I. ECOLOGY

INTRODUCTION

Ecology is defined as the study of inter relationship and interaction of different organisms with each other and with their environment. It is concerned with the general principles that apply to both animals and plants. The meaning of the word ecology was given by German Biologist Ernst Haeckel in 1869. The word ecology is derived from Greek words 'Oikos' meaning house, habitat or place of living and 'Logos' meaning to study.

OBJECTIVES OF ECOLOGICAL STUDIES

It is important for humanity to understand its environment because we have the ability to modify the environment through the use of technology. Therefore, ecology is more than just the understanding of the interrelationships between organisms and their environment; it also has social, political, economic and technological dimensions. It also is a study of evolutionary development of organisms, the biological productivity and energy flow in the natural system. To develop mathematical models to relate interaction of parameters and to predict the effects.

CLASSIFICATION OF ECOLOGY

Based on study area :

Autecology : It deals with the study of an individual species of organisms and it's population. The ecologists study the behaviour and adaptations of particular species to the environmental condition at every stage of that individual's life cycle. It is also called the Species ecology.

Synecology : It deals with the study of communities, their composition, their behaviour and relation with the environment. It is also called as Ecology of communities.

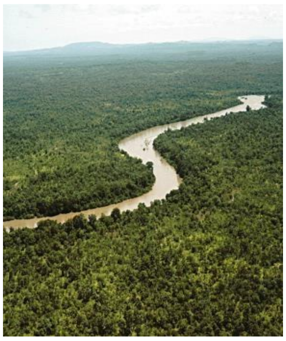
Based on Environment or habitat :

Aquatic ecology : The study of interaction of organisms in the water

Marine water ecology - Ocean, Deep Sea, Estuary

Freshwater Ecology - Letic (Running water) – River, Stream, Spring

Lentic (Standing Water) –Pond, Lake.



Terrestrial Ecology : The study of interaction of organisms on land surfaces divided as grassland ecology, forest ecology & desert ecology.

Based on Advancement in the field of ecology

a. Productive ecology
b. Population ecology
c. Community ecology
d. Ecosystem ecology
e. Microbial ecology
f. Radiation ecology
g. Pollution ecology
h. Space ecology

TYPES OF ECOLOGY LEVELS

Organism Ecology: Organismal ecology is the study of an individual organism's behaviour, morphology, physiology, etc. in response to environmental challenges. Ecologists research how organisms are adapted to these non-living and living components of their surroundings. Individual species are related to various adaptations like physiological adaptation, morphological adaptation, and behavioural adaptation.

Population Ecology:

It deals with factors that alter and impact the genetic composition and the size of the population of same species. Population ecology examines the population distribution and density. Population density is the number of individuals in a given volume or area. This helps in determining whether a particular species is in endanger or its number is to be controlled and resources to be replenished.

Community Ecology :

It deals with how community structure is modified by interactions among living organisms. Ecology community is made up of two or more populations of different species living in a particular geographic area.

Ecosystem Ecology

It deals with the entire ecosystem, including the study of living and non-living components and their relationship with the environment. This science researches how ecosystems work, their interactions, etc.

Landscape Ecology

It deals with the exchange of energy, materials, organisms and other products of ecosystems. Landscape Ecology study the habitat fragmentation (such as deforestation) or the migration of organisms between ecosystems, etc. **Biosphere**

It deals with interactions among earth's ecosystems, land, atmosphere and oceans. It helps to understand the large-scale interactions and their influence on the planet, the role of greenhouse gases, the effects of climate change on ecosystems and organisms, etc.

ECOSYSTEM

INTRODUCTION

Ecosystem is a biological community where the living and non-living components interact with each other as their physical environment. It is the functional unit of nature and varies greatly in size.

Types of Ecosystem 1. Natural ecosystem

a) Aquatic Ecosystem. Eg- Running water, standing water, Marine ecosystem

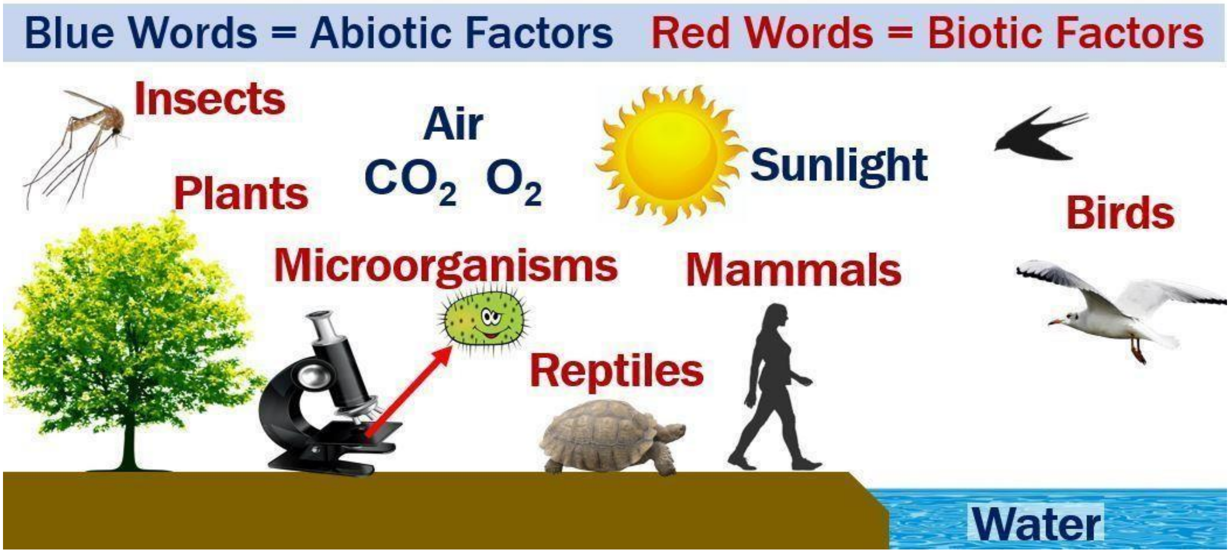
b) Terrestrial Ecosystem. Eg- Grassland, forest, desert ecosystem.

2. **Artificial ecosystem** - Man made ecosystem – operated and maintained by man himself Eg : Cropland, Gardens.

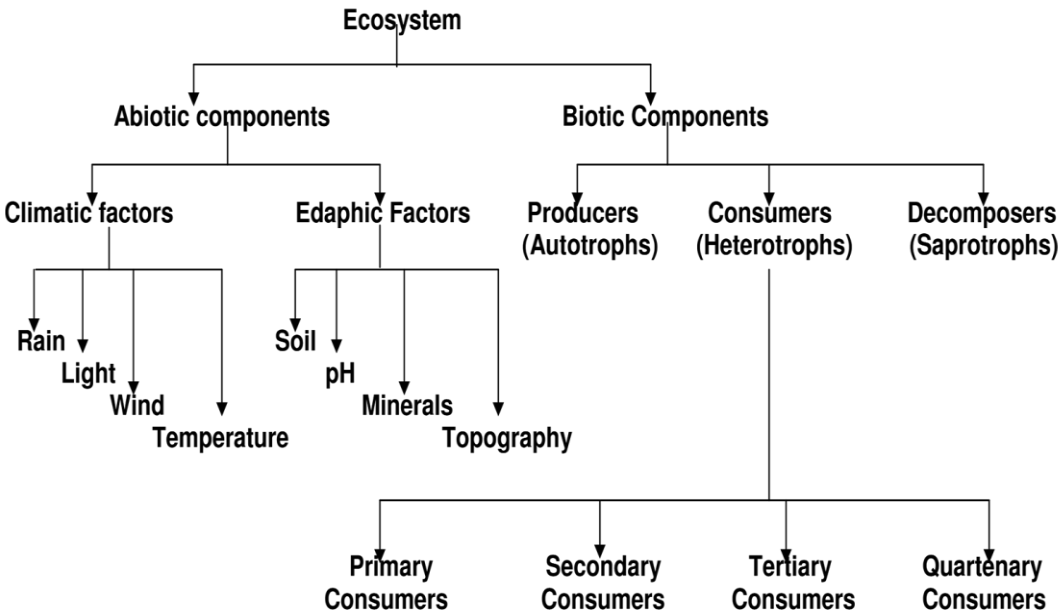
STRUCTURE (or) COMPONENTS OF AN ECOSYSTEM

The structure of an ecosystem explains the relationship between the abiotic (non –living) and the biotic (living) components. An ecosystem has two major components.

- Biotic (living) components.
- Abiotic (non living) components.



COMPONENTS OF ECOSYSTEM



Biotic components

The living organisms (or) living members in an ecosystem collectively form its community called biotic components (or) biotic community. Examples:-Plants (producers),animals (consumers) and micro-organisms (decomposers). The members of biotic components of an ecosystem are grouped in to three, based on how they get food.

- Producer (plants)
- Consumer (Animals)
- Decomposers (Micro-organisms)

Producers (Autotrophs)(self-feeders)

Make their own food from compounds that are obtained from their environment. They are the source of all food in an ecosystem. On land, most producers are green plants. In freshwater and marine ecosystems, algae and plants are the major producers near shorelines. In open water, the dominant producers are phytoplankton (most of them microscopic) that float or drift in the water.

Most producers capture sunlight to make carbohydrates (such as glucose) by photosynthesis. Eg- Photosynthesis The green pigments called chlorophyll, present in the leaves of plants, converts CO_2 and H_2O in the presence of sunlight into carbohydrates.

