notochord and presumptive mesoderm. Initially they form dorsal lining of archenteron near blastopore. Later they detach from endoderm and move between endoderm and ectoderm in the region of blastopore. This is called **chordamesoderm** which differentiates into notochord. Lateral to notochord mesodermal cell spread and thicken along sides of embryo. These thickenings are called **somites**. Somites appear as row of pumps from side view. Eventually somites split to form coelom

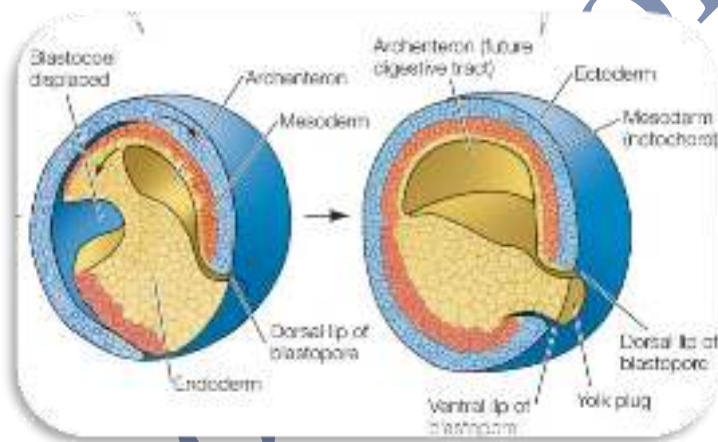


Fig. Mesoderm formation in amphibians

LESSON 173

Neurulation: The process of forming neural tube is called neurulation. An oval shape area on the dorsal surface of embryo is formed. Microfilament flatten and thicken this area. This region is neural plate. The edges of the neural plate roll up and over the midline of neural plate. These raised edges in longitudinal direction are called neural folds. The raised neural folds meet with each other longitudinally over the midline of neural plate. Now neural plate is converted into a tubular structure called neural tube. The portion of neural tube that is close at the end will form brain

LESSON 174

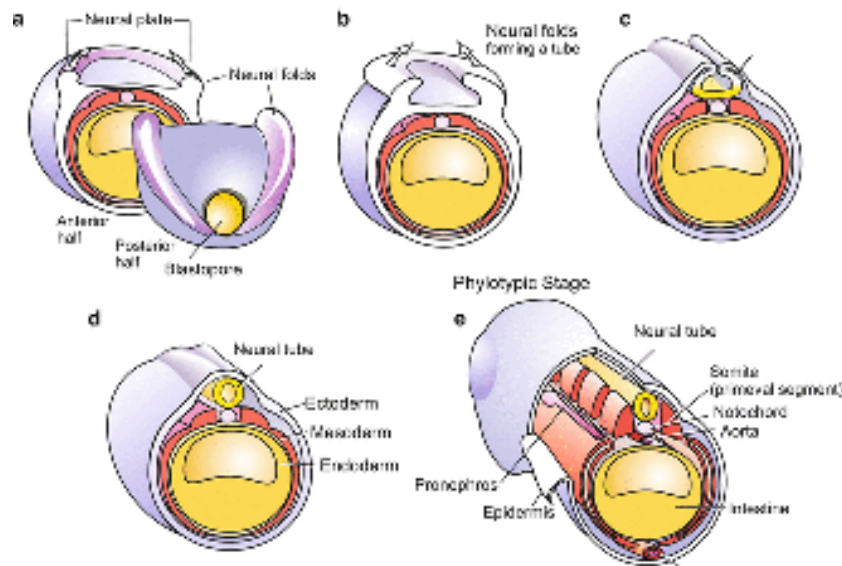


Fig. Neurulation in amphibians

AVIAN EMBRYOLOGY

Chicken development is used as a model for the development of birds and reptiles. Birds egg is macrolecithal and contains large amount yolk. Due to large amount of yolk egg nucleus is present at one side, so they are called as telolecithal eggs. Yolk is also protected by albumin CaCO_3 shell. In birds fertilization is internal and it takes place in upper portion of oviduct. Development starts right after fertilization while egg is still in oviduct. All developmental stage are completed within shelled egg. In chicken development is completed in approximately three weeks.

LESSON 175

Structure of Avian Egg

Membranes and fluids are collected around the egg while moving through oviduct. Water and albumin is deposited around the egg. This protect from desiccation and mechanical damage. Albumin is used for protection and a source of nutrition. Two denser strands of albumin called chalaza are attached to the egg shell. They suspend egg in the center of albumen. Shell gland secrete CaCO_3 which deposit around the egg. It is also impregnated with proteins. Thousands of tiny pores (40-50 μm) are for exchange of gases. Inside the shell two membranes are present. At the round end of egg an air pocket is present between two membranes. Air pocket enlarges with

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time. Near the time of hatching the chick breaks air pocket, the air inflates its lungs and the chick start breathing.