$6CO_2 + 12H_2O \text{---->} C_6H_{12}O_6 + 6O_2 + 6H_2O$.

Consumers (Heterotrophs) ("other feeders")

Get their energy and nutrients by feeding on other organisms or their remains.

Primary consumers : Are those that eat producers (plants) as a source of food. They are also known as herbivores.

Secondary consumers or carnivores : Eat other animals.

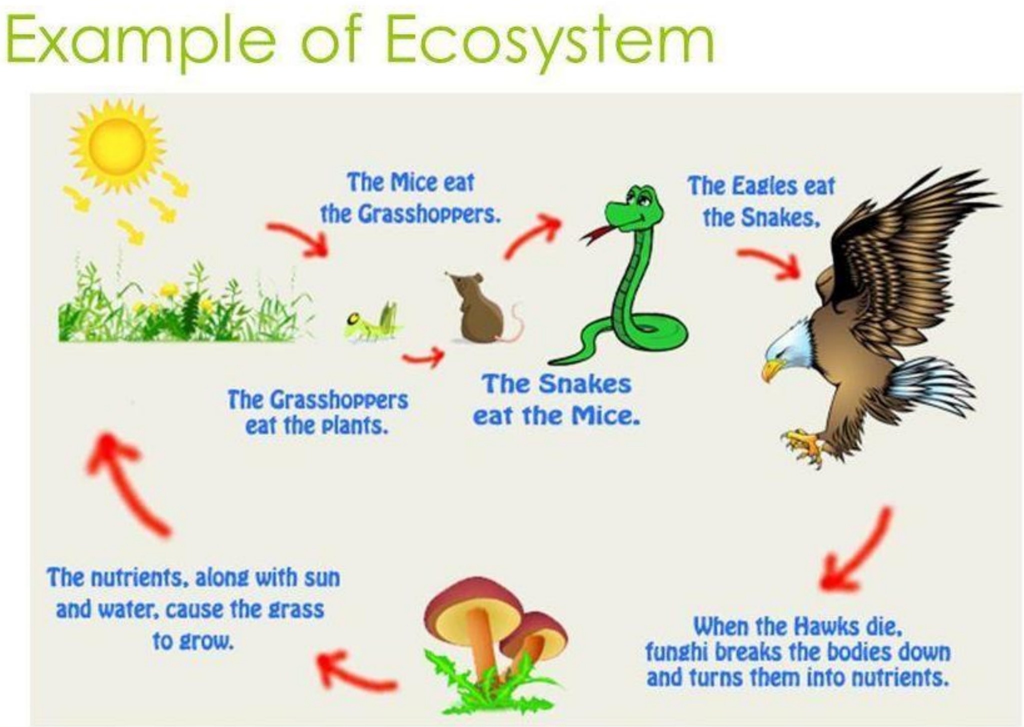
Tertiary Consumers : Large Carnivores which feed on secondary consumers.

Quaternary Consumers : Largest Carnivores that feed on tertiary consumers. They are not eaten by any animals.

Omnivores : Have mixed diet that include both plants and animals.

Decomposer :

Mostly certain types of bacteria and fungi are specialized consumers that recycle organic matter in ecosystems. They do this by breaking down (biodegrading) dead organic material to get nutrients and releasing the resulting simpler inorganic compounds into the soil and water, where they can be taken up as nutrients by producers.



Abiotic components

Consists of Non-living chemical & physical components such as water, air, nutrients in the soil or water & Solar Energy. Physical & chemical factors that influence living organisms in land (terrestrial) ecosystem & aquatic life zones. Abiotic factors can act as limiting factors that keep a population at a certain level.

Abiotic Components are mainly of two types they are Climatic factors and Edaphic factors
Climatic Factors: which include rain, temperature, light, wind, etc.
Edaphic Factors: which include soil, pH, Topography, Minerals, etc.

ECOLOGICAL BALANCE

Introduction

Ecological balance is a term used to describe the equilibrium between living organisms such as human being, plants, and animals as well as their environment. Human being plays a key role to maintain ecological balance because they have the highest thinking capacity as compared to other living organisms. Sufficient food availability to all living organisms and their stability reflect the existence of ecological balance. Therefore, this balance is very important because it ensures survival, existence and stability of the environment. For example, human activities such as farming and resources exploitation are checked to prevent excessive destruction of the forests. Deforestation leads to drought. Drought reduces food production resulting to insufficient food. Insufficient food leads to starvation and later death occurs, hence reducing the existence of some species.

ECOLOGICAL IMBALANCE

Ecological imbalance is when a natural or human-caused disturbance disrupts the natural balance of an ecosystem. A disturbance is any change that causes a disruption in the balance of an ecosystem.

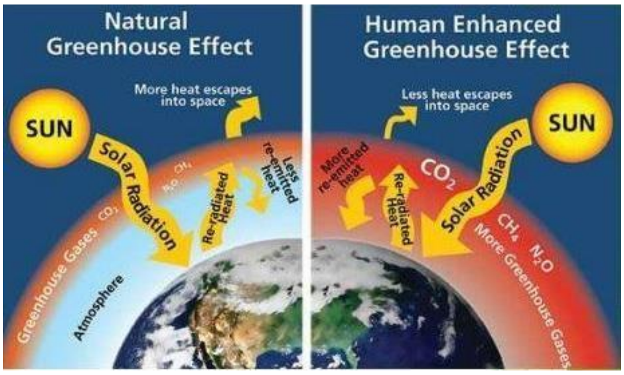
Examples of natural disturbances are volcanic eruptions, floods and natural fires.

Examples of human-caused disturbances are the introduction of a new species against nature logging a forest, pollution and overhunting of a species.

Environmental Issues Related to Ecological Imbalance

Global problems:- These are problems that affect different nations and can only be resolve through solidarity of affected nation. Some global problems are global warming or greenhouse effect, acid rain, pollution (Air and Marine Pollution), depletion of ozone layer in the atmosphere and radioactive fallout because of nuclear war.

National problem:- These are problems that affect a country and can only be resolved within the country. These national environmental issues are pollution (air, water and soil), degradation of natural resources such as soil erosion, deforestation, depletion of wildlife, shortage of energy, degradation of marine ecosystems and depletion of mineral resources and alteration and inconsistent land use like the conversion of agricultural land into industrial estates, conversion of mangrove swamps into fishponds and salt beds. **Greenhouse effect:** When the Sun's energy reaches the Earth's atmosphere, some of it is reflected back to space and the rest is absorbed and re-radiated by greenhouse gases. Greenhouse gases include water vapour, carbon dioxide, methane, nitrous oxide, ozone and some artificial chemicals such as chlorofluorocarbons (CFCs). The problem we now face is that human activities – particularly burning fossil fuels (coal, oil and natural gas), agriculture and land clearing – are increasing the concentrations of greenhouse gases. This is the enhanced greenhouse effect, which is contributing to warming of the Earth.



Acid Rain:

Acid rain refers to rain which is acidic in nature. It is generally complex mixture of $H2$S04 along with $H2$SO3 and HNO3 along with HNO2 .The SO2 and NOX react with water, oxygen and other chemicals to form sulfuric and nitric acids. These then mix with water and other materials before falling to the ground. The major sources of SO2 and NOX in the atmosphere are burning of fossil fuels to generate electricity -Two thirds of SO2 and one fourth of NOX in the atmosphere come from electric power generators, vehicles and heavy equipment, manufacturing, oil refineries and other industries.

Theories of balance Gaia hypothesis

The entire range of living matter on Earth from whales to viruses and from oaks to algae could be regarded as constituting a single living entity capable of maintaining Earth's atmosphere to suit its overall needs and endowed with faculties and powers far beyond those of its constitute parts" . Two ways Gaia accomplishes this include:

1. Allowing evolution so species may meet new environmental changes 2. Ensuring a great diversity of life.

Chaos Hypothesis:

Chaos theory, in mechanics and mathematics, the study of apparently random or unpredictable behavior in systems governed by deterministic laws. Chaotic behavior exists in many natural systems, such as weather and climate. It also occurs spontaneously in some systems with artificial components, such as road traffic.

Maintaining The Ecological Balance

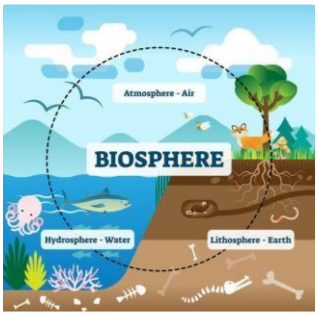
Manage Natural Resources Carefully, Control the Population, Protect the Water, Reduce Logging, Reduce chlorofluorocarbon, Stop open burning.

BIOSPHERE

The biosphere is made up of the parts of Earth where life exists. The biosphere extends from the deepest root systems of trees, to the dark environment of ocean trenches, to lush rain forests and high mountain tops.

The biosphere is made of three parts, called

- Lithosphere - Earth
- Atmosphere - Air
- Hydrosphere - Water



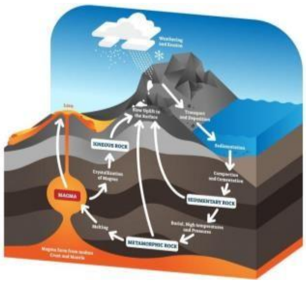
LITHOSPHERE

The lithosphere is the terrestrial part of the biosphere. The deeper parts of the lithosphere, known as the lower mantle and the core, do not support life, other parts of lithosphere supports a variety of life from bacteria to large mammals and trees. The weathering of the lithosphere crust forms soil, which provides minerals and organic waste to support life. This solid, rocky crust is composed of a number of different rocks that have been grouped into three categories are metamorphic rocks, igneous rocks and sedimentary rocks.

Metamorphic rocks – Metamorphic rocks are formed by heat and pressure from pre-existing rocks. **Igneous rocks** – igneous rocks are formed by the cooling of hot molten rock also known as magma. When the hot magma cools it begins to harden meaning once it had fully cooled it create what is known to be an igneous rock

Sedimentary rocks – sedimentary rocks are formed from pre-existing rocks. When rocks erode and mix with other dirt, clay and particles then settle together the mix together to form a sedimentary rock

CYCLE OF ROCK FORMATION



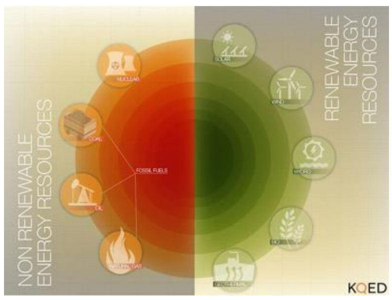
ATMOSPHERE

The atmosphere is the gaseous envelope surrounding a planet. On Earth, it is also called air. The lower regions of the atmosphere contain gases such as oxygen and carbon dioxide that are essential for plant and animal respiration. Birds, insects and other life can be found up to approximately 2,000 meters above the earth's surface. The atmosphere also plays critical roles in shaping the biosphere by deflecting harmful radiation from the sun and determining weather patterns.

HYDROSPHERE

The hydrosphere is the aquatic part of the biosphere. This includes oceans, rivers, lakes and other bodies of water. The hydrosphere is always in motion as seen through the movement and flow of water in rivers, streams and the ocean. Plant and animal organisms rely on the hydrosphere for their survival as water is essential. The hydrosphere is also home to many plants and animals and it believed that the hydrosphere covers approximately 71% of the earth's surface. The hydrosphere also plays an important part in atmosphere formation. The frozen part of Earth's hydrosphere is made of ice: glaciers, ice caps and icebergs. The frozen part of the hydrosphere has its own name, the cryosphere.

RENEWABLE ENERGY NON RENEWABLE ENERGY

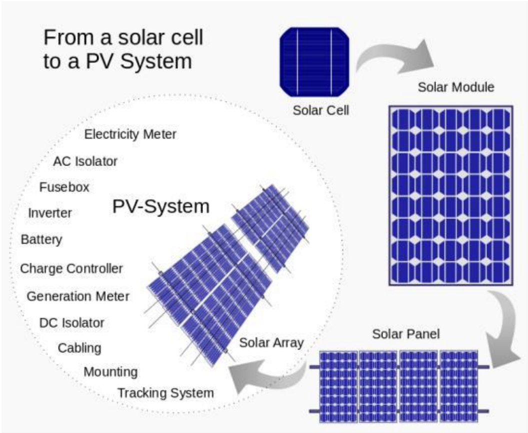


RENEWABLE ENERGY

Renewable energy, often referred to as clean energy, comes from natural sources or processes that are constantly replenished. The five major renewable energy resources are solar, wind ,water, also called hydro, biomass, or organic material from plants and animals geothermal, which is naturally occurring heat from the earth.

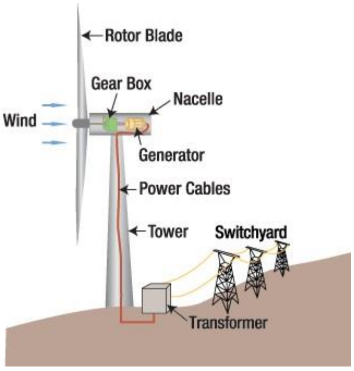
SOLAR ENERGY

Sunlight is one of our planet's most abundant and freely available energy resources. The amount of solar energy that reaches the earth's surface in one hour is more than the planet's total energy requirements for a whole year**.**



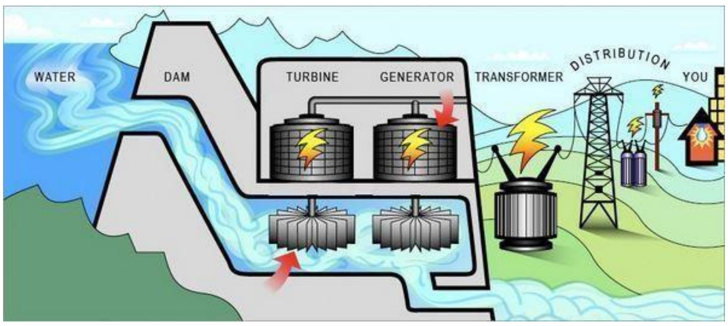
The term solar panel is used for a photo-voltaic (PV) module. A PV module is an assembly of photovoltaic cells mounted in a framework for installation. Photo-voltaic cells use sunlight as a source of energy and generate direct current electricity. A collection of PV modules is called a PV Panel, and a system of Panels is an Array. Arrays of a photovoltaic system supply solar electricity .

WIND ENERGY



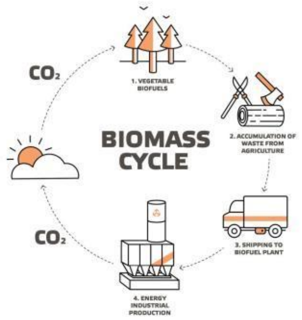
Wind is a plentiful source of clean energy. Wind energy generates electricity by turning wind turbines. The wind pushes the turbine's blades, and a generator converts this mechanical energy into electricity. This electricity can supply power to homes and other buildings, and it can even be stored in the power grid.

HYDRO ENERGY



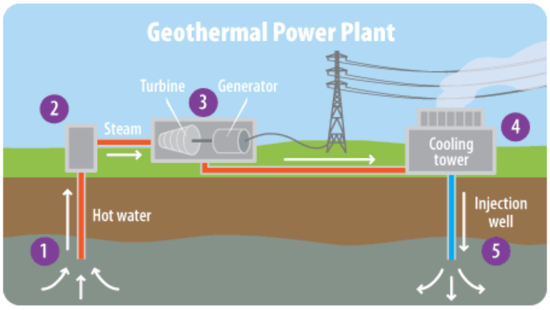
As a renewable energy resource, hydro power is one of the most commercially developed. By building a dam or barrier, a large reservoir can be used to create a controlled flow of water that will drive a turbine, generating electricity. This energy source can often be more reliable than solar or wind power and also allows electricity to be stored for use when demand reaches a peak.

BIOMASS ENERGY



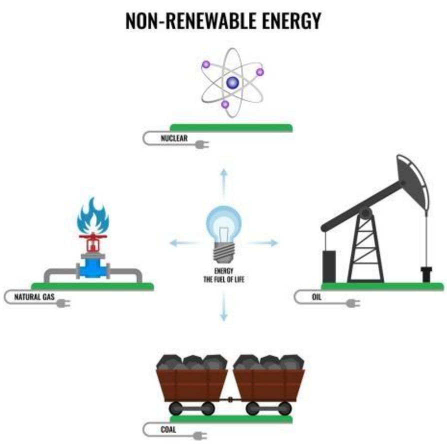
Biomass energy is the conversion of solid fuel made from plant materials into electricity. Although fundamentally, biomass involves burning organic materials to produce electricity, and nowadays this is a much cleaner, more energy-efficient process. By converting agricultural, industrial and domestic waste into solid, liquid and gas fuel, biomass generates power at a much lower economic and environmental cost.

GEOTHERMAL ENERGY



Geothermal energy comes from the heat generated deep within the Earth's core. Geothermal reservoirs can be found at tectonic plate boundaries near volcanic activity or deep underground. Geothermal energy can be harnessed by drilling wells to pump hot water or steam to a power plant. This energy is then used for heating and electricity.

NON RENEWABLE ENERGY



Non-renewable energy resources are available in limited supplies, usually because they take a long time to replenish. The advantage of these non-renewable resources is that power plants that use them are able to produce more power on demand. The non-renewable energy resources are coal , nuclear , oil and natural gas. Fossil fuels were formed within the Earth from dead plants and animals over millions of years. They are found in underground layers of rock and sediment. Pressure and heat worked together to transform the plant and animal remains into crude oil, coal, and natural gas. The energy in the plant and animal remains originally came from the sun; through the process of photosynthesis, solar energy is stored in plant tissues, which animals then consume, adding the energy to their own bodies. When fossil fuels are burned, this trapped energy is released. Crude oil is a liquid fuel fossil fuel that is used mostly to produce gasoline and diesel fuel for vehicles, and for the manufacturing of plastics. It is found in rocks below Earth's surface and is pumped out through wells.

Natural gas is widely used for cooking and for heating homes. It consists mostly of methane and is found near oil deposits below Earth's surface. Natural gas can be pumped out through the same wells used for extracting crude oil. Coal is a solid fossil fuel that is used for heating homes and generating power plants. It is found in fossilized swamps that have been buried beneath layers of sediment. Since coal is solid, it cannot be extracted in the same manner as crude oil or natural gas; it must be dug up from the ground. Nuclear energy comes from radioactive elements, mainly uranium, which is extracted from mined ore and then refined into fuel. Unfortunately, human society is for the time being dependent on non-renewable resources as primary source of energy. Approximately 80 percent of the total amount of energy used globally each year comes from fossil fuels.