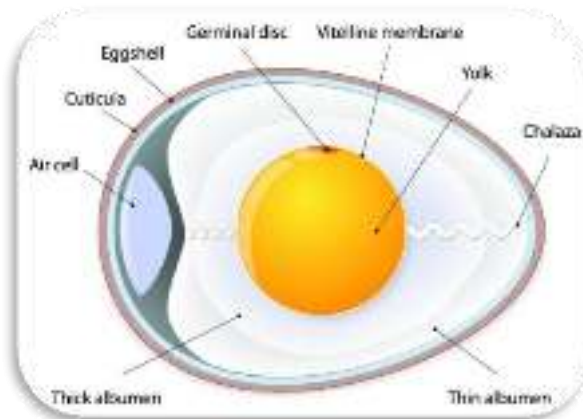


Fig. Structure of chicken egg

LESSON 176

Cleavage: Due to large amount of yolk cleavage do not divide cell in two. There is no division in the large amount of yolk. All the divisions are at one end of egg forming a disc shape structure. Such a cleavage is called discoidal cleavage. Cleavage is radial as cleavage lines pass in such a way that cells lie exactly one above the other. Radial cleave is the characteristic of deuterostomes. First two cleavage are vertical and perpendicular to each other. Third cleavage is equatorial and right angle to first two. Fourth cleavage is vertical.

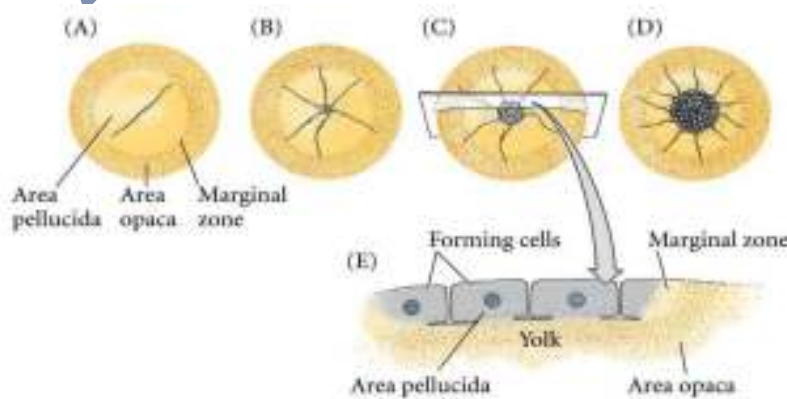


Fig. discoidal cleavage in chick embryo

LESSON 177

Blastulation: The cells in the animal pole divided. When the cells are approximately 60,000, they form a blastoderm. The yolk below blastoderm is used which forms a fluid-filled cavity called blastocoel. Blastoderm splits into two layers: Outer layer is called epiblast while the inner layer is hypoblast.

LESSON 178-179

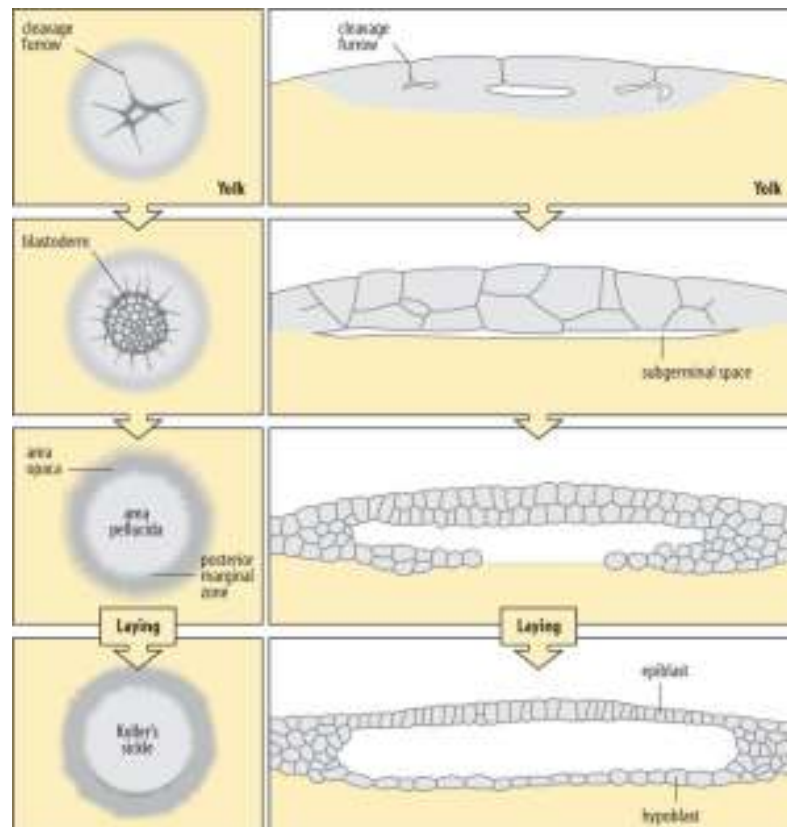


Fig. Blastulation in chick embryo

Gastrulation: The dorsal cells of blastoderms form a medial linear invagination called primitive streak. Primitive streak gradually extends anteriorly. It defines the axis of embryo. It also separates right and left side. The anterior margin of primitive streak there is a regional thickening called Henson's node.