ELEMENTS OF ENVIROMENTAL PLANNING

Environmental planning concerns itself with the decision making process where they are required for managing relationships that exist within and between natural systems and human systems. Environmental planning endeavours to manage these processes in an effective, orderly, transparent and equitable manner for the benefit of all constituents within such systems for the present and for the future. Some of the main elements of present day environmental planning are socio-economic development, urban development, regional development, natural resources management and governance frameworks.

Socio-economic development is the process of social and economic development in a society. Socioeconomic development is measured with indicators, such as GDP, life expectancy, literacy and levels of employment. Changes in less-tangible factors are also considered, such as personal dignity, freedom of association, personal safety and freedom from fear of physical harm, and the extent of participation in civil society.

Urban planning is a technical and political process concerned with the use of land and design of the urban environment, including air, water, and the infrastructure passing into and out of urban areas such as transportation and distribution networks.

Urban Planning is also referred to as urban, regional, town, city, rural planning. Urban planning guides and ensures the orderly development of settlements and satellite communities which commute into and out of urban areas or share resources with it. It concerns itself with research and analysis, strategic thinking, architecture, urban design, public consultation, policy recommendations, implementation and management. Urban

Planners work with the cognate fields of Architecture, Landscape Architecture, Civil Engineering, and City Administration to achieve strategic, policy and sustainability goals.

Regional development is the provision of aid and other assistance to regions which are less economically developed. Regional development may be domestic or international in nature. The implications and scope of regional development may therefore vary in accordance with the definition of a region, and how the region and its boundaries are perceived internally and externally.

Natural resource management refers to the management of natural resources such as land, water, soil, plants and animals, with a particular focus on how management affects the quality of life for both present and future generations. Natural resource management deals with managing the way in which people and natural landscapes interact. It brings together land use planning, water management, biodiversity conservation, and the future sustainability of industries like agriculture, mining, tourism, fisheries and forestry. Natural resource management specifically focuses on a scientific and technical understanding of resources and ecology and the life-supporting capacity of those resources.

Governance frameworks - Environmental governance refers to the processes of decision-making involved in the control and management of the environment and natural resources. International Union for Conservation of Nature (IUCN), define environmental governance as the 'multi-level interactions i.e., local, national, international/global. Interest in environmental governance has led to research at all scales from the local to the global and focused on issues such as resource scarcity and conflicts, allocation and access, and biodiversity conservation in forest, agricultural, freshwater, marine, and even atmospheric systems.

AREAS OF ENVIROMENTAL PLANNING ASSESSMENT

The environmental planning assessments encompass areas such as

- Land use,
- transportation,
- economic and housing characteristics,
- air pollution,
- noise pollution,
- the wetlands,
- habitat of the endangered species,
- flood zones susceptibility,
- coastal zones erosion,
- visual studies among others, and is referred to as an Integrated environmental planning assessment. It is the ability to analyze environmental issues that will facilitate critical decision making.

MAIN SPHERS OF ENVIROMENTAL PLANNING

The primary concern of environmental planning is expressed in the assessment of three spheres of environmental impact by human economic activity and technological output.

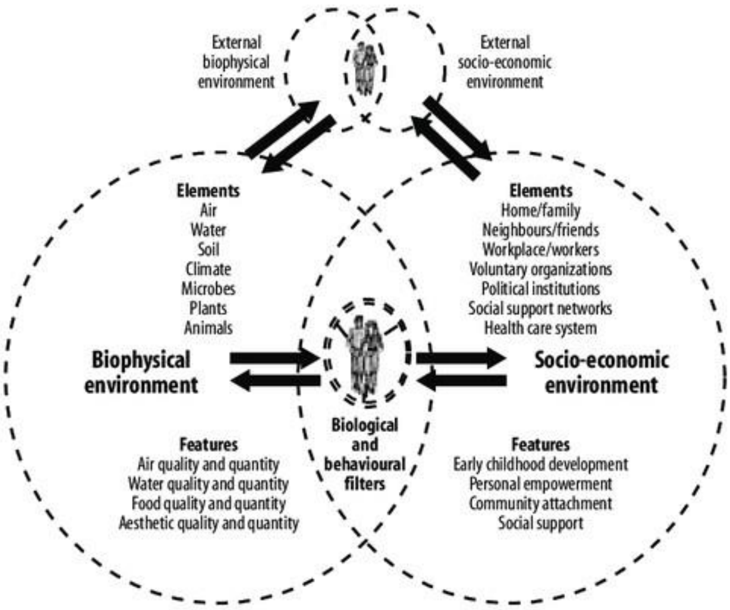
1. Bio-physical environement.
2. Socio-economic environment.
3. Built environment.

Bio-physical environement.

Biophysical environment comprising the earth life support system – air minerals , soil and water- and the biodiversity which these sustain. The biophysical environment is the biotic and abiotic surrounding of an organism or population, and consequently includes the factors that have an influence in their survival, development and evolution. The biophysical environment can vary in scale from microscopic to global in extent. It can also be subdivided according to its attributes.

Socio-economic environment.

Socio-economic environment composed of human social groupings, their cultural activities and the economic process of which they are interrelated.



Built environment- The term built environment, refers to the human-made environment that provides the setting for human activity, ranging in scale from buildings and parks or green space to neighbourhoods and cities that can often include their supporting infrastructure, such as water supply, or energy networks. The built environment is a material, spatial and cultural product of human labor that combines physical elements and energy in forms for living, working and playing. It has been defined as “the human-made space in which people live, work, and recreate on a day-today basis”. The “built environment encompasses places and spaces created or modified by people including buildings, parks, and transportation systems”.

NATURAL RESOURCES

Natural resources are resources that exist without any actions of humankind. This includes all valued characteristics such as commercial and industrial use, aesthetic value, scientific interest and cultural value. Major Natural Resources are

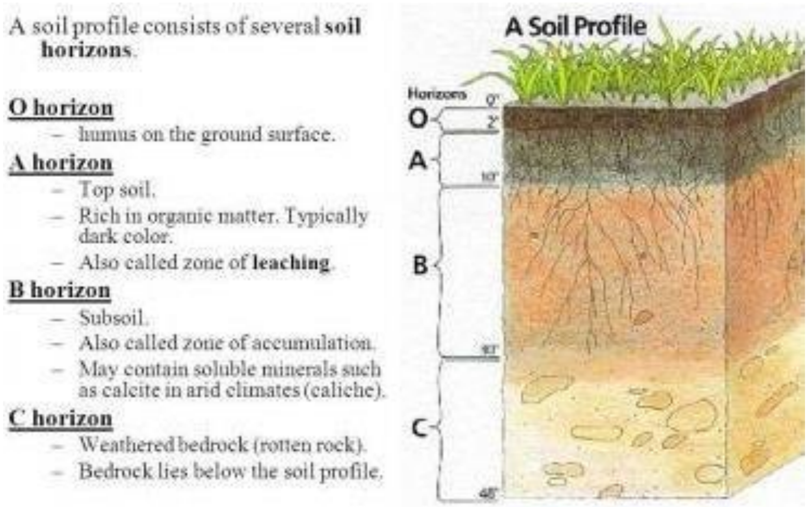
- Land
- Soil
- Water
- Natural Vegetation

Land

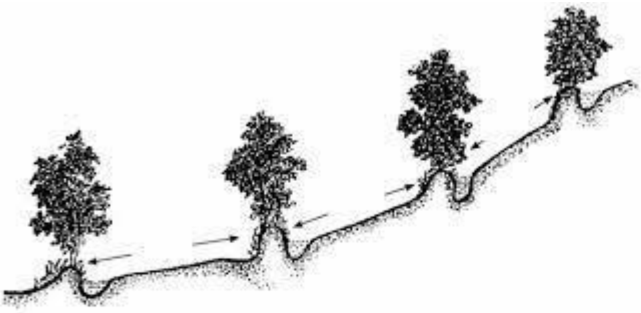
Land is the most important natural resources. It covers only about thirty per cent of the total area of the earth's surface. The supporter of natural vegetation, wildlife, human life, economic activities, transport and communication systems. Land is used for different purposes such as agriculture, forestry, mining, building houses, roads and setting up of industries.

The use of land is determined by physical factors such as topography, soil, climate, minerals and availability of water. Human factors such as population and technology are also important determinants of land use pattern. **Soil**

Soil The thin layer of grainy substance covering the surface of the earth is called soil. It is closely linked to land. Landforms determine the type of soil. Soil is made up of organic matter, minerals and weathered rocks found on the earth. This happens through the process of weathering. The right mix of minerals and organic matter make the soil fertile.



Factors which lead to soil degradation are deforestation, overgrazing, overuse of chemical fertilisers or pesticides, rain wash, landslides and floods. Some methods of soil conservation are listed below are



Mulching: The bare ground between plants is covered with a layer of organic matter like straw. It helps to retain soil moisture.

Contour barriers: Stones, grass, soil are used to build barriers along contours. Trenches are made in front of the barriers to collect water.

Rock dam: Rocks are piled up to slow down the flow of water. This prevents gullies and further soil loss.

Terrace farming: Broad flat steps or terraces are made on the steep slopes so that flat surfaces are available to grow crops. They reduce surface runoff and soil erosion .

Intercropping: Different crops are grown in alternate rows and are sown at different times to protect the soil from rain wash.

Contour ploughing: Ploughing parallel to the contours of a hill slope to form a natural barrier for water to flow down the slope.