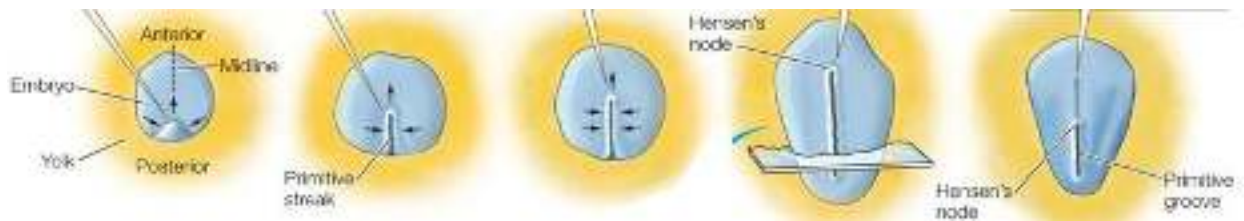


Fig. primitive streak and Hensen's node in chick embryo

Hensen's node contains funnel shaped depression through which cell enter between epiblast and hypoblast. Hensen's node is functionally equivalent to blastopore of amphibians. First cells migrating through Hensen's node move anteriorly and ventrally to form pharyngeal endoderm of foregut. Hypoblast cell are moved anteriorly. Next migrating cells move anteriorly, but not far away. They remain between endoderm and epiblast to form prechordal plate mesoderm. They form head process. After that the migrating cells form chordamesoderm which forms notochord. Cells that ingress through middle part of streak give rise to middle part of somites and to heart and kidney. Cell which ingress through posterior end give rise to lateral plate and extra embryonic mesoderm.

After migration, the cell remaining outside form ectoderm. Ectodermal cells close to streak form neural tube and the cells farther from streak will form epidermis. Hensen's node attains a more posterior position due to regression of primitive streak. Now the epiblast cells are all ectodermal cells. The ectodermal cell migrate and enclose the yolk. This process is called epiboly. Embryo lift it off the yolk. Only a connection is retained between embryo and yolk. Blood vessels develop in yolk stalk to carry nutrients from yolk.

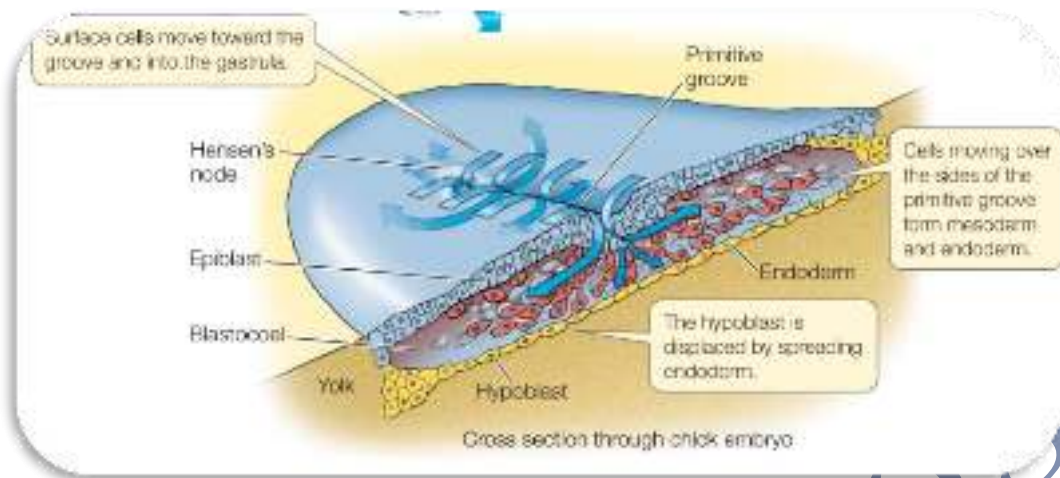


Fig. Cross section through chick embryo

LESSON 180

MAMMALIAN EMBRYOLOGY

Class mammalia is divided into three subclasses. Prototheria are egg laying mammals. Their eggs have large amount of yolk. Marsupial mammals are pouched mammals. Their eggs have very little amount of yolk (microlecithal eggs). Placental mammals have almost no amount of yolk (alecithal eggs). Placental mammals egg is smallest in animal kingdom. Mammals have internal fertilization. Placental and marsupial mammals have internal development and both give birth to young ones.

Marsupial mammals have premature birth. They keep the newborn in marsupium and nourish with their nipples. Placental mammals have long gestation period. Fetus is fed through placenta.