Shelter belts: In the coastal and dry regions, rows of trees are planted to check the wind movement to protect soil cover.

Water

Water About 97% of the earth's water supply is in the ocean. Due to high salt content, it is unfit for human consumption as well as other activities. Out of the remaining 3 percent, 2.3 percent is locked in polar ice caps. Subsequently, balance 0.7 percent is available as freshwater of which 0.66 percent is groundwater. Thus leaving a mere 0.03 percent available to us as freshwater in rivers, lakes, and streams. Therefore despite the earth's surface being covered with water, a very small percentage is usable. Thus there is a need for conservation of water.

Forest and other vegetation cover slow the surface runoff and replenish underground water. Water harvesting is another method to save surface runoff. The canals used for irrigating field should be properly lined to minimise losses by water seepage. Sprinklers effectively irrigate the area by checking water losses through seepage and evaporation. In dry regions with high rates of evaporation, drip or trickle irrigation is very useful. The valuable water resource can therefore be conserved by adopting these means of irrigation.

Natural vegetation

Natural vegetation refers to a plant community which has grown naturally without human aid as well as has been left undisturbed by humans for a long time. The following major categories of forests.

Tropical Evergreen Rain Forests - precipitation is more than 200 cm, Arunachal Pradesh, Meghalaya, Assam, Nagaland, the Western Ghats

Deciduous or Monsoon Type of Forests - The precipitation in this area is between 100 cm and 200 cm, lower slope of the Himalayas, West Bengal, Chhattisgarh, Bihar, Orissa, Karnataka, Maharashtra Jharkhand

Dry Deciduous Forests - precipitation is between 50 cm and 100 cm, Central Deccan plateau,

Punjab, Haryana, parts of Uttar Pradesh, Madhya Pradesh, and South-east of Rajasthan

Mountain Forests - slopes of the mountain

Tidal or Mangrove Forests - Forests grow by the side of the coast and on the edges of the deltas **Semi-Desert and Desert Vegetation's -** receives rainfall of less than 50 cm, Gujarat's, Punjab, and Rajasthan.

BLOCK-1 CELL BIOLOGY

UNIT-1THE CELL

1.2 INTRODUCTION

The basic structural and functional unit of cellular organization is the *cell*. Within a selective and relative semi permeable membrane, it contains a complete set of different kinds of units necessary to permit its own growth and reproduction from simple nutrients. All organisms, more complex than viruses, consist of cells, yet they consist of a strand of nucleic acid, either DNA or RNA, surrounded by a protective protein coat (the capsid). The word cell is derived from the Latin word *cellula*, which means small compartment. Hooke published his findings in his famous work, *Micrographia*. Actually, he only observed cell walls because cork cells are dead and without cytoplasmic contents. A.G. Loewy and P. Siekevitz have defined cell as —*A unit of biological activity delimited by a semi permeable membrane and capable of self reproduction in a medium free of other living organisms*‖. John Paul has defined the cell as —The simplest integrated organization in living systems, capable of independent survival‖.

On the basis of internal organization and architecture, all cells can be subdivided into two major classes, prokaryotic cells and eukaryotic cells. Cells which have the unit membrane bound nuclei are called eukaryotic, whereas cells that lack a membrane bound nucleus are prokaryotic. Besides the nucleus, the eukaryotic cells have other membrane bound organelles (small organs) like the Endoplasmic reticulum, Golgi complex, Lysosomes, Mitochondria, Microbodies and Vacuoles. The prokaryotic cells lack such unit membrane bound organelles.

1.3 HISTORICAL BACKGROUND

Ancient Greek philosophers such as Aristotle 384-322 B.C and Paracelsus concluded that *—All animals and plants, however, complicated, are constituted of a few elements which are repeated in each of them‖*. They were referring to macroscopic structures of an organism such as roots, leaves and flowers common to different plants, or segments and organs that are repeated in the animal kingdom. Many centuries later, owing to the invention of magnifying lenses, the world of microscopic dimensions was discovered. Da Vinci (1485) recommended the uses of lenses in viewing small objects. In 1558, Swiss biologist, Conard Gesner (1516-1565) published results on his studies on the structure of a group of protists called foraminifera. His sketches of these protozoa included so many details that they could only have been made if he had used form of magnifying lenses. Perhaps, this is earliest recorded use of a magnifying instrument in a biological study.

Further growth and development of cell biology are intimately associated with the development of optical lenses and to the combination of these lenses in the construction of the compound microscope. Thus, the invention of the microscope and its gradual improvement went hand-in-hand with the development of cell biology.

Growth of Cell Biology during 16th and 18th Centuries

The first useful compound microscope was invented in 1590 by Francis Janssen and Zacharias Janssen. Their microscope had two lenses and total magnifying power between 10X and 30X.

Such types of microscopes were called —flea glasses", since they were primarily used to examine small whole organisms such as fleas and other insects. In 1610, an Italian Galileo Galilei (15641642) invented a simple microscope having only one magnifying lens. This microscope was used to study the arrangement of the facets in compound eye of insects.

The Italian microanatomist Marcello Malpighi (1628-1694) was among the first to use a microscope to examine and describe thin slices of animal tissues from such organs as the brain, liver, kidney, spleen, lungs and tongue. He also studied plant tissues and suggested that they were composed of structural units that he called —utricles‖. An English microscopist Robert Hooke (1635-1703) is credited with coining the term cell in 1665. He examined a thin slice cut from a piece of dried cork under the compound microscopes which were built by him.

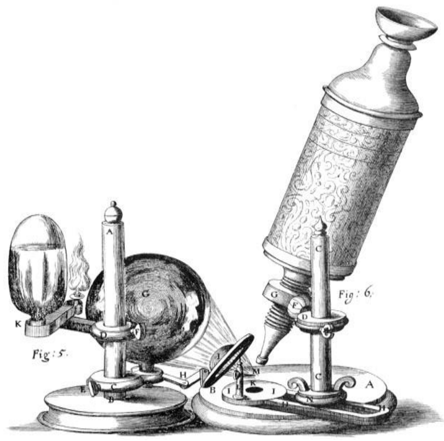


Fig. 1.1: Hooke's compound microscope

1.4 CELL THEORY

In biology, cell theory is a scientific theory which describes the properties of cells. These cells are the basic unit of structure in all organisms and also the basic unit of reproduction. With continual improvements made to microscopes over time, magnification technology advanced enough to discover cells in the 17th century. This discovery is largely attributed to Robert Hooke, and began the scientific study of cells, also known as cell biology. Over a century later, many debates about cells began amongst scientists. Most of these debates involved the nature of cellular regeneration, and the idea of cells as a fundamental unit of life.

Fig.1.2 Mathias Jakob Schleiden (1804–1881) **Fig.1.3 Theodor Schwann (1810–1882)**

Matthias Jakob Schleiden (5 April 1804 – 23 June 1881) was a German botanist and cofounder of cell theory, along with Theodor Schwann (7 December 1810 – 11 January 1882) a German physiologist and Rudolf Ludwig Carl Virchow (13 October 1821 – 5 September 1902) was a German physician, anthropologist, pathologist, prehistorian, biologist, writer, editor, and politician, known for his advancement of public health. Credit for developing cell theory is usually given to these scientists- Schleiden and Schwann. While Rudolf Virchow contributed to the theory, he is not as credited for his attributions toward it. In 1838, Schleiden suggested that every structural part of a plant was made up of cells or the result of cells. He also suggested that cells were made by a crystallization process either within other cells or from the outside. However, this was not an original idea of Schlieden. He claimed this theory as his own, though Barthelemy Dumortier had stated it years before him. This crystallization process is no longer accepted with modern cell theory. In 1839, Theodor Schwann states that along with plants, animals are composed of cells or the product of cells in their structures. This was a major advancement in the field of biology since little was known about animal structure up to this point compared to plants. From these conclusions about plants and animals, two of the three tenets of cell theory were postulated.

1. All living organisms are composed of one or more cells.
2. The cell is the most basic unit of life.

Schleiden's theory of free cell formation through crystallization was refuted in the 1850s by
Robert Remak, Rudolf Virchow, and Albert Kolliker. Robert Remak (26 July 1815 – 29 August 1865) was a Jewish Polish-German embryologist, physiologist, and neurologist, born in Posen, Prussia, who discovered that the origin of cells was by the division of pre-existing cells. In 1855, Rudolf Virchow added the third tenet to cell theory. In Latin, this tenet states "*Omnis cellula e cellula*". This translated to-

3. All cells arise only from pre-existing cells.

However, the idea that all cells come from pre-existing cells had in fact already been proposed by Robert Remak; it has been suggested that Virchow plagiarized Remak and did not give him credit. Remak published observations in 1852 on cell division, claiming Schleiden and Schawnn were incorrect about generation schemes. He instead said that binary fission, which was first introduced by Dumortier, was how reproduction of new animal cells was made. Once this tenet was added, the classical cell theory was complete. Barthélemy Charles Joseph Dumortier (3 April 1797 in Tournai – 9 June 1878) was a Belgian who conducted a parallel career of botanist and Member of Parliament.

Modern Interpretation

The generally accepted parts of modern cell theory include:

1- All known living things are made up of one or more cells.
2- All living cells arise from pre-existing cells by division.
3- The cell is the fundamental unit of structure and function in all living organisms.
4- The activity of an organism depends on the total activity of independent cells.
5- Energy flow (metabolism and biochemistry) occurs within cells.
6- Cells contain DNA which is found specifically in the chromosome and RNA found in the cell nucleus and cytoplasm.
7-All cells are basically the same in chemical composition in organisms of similar species.