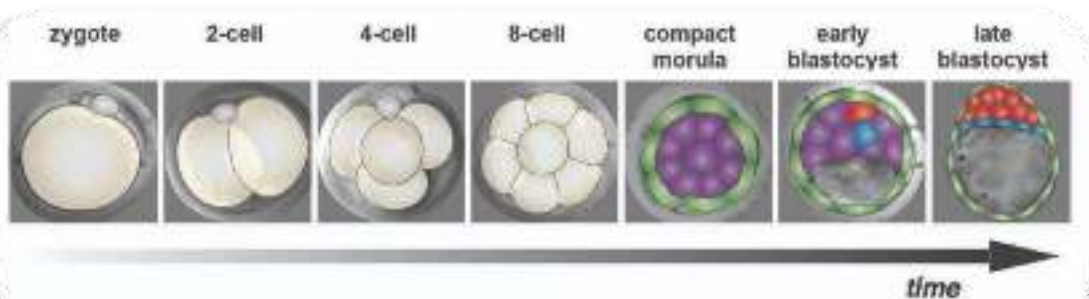
LESSON 181

Cleavage and Blastulation: Mammalian cleavage is slowest in animal kingdom. Blastomeres have unique orientation. There is rotational cleavage. First cleavage is meridional while in second cleavage one is meridional and other is horizontal. Cell division is asynchronous in the very beginning. Cells are not 2-4-8, but may be odd number. Cells switch from maternal to zygote control at 2 cell stage for protein synthesis. Through 8 cell stage, loose arrangement with plenty of space. After third cleavage the cells tightly huddle together to form a compact ball. Eight cells divide to produce 16 cell **morula**. A small group of internal cells is called **inner cell mass (ICM)** while the outer cells form **trophoblast**. ICM forms embryo while trophoblast forms chorion for placenta formation. 8 cells stage blastomere can form both ICM and trophoblast, they are called **totipotent**. ICM cells can form any type of embryo cells, they are called **pluripotent**. Trophoblast cells of morula secrete fluid that creates blastocoel. As blastocoel expands ICM and trophoblast take their positions. At this stage blastula is called **blastocyst**.

LESSON 182

GASTRULATION

amount of
inner cell



bilaminar germ disc. Hypoblast cells form extraembryonic endoderm which form yolk sac. Epiblast form embryonic endoderm and amnion cavity. Epiblast cells move through primitive streak for form endoderm and mesoderm. The cell anterior and lateral to primitive streak form ectoderm.

LESSON 183

HORMONAL REGULATION IN PREGNANT FEMALE

The cells developing embryo and placenta release **human chorionic gonadotropin (hCG)**. hCG maintains the corpus luteum so it may not disintegrate. High level of hCG is used as immunological test for pregnancy by 2 weeks. **Progesterone** is released by corpus luteum. Progesterone maintains the endometrium lining to retain pregnancy. **Prolactin** is secreted by pituitary gland. It is produced in pregnant female to start the process of milk production and eject milk after childbirth. **Oxytocin** is also produced by pituitary gland. It caused contraction of smooth muscles to start labour and expulsion of young one. It also stimulate nipples to release milk. **Prostaglandins** secretion increase during labour. They also cause smooth muscle contraction.

LESSON 184

PRENATAL DEVELOPMENT IN HUMAN

In human the development can be divided into two phases: prenatal (before birth) and postnatal (after birth) phases. After two weeks of fertilization till the end of 8th week it is called embryo and from 9th week till birth is called fetus. After the birth it is called newborn or baby. The total gestation period in human is 280 days. This duration is divided into 3 months periods called trimesters.

First Trimester starts from fertilization. Zygote divides to become morula. By 4th day it is converted into 50- 120 cell blastocyst. As embryo reaches into uterus, it implants itself onto uterine wall. Trophoblast invade the endometrium. Gastrulation is similar to birds and reptiles. Once gastrulation completed different organ formation starts called organogenesis. By middle of first trimester all body organ begin to develop and embryo also grows in size.

LESSON 185

Second Trimester: It ranges from 14 to 27 week. Almost all major and vital organs have been completed during this trimester. Growth is magnificent. Heart beat can be heard by the end of fourth month (18 Week). Eyes become open and bones ossification started.

LESSON 186

Third Trimester: It start from 7th month till birth. Fetus has potential to survive if born premature in this trimester. Hair and nail grow in this trimester and the fetus weighs almost double.

LESSON 187

THE PLACENTA

Placenta is a temporary organ which connects developing fetus to mother via umbilical cord. Human have placenta formed from chorion and allantois. The tiny chorionic villi sent out from blastocyst form placenta. Placenta formation starts from day 6 and is completed by 1st trimester. Embryonic blood vessels of placenta do not merge with maternal blood vessels. Placenta is about 22cm in length. Placenta is used for nutrient uptake, thermoregulation, waste elimination, gaseous exchange, fight against internal infection and placental hormone production. Placenta is connected to fetus through umbilical cord which contains two fetal umbilical arteries and one fetal umbilical vein. They spiral about each other in umbilical cord. Average size of umbilical cord is 55cm with 1-2cm diameter.