The modern version of the cell theory:
The modern version of the cell theory includes the ideas that:
1- Energy flow occurs within cells.
2- Heredity information (DNA) is passed on from cell to cell.
3- All cells have the same basic chemical composition.

1.5 SIZE AND STRUCTURE OF CELL

There are many cells in an individual, which performs several functions throughout the life. The different types of cell include- prokaryotic cell, plant and animal cell. The size and the shape of the cell range from millimeter to microns, which are generally based on the type of function that it performs. A cell generally varies in their shapes. A few cells are in spherical, rod, flat, concave, curved, rectangular, oval and etc. These cells can only be seen under microscope.

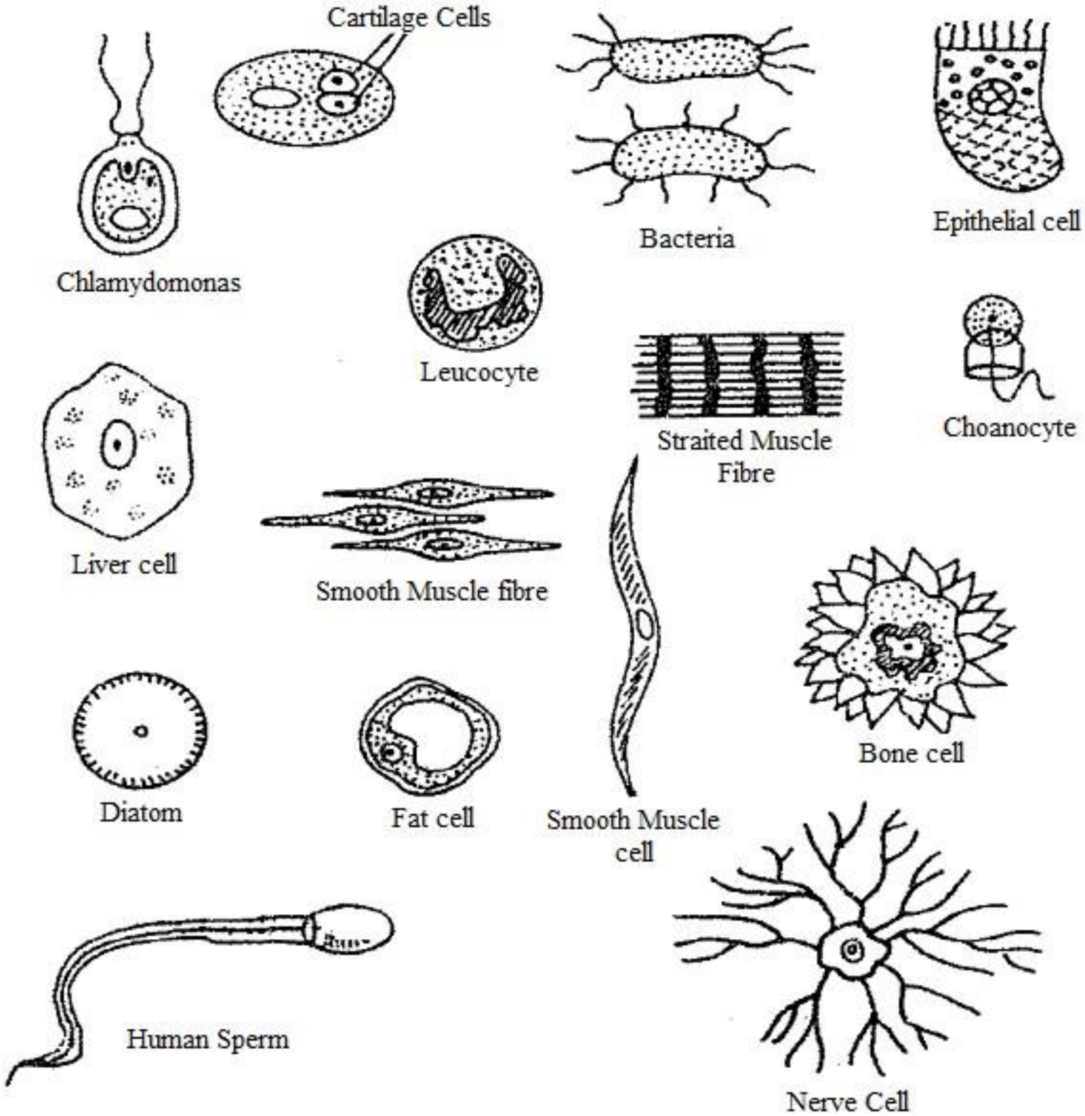


Fig. 1.4 Different types of cells

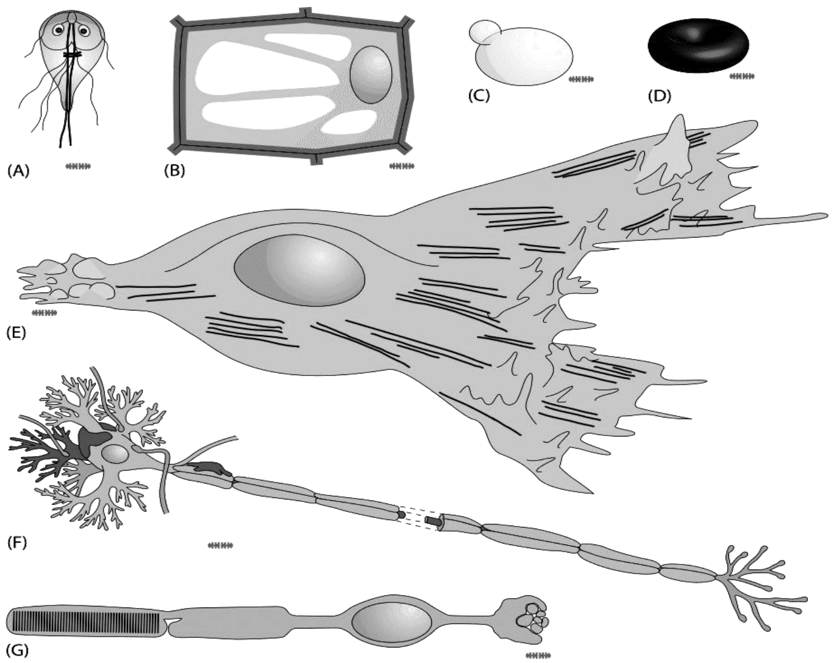


Fig.1.5 : Several different types of cells all referenced to a standard E. coli ruler of 1 micron (A) The protist *Giardia lamblia*, (B) a plant cell, (C) a budding yeast cell, (D) a red blood cell, (E) a fibroblast cell, (F) a eukaryotic nerve cell, and (G) a rod cell from the retina.

Cell Size

One may wonder why all cells are so small. If being able to store nutrients, is beneficial to the cell, how come there are no animals existing in nature with huge cells? Physical limitations prevent this from occurring. A cell must be able to diffuse gases and nutrients in and out of the cell. A cell's surface area does not increase as quickly as its volume, and as a result a large cell may require more input of a substance or output of a substance than it is reasonably able to perform. Worse, the distance between two points within the cell can be large enough that regions of the cell would have trouble communicating, and it takes a relatively long time for substances to travel across the cell.

That is not to say large cells don't exist. They are, once again, less efficient at exchanging materials within themselves and with their environment, but they are still functional. These cells typically have more than one copy of their genetic information, so they can manufacture proteins locally within different parts of the cell. Features of such large cells are following:

1. Is limited by need for regions of cell to communicate
2. Diffuse oxygen and other gases
3. Transport of mRNA and proteins
4. Surface area to volume ratio limited

Larger cells typically:

a) Have extra copies of genetic information

b) Have slower communication between parts of cell

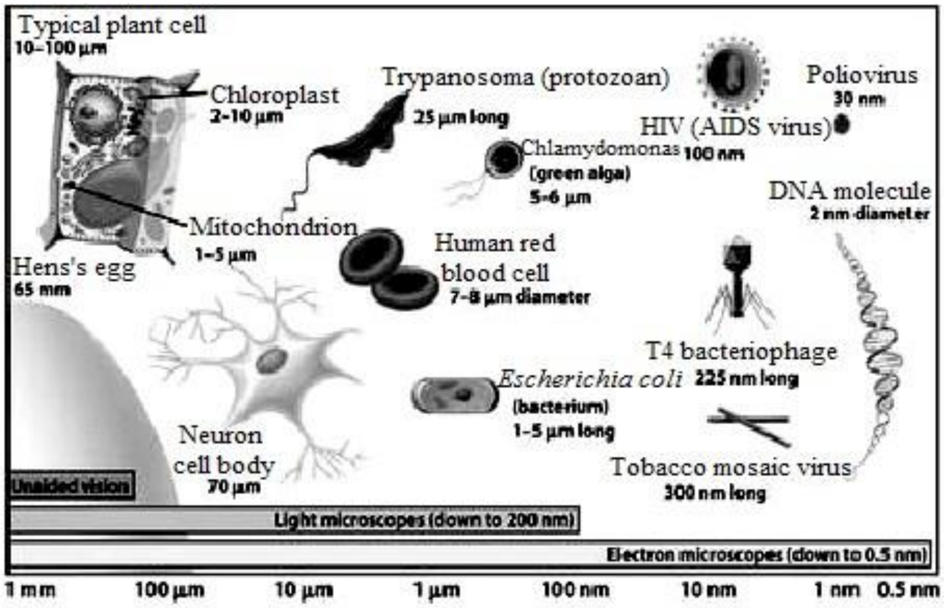


Fig. 1.6- Various types of cells ranging in different sizes

The shapes of cells are quite varied with some, such as neurons, being longer than they are wide and others, such as parenchyma (a common type of plant cell) and erythrocytes (red blood cells) being equidimensional. Some cells are encased in a rigid wall, which constrains their shape, while others have a flexible cell membrane (and no rigid cell wall).