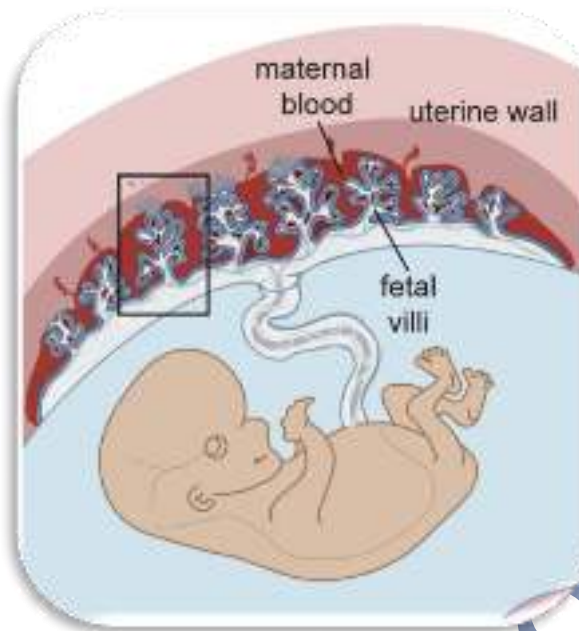


Fig. placenta and umbilical in human

LESSON 188

BIRTH IN HUMAN

Gestation is the total time period which embryo or fetus spends within body of mother. In human it is 280 days or 40 weeks. The process of birth is called parturition. During parturition, mother's uterine muscles begin to contract and cervix begins to dilate. Mother ovaries and placenta produce relaxin hormone. Relaxin causes mother pelvic bone to slightly separate, so the baby may pass from birth canal. During birth baby pituitary gland secretes Adrenocorticotrophic hormone (ACTH). ACTH stimulates adrenal glands to secrete prostaglandins which work along with oxytocin. Stretch in uterine wall stimulate pituitary to secrete oxytocin hormone in mother. Oxytocin and prostaglandins cause powerful muscular contractions. Usually within an hour of muscular contraction baby is expelled out from uterus. After baby comes out the process of contraction continue to expel placenta, the process is called afterbirth.

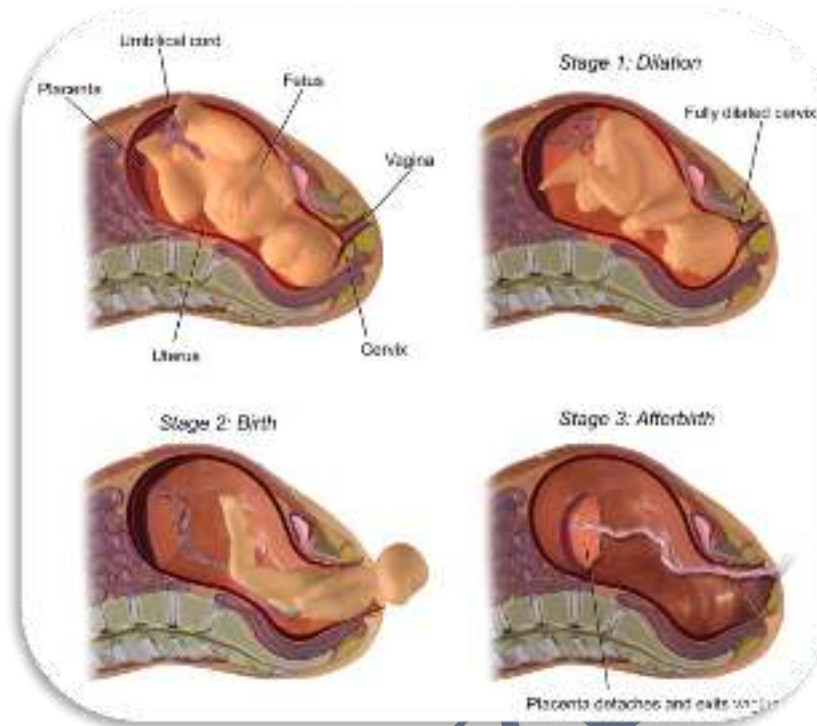


Fig. Stages of birth in human

LESSON 189

MULTIPLE BIRTHS

The organisms which give birth to only one offspring at a time are called **uniparous**. *e.g.*, human, cows, buffalo. Those animals which give birth to more than one young ones are called **multiparous**. *e.g.*, mice, rat, dogs, cats. Usually the young ones are both male and female. However armadillo give birth to four young ones at same time, all males or females.