The size of cells is also related to their functions. Eggs (or to use the Latin word, ova) are very large, often being the largest cells an organism produces. The large size of many eggs is related to the process of development that occurs after the egg is fertilized, when the contents of the egg (now termed a zygote) are used in a rapid series of cellular divisions, each requiring tremendous amounts of energy that is available in the zygote cells. Later in life the energy must be acquired, but at first a sort of inheritance/trust fund of energy is used. Cells range in size from small bacteria to large, unfertilized eggs laid by birds and dinosaurs. Here are some measurements and conversions that will aid your understanding of biology.

1 meter = 100 cm = 1,000 mm = 1,000,000 µm = 1,000,000,000 nm
1 centimeter (cm) = 1/100 meter = 10 mm
1 millimeter (mm) = 1/1000 meter = 1/10 cm
1 micrometer (µm) = 1/1,000,000 meter = 1/10,000 cm
1 nanometer (nm) = 1/1,000,000,000 meter = 1/10,000,000 cm

1.6 PROKARYOTIC AND EUKARYOTIC CELL

Body of all living organisms except virus has cellular organization and may contain one or many cells. The organisms with only one cell in their body are known as unicellular (bacteria, protozoa etc.) and organisms with many cells in their body are known as multicellular organisms (most plants and animals). Any cellular organization may contain only one type of cell from the following types:

A- Prokaryotic cell

B- Eukaryotic cell

These terms were suggested by Hans Ris in the 1960‘s.

A: PROKARYOTIC CELL

The prokaryotic (Gr., *pro*= primitive or before and *karyon* = nucleus) are small, simple, and most primitive. They are probably first to come into existence perhaps 3.5 billion years ago. These cells occur in bacteria (i.e., Mycoplasma, Cyanobacteria etc). Prokaryotic cell is a one envelope system organized in depth. It consists of central nuclear components surrounded by cytoplasmic ground substance, with whole enveloped by a plasma membrane. The cytoplasm of prokaryotic cell lacks nuclear envelope and any other cytoplasmic membrane and well defined cytoplasmic organelles.

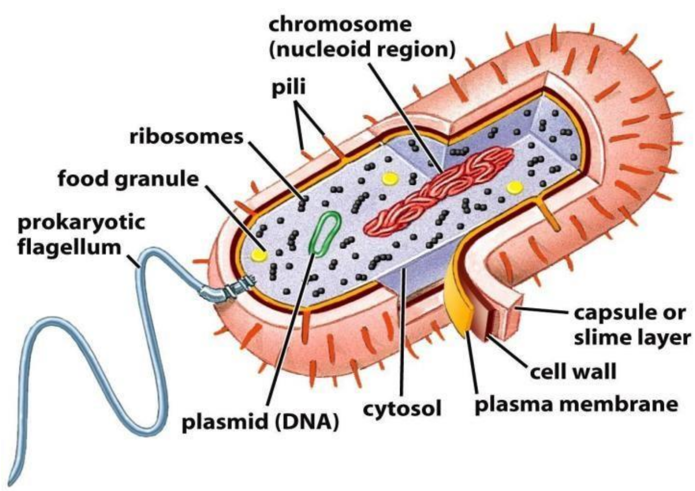


Fig.1.7- Structure of a prokaryotic cell

Bacteria

The bacteria are amongst smallest organisms, most primitive, prokaryotic and microscopic organisms. They occur almost everywhere; in air, water, soil and inside other organisms. They lead either autotrophic or heterotrophic mode of existence.

1. **Size of Bacteria:** It ranges between 1-3µm and are barely visible under light microscope.

2. **Shape of Bacteria:** The three basic bacterial shapes are:

Cocci – (spherical shaped). e.g., *Diplococcus pneumonia, Streptococcus pyogenes* etc.

Bacilli – (rod-shaped) e.g. *Mycobacterium, Clostridium botylinum* etc.

Spirilla (spiral or twisted) e.g. *Treponema pallidum* etc However pleomorphic bacteria can assume several shapes.

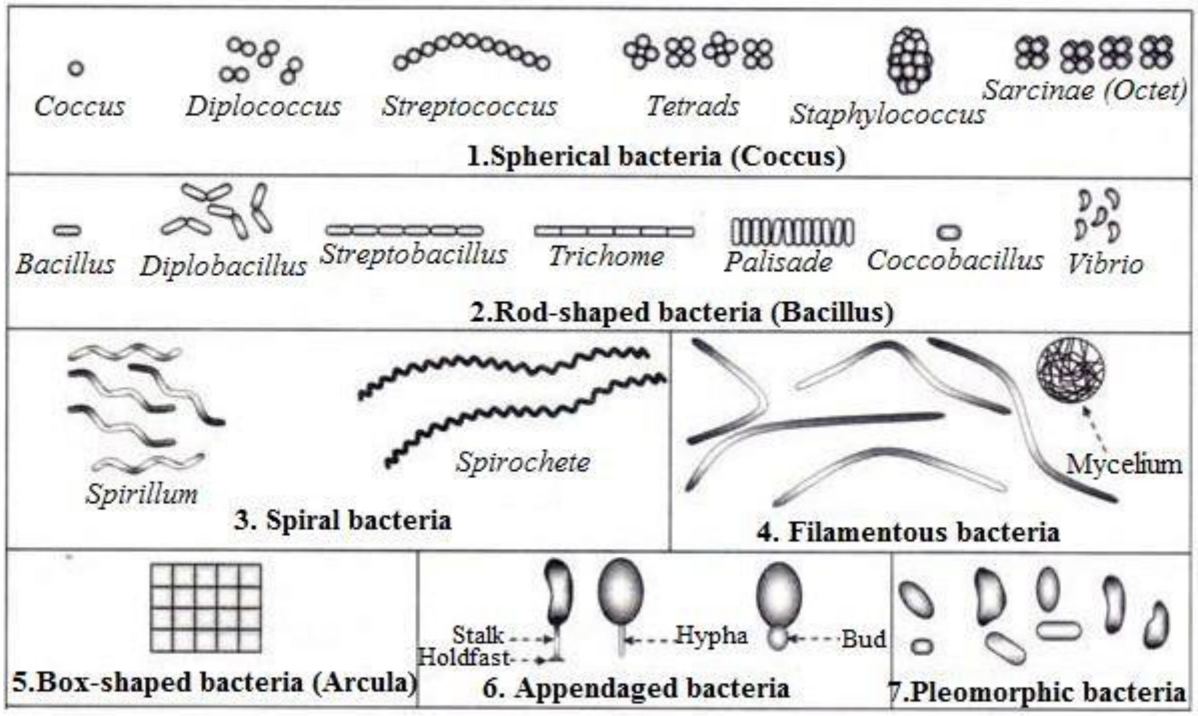


Fig. 1.8 Different shapes of bacteria

3. Structure of Bacteria:

(i) Plasma membrane- It is an ultra thin membrane 6-8 nm thick, chemically comprised of molecules of lipids and proteins, arranged in a fluid mosaic pattern. Infoldings in it gives rise to two main types of structures:

(a) Mesosomes- (Also known as Chondriods); are extensions involving complex whorls of convoluted membranes. They increase surface area of plasma membrane and enzymatic contents. **(b) Chromatophores-** These are photosynthetic pigment- bearing membranous structures of photosynthetic bacteria and are present as vesicles, thylakoids, tubes etc.

(ii) **Cell Wall-** It is strong and rigid and covers plasma membrane to provide chemical protection and characteristic shape of bacteria. It is made up of peptidoglycan and contains muramic acid.

(iii) **Capsule-** In some bacteria, cell wall is surrounded by an additional slime or gel layer called capsule that acts as protective layer against viruses and phagocytes.

(iv) **Cytoplasm**- It is the ground substance surrounded by plasma membrane and is site of all metabolic activities of bacteria. It consists of water, proteins, enzymes, different types of RNA molecules and reserve materials like glucogen, volutin and sulphur. The dense nuclear areas of cytoplasm contain 70S ribosomes granules, composed of RNA and protein and are the site of protein synthesis.

(v) **Nucleoids-** The nuclear membrane includes a single, circular and double stranded DNA molecule often called as bacterial chromosome. It is not separated by nuclear membrane and is usually concentrated in a specific clear region of the cytoplasm called nucleoid. It has no ribosomes, nucleolus and histone proteins.

(vi) **Plasmids –** Many species of bacteria may also carry extrachromosomal genetic elements in the form of small, circular, and closed DNA molecules called plasmids. They produce antibiotically active protein or colicins which inhibit the growth of other bacterial strain in their vicinity. They may also act as sex or fertility factors (F factor) which stimulate bacterial conjugation. R factors are also plasmid carrying genes for resistance to drugs.

(vii) **Flagella-** Many bacteria are motile and contain one or more flagella for cellular locomotion.