Monozygotic Twins are from single zygote and are identical twins. They are strikingly alike and of same sex. About 33% have separate placenta. Majority have separate amniotic sac. Small proportion have one placenta and one amniotic sac which indicate separation occur after 9 day of pregnancy. There is conjoining risk, the condition is Siamese twinning.

Dizygotic Twins are produced from two zygotes. They are called as fraternal twins. They do not have striking similarities and may be of same or different sex. They have separate placenta and separate amniotic sac.

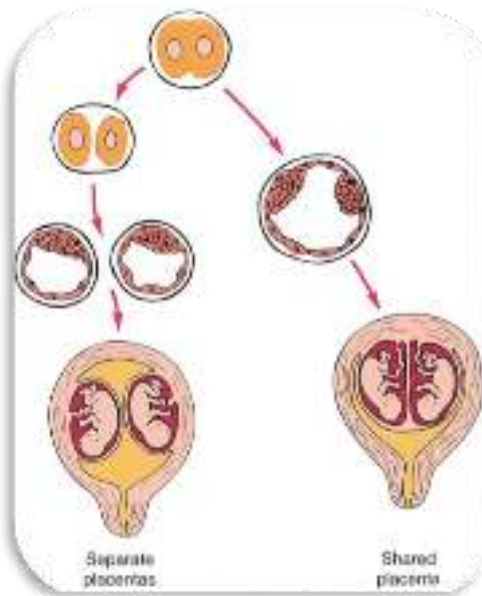


Fig. Monozygotic twins in human

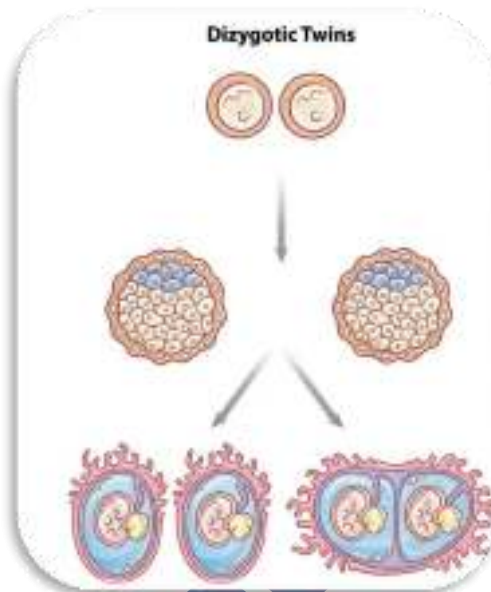


Fig. Dizygotic twins in human

LESSON 190

MILK PRODUCTION AND LACTATION

Mammary glands are unique feature of mammals. They are evolved from sweat glands in the skin. The process of milk production by the mammary glands is called lactation. During pregnancy breasts enlarges due to hormone prolactin. Estrogen and progesterone inhibit the secretion of milk before birth. After birth both decrease and milk production starts. Newborn stimulate pituitary to release oxytocin and prolactin. Prolactin produce milk while oxytocin triggers its release from mammary glands. The higher protein fluid in breast at the time of birth is called **colostrum**. It contains maternal antibodies to boost immune system. Colostrum works as laxative to remove meconium (stool of infant). Mother's breast don't release milk for 1-3 days.

LESSON 191

EXTRAEMBRYONIC MEMBRANES

Extraembryonic membranes are yolk sac, amnion, chorion and allantois. Reptiles, birds and mammals embryos have amnion, chorion and allantois are called amniotes whereas eggs of fishes and amphibians having amnion, chorion and allantois are called anamniotes. Amnion encloses embryo in a fluid filled sac. Protects against shock and desiccation. Chorion is near to shell, mechanical support, highly vascular, gaseous exchange. Allantois is for storage and

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excretion of toxic wastes, also for gaseous exchange. Yolk sac is involved in distribution of nutrients to developing embryo.

Ectoderm and mesoderm on both side of embryo lift off the yolk and grow dorsally, they fuse to form chorion (outer side) and amnion (inner side). A ventral outgrowth of gut tract give rise to allantois. It gradually increase in its size along with development. Yolk sac develops from proliferation of endoderm and mesoderm around yolk.

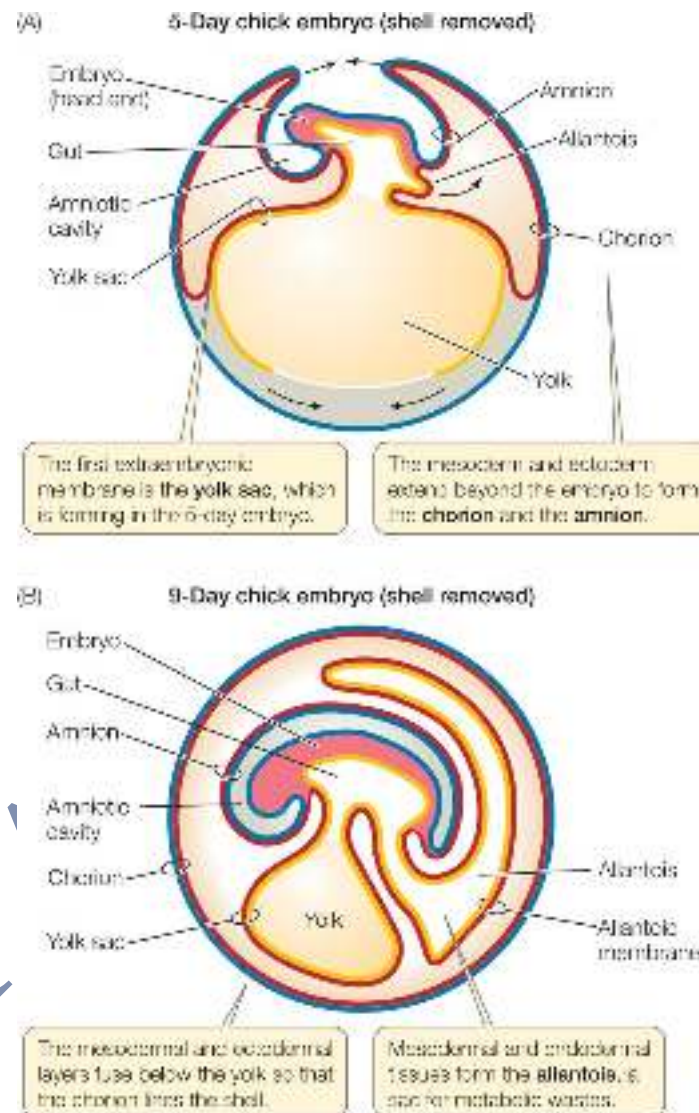


Fig. Development of extra embryonic membranes. (Ref. macmillanhighered.com)

LESSON 192

PRIMARY GERM LAYERS

During gastrulation three germ layers are formed. These are ectoderm, mesoderm and endoderm. These germ layers give rise to different body parts.

Ectoderm: It is the outer most layer of cells formed during gastrulation. Some of the ectodermal cells aligned themselves into a columnar pattern to form **neural plate** which is converted into neural tube. Neural tube will form central nervous system while cells of neural crest will form peripheral nervous system. After neurulation all ectodermal cells form epidermis. Epidermis also give rise to hair, sebaceous glands, sweat glands, nails, claws and hoofs.

LESSON 193

Endoderm is the inner most primary germ layer formed during gastrulation. The entire gastrointestinal tract except mouth, pharynx and anus develop from endoderm. Endoderm also give rise to the lining of all glands which are part of digestive system e.g., liver, gall bladder and pancreas. Endoderm also give rise to respiratory tract, thyroid, parathyroid, thymus, pancreas, auditory tube, tympanic cavity and urinary system.

LESSON 194

Mesoderm is one of the primary germ layer formed during gastrulation. It is present between ectoderm and endoderm. Mesoderm give rise to skeletal system, urinogenital structures, circulatory system, muscular tissues, skin, tendons, ligaments and adipose tissues. Coelom is also formed by out pouching or splitting of mesoderm.

MECHANISM OF DEVELOPMENT

LESSON 195

Nuclear equivalence

In nineteenth century, scientist were working that how developing embryo develop multiple types of cells? Roux-Weismann gave the hypothesis that genome is broken down into smaller and smaller fragment. This is the reason that different cells give rise to different types of cells. In 1892, Hans Driesch Discovered that if two cell stage sea urchin embryo is mechanically shaken to get cells apart, both develop into normal larvae. This shows that both cells contain same genetic material. Hans Spemann placed a minute ligature of hair around salamander zygote. Nucleus containing portion remain dividing while the other didn't. Later at 16 cell stage, one nucleus move to anucleated portion and it also started cell division. When separated both developed into normal embryos. Hans Spemann further concluded that both halves developed

normally only if both receive gray crescent. This means cytoplasmic contents play their role in formation of different types of cells.

LESSON 197

Embryonic Induction

The capacity of some cells to evoke developmental process in others is called embryonic development. It is a widespread phenomenon in development. Spemann and Mangold first reported embryonic induction. When the dorsal lip of blastopore was transplanted to lateral or ventral side of other embryo, it developed notochord, somite, ectoderm of host and formed the whole system. Dorsal lip of blastopore can induce the development of whole embryo, it is called as primary organizer. The phenomenon of induction by blastopore is called primary induction. Formation of other type of cell by inductive process is termed as secondary induction.

LESSON 198-199

PROTOSTOME VS DEUTEROSTOME

Protostomes belong to group protostomia of animal kingdom. They are part of grade bilateria along with deuterostomes. Platyhelminthes, rotifera, nematoda, annelida, arthropoda and Mollusca are the member phyla of protostomes.