They are 15-20nm in diameter and up to 20μm long. e.g., *E.coli* etc

4. **Nutrition:** They show diversity in their nutrition from being chemosynthetic, to photosynthetic; but most of them are heterotrophic. Heterotrophic bacteria are mostly either saprophytic or parasitic. Parasitic lives on the bodies of other organisms. Most bacteria are pathogenic.

5. **Mode of Respiration:** It is of both types; aerobic (which respire in the presence of oxygen.eg *Lactobacillus*) and anaerobic (which respire in the absence of oxygen. e.g. *Pseudomonas*).

6. **Reproduction:** Bacteria reproduce through asexually by binary fission and endospore formation and sexually by conjugation. In conjugation, genetic exchange and recombination occurs through sex pili, but this is a form of horizontal gene transfer and is not a replicative process, simply involving the transference of DNA between two cells.

B: Eukaryotic Cell

The Eukaryotic cells are essentially two envelope systems and they are very much larger than prokaryotic cells. Secondary membranes envelop the nucleolus and other internal organelles and to a great extent they pervade the Cytoplasm as the Endoplasmic reticulum. The Eukaryotic cells are true cells which occur in the plants (from algae to angiosperms) and the animal (from Protozoa to mammals). Though the Eukaryotic cells have different shape, size, and physiology; all the cells are typically composed of plasma membrane, cytoplasm and its organelles, viz. Mitochondria, Endoplasmic reticulum, ribosomes, Golgi apparatus etc; and a true nucleus. Here the nuclear contents, such as DNA, RNA, Nucleoproteins and Nucleolus remain separated from the Cytoplasm by the thin perforated nuclear membranes. Before going into the detail of cells and its various components; it will be advisable to consider the general features of different types of eukaryotic cells which are as follow:

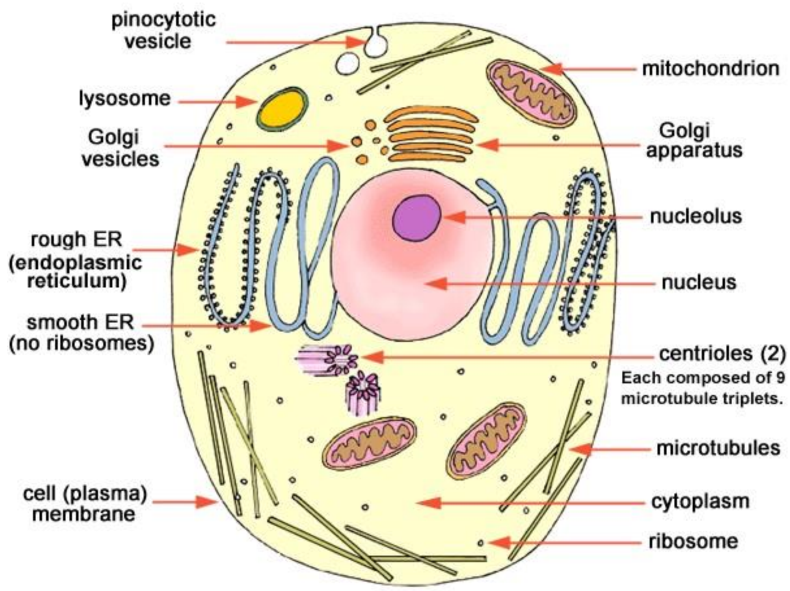


Fig.1.9- Structure of a Eukaryotic cell

1. **Cell Shape:** The basic shape of Eukaryotic Cells is **Spherical**; however the shape is ultimately determined by the specific function of the cell. Thus, the shape of the cell may be **Variable** or **Fixed.** Variable or irregular shape occurs in Amoeba and white blood cells or Leucocytes. Fixed shape cells occur in almost all protests‘, plant, animals. In unicellular organisms the cells shape is maintained by tough plasma membrane and exoskeleton. The shape of cells may vary from animal to animal and from organ to organ. Even cells of the same organ may display variations in the shape. Thus cells may have diverse shape such as Polyhedral, Flattened, Cuboidal, Columnar, Discoidal, Spherical, Spindle Shaped, Elongated or Branched.

2. **Cell Size:** The eukaryotic cells are typically larger (mostly ranging between 10 to 100 µm) than the prokaryotic cells (mostly ranging between 1 to 10 µm). Size of the cell of the unicellular organisms is larger than typical multicellular organisms‘ cells. For example, *Amoeba proteus* is biggest among the unicellular organisms. One species of *Euglena* is found up to 500 µm in length. Diatoms have length of 200µm or more.

The size of multicellular organism ranges between 20 to 30µm. Among animal's the smallest cells have a diameter 4µm. (e.g. Polocytes); Human erythrocytes being 7 to 8 µm in diameter. Largest animal cell is the egg of Ostrich, having a diameter of 18cm and the longest cell is human nerve cell, a meter long.

3. **Cell Volume:** The volume of cell is fairly constant for a particular cell type and is independent of the size of the organism (**Law of Constant Volume**). For example, kidney or liver cells are about the same size in the bull horse and mouse. The difference in the total mass of organ depend upon the number not on the volume of the cells. If a cell is to be efficient, the ratio of volume to surface should be within a limited range. An increase in the cell volume is accompanied by much smaller expansion in surface area of the cells. In other words, a large cell has a proportionately smaller surface area and a higher volume: Surface ratio than a small a cell.

4. **Cell Number:** The number of cell present in organism is varies from a single cell in unicellular organism to many cell in multi cellular organism. The number of cell in multicellular organism usually remains correlated with the size of organism and, therefore, a small sized organism has a less number of cells in comparison to large sized organism. Further, the number of cells in most of multicellular organism is indefinite, but the number of cells may be fixed in some multicellular organism. For example, in rotifers, numbers of nuclei in the various organs are found to be constant in any given species. The phenomenon of cells or nuclear constancy is called Eutely. In one species of rotifers, Martini (1912) always found 183 nuclei in the brain, 39 in stomach and so on.

5. **Structure:**

(i) **Cell Wall:** The outermost structure of most plant cells is a dead and rigid layer called cell wall. It is mainly composed of carbohydrates such as cellulose, pectin hemicelluloses and lignin and certain fatty substances like waxes. There is pectin- rich cementing substance between the walls of adjacent cells which is called middle lamella. The cell wall which is formed immediately after the division of cell, constitute the primary cell wall. In certain types of cells such as phloem and xylem, an additional layer is added to the inner surface of primary cell wall called, secondary cell wall and it consist mainly of cellulose, hemicelluloses and lignin. In many plant cells, there are tunnels running through the cell wall called **Plasmodesmata** which allow communication with the other cells in a tissue.

(ii) **Plasma Membrane:** Every kind of animal cell is bounded by a living, extremely thin and delicate membrane called Plasma lemma, cell membrane or plasma membrane. In plant calls plasma membrane occurs just inner to cell wall, bounding the cytoplasm. The plasma membrane exhibits a tri- laminar structure with a translucent layer sandwiched between two dark layers. The plasma membrane is selectively permeable membrane; its main function is to control selectively the entrance and exit of materials. This allows then cell to maintain a constant internal environment (Homeostasis). Molecules of water, oxygen, carbon-dioxide, glucose etc., are transported across the plasma membrane takes place by various means such as osmosis, diffusion, and active transportation.

(iii) Cytosol: The plasma membrane is followed by the colloidal organic fluid called matrix or cytosol. The cytosol is aqueous part of cytoplasm and nucleoplasm. Cytosol is particularly rich in differentiation cells and many fundamental properties of cells are because of this part of cytoplasm. The cytosol serves to dissolve or suspend the great verity of small molecules concerned with cellular metabolism, e.g., glucose amino acids, nucleotides, vitamins, minerals, oxygen. In all type of cells, cytosol contains the soluble proteins and enzymes which form 20-25 % of the total protein content of the cells. In many types of cells, the cytosol is differentiated into two parts:

(a) **Ectoplasm or cell cortex** is the peripheral layer of cytosol which is relatively non granular, viscous, clear and rigid.

(b) **Endoplasm** is the inner portion of cytosol which is granular and less viscous.

Cytoskeleton and Microtrabecular Lattice

The cytosol of cells also contains fibers that help to maintain cell shape and mobility and that probably provide anchoring points for the other cellular structures. These fiber‘s are called cytoskeleton. At least three general classes of such fibers have been identified. 1-

The thickest are the microtubules (20 nm in diameter) which consists primarily of the tubulin protein. The function of microtubules is the transportation of water, ions or small molecules, cytoplasmic streaming (cyclosis), and the formation of fibers or asters of the mitotic or meiotic spindle during cell division.

2-The thinnest are the microfilaments (7mm in diameter) which are solid and are solid and are principally formed of actin protein.

3-The fibers of middle order are called the intermediate filaments (Ifs) having a diameter of 10nm. They have been classified according to their constituent protein such as desmin filaments, keratin filament, Neurofilaments, vimentin and glial filaments.

(i) Cytoplasmic structures: In the cytoplasmic matrix certain non living and living structures remain suspended. The non living structures are called paraplasm and inclusion, while the living structures can be studied under the following headings:

Cytoplasmic Inclusion

The stored food and secretory substances of the cell remain suspended in the cytoplasmic matrix in the form of refractile granules forming the cytoplasmic inclusion. The cytoplasmic inclusion involves oil drops, yolk granules, triacylglyerol and starch grains.

Cytoplasmic Organelles

Besides