Deuterostomes belong to group deuterostomia of animal kingdom. They are part of grade bilateria along with protostomes. Echinodermata, hemichordata and chordata are the member phyla of deuterostomes.

- Both differ in cleavage pattern. In protostomes cleavage is spiral while in deuterostomes cleavage is radial.
- In protostomes cleavage is determinate as the fate of blastomeres is established at very early stage *i.e.*, 2 or 4 cell stage. In deuterostomes cleavage is indeterminate as the fate of blastomeres is established at later stages of development.
- In protostomes blastopore develops into mouth while in deuterostome blastopore develops into anus.
- In protostomes coelom is formed by splitting of mesoderm. This pattern is called schizocoelous while in deuterostome coelom is formed by out pouching of primitive gut (archenteron). This pattern is called enterocoelous.
- Development of many protostomes include a top shape larva called trochophore larva while some deuterostomes have a kidney-bean shaped larva called dipleurula.



LESSON 200

METAMORPHOSIS

Metamorphosis is an abrupt change in structure and function from immature stage to adult. It takes place in insects, mollusks, crustaceans, cnidarians, echinoderms, tunicates, fishes and amphibians. During metamorphosis animals undergo a series of molts to grow, and each stage between molts is called an instar e.g., mosquito larvae have four instars and butterfly larvae have five instars.

Metamorphosis is beneficial for animals because animal uses different types of food at different stages. This reduces the competition between juvenile and adult stages e.g., tadpole of frog is herbivore while adult is insectivore.

The disadvantages of metamorphosis include short life of adult while metamorphosis stages are pretty long. As larva and adult do not share same food, this may be disadvantageous in food poor environment.

Hormonal Control of Metamorphosis: Metamorphosis is controlled by thyroid hormones in vertebrates. In insects prothoracicotropic hormone from insect brain stimulates ecdysone hormone released by prothoracic gland. At larval stage juvenile hormone is also released this results in next larval instar. At final stage of larva, juvenile hormone is not released and ecdysone converts larva into pupa.

Metamorphosis is of two types: complete metamorphosis (holometabolous) and incomplete (hemimetabolous) metamorphosis.

LESSON 201

Holometamorphosis (Complete metamorphosis) occurs in about 88% insects. It is the type of metamorphosis which separates the physiological process of growth from differentiation and sexual stages. There are four stages i.e., egg, larva, pupa and adult stage. Each process is completed without intervention of other stage.

Early embryonic development completed at egg stage. Larval stage is motile and worm like form. Larva actively feed and grow in size. It never possess wings and have simple eyes. Larva undergo metamorphosis to become pupa. It is quiescent, non-feeding and mostly very little motile. During pupa stage, there are drastic changes in morphology and physiology. Adults have

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wings and reproductive organs. Most insects adult grow very little. Some do not feed and entirely focus on mating and reproduction.

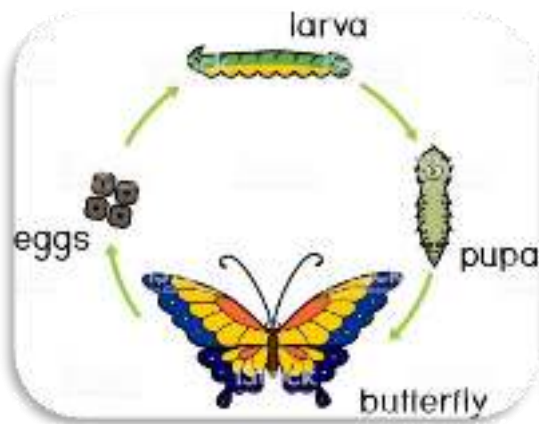


Fig. Complete metamorphosis

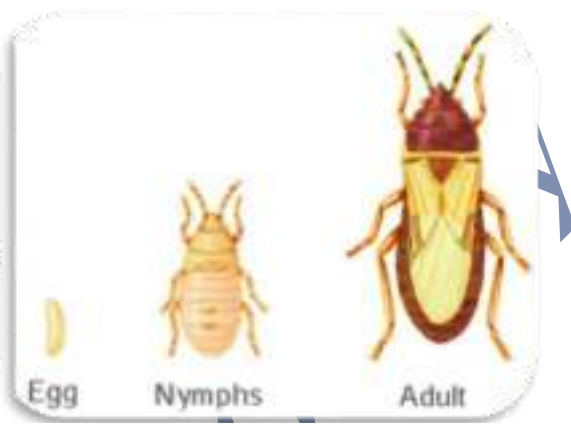


Fig. Incomplete metamorphosis

LESSON 202

Hemimetabolous metamorphosis (Incomplete metamorphosis) is the mode of development of certain insects like aphid, grasshopper and cockroach. They have three distinct stages i.e., egg, nymph and adult.

Initial stages of development are completed at egg stage. Nymph is an immature form hatched out from the eggs. It lacks wings and have underdeveloped reproductive organs. They adult have wings and reproductively mature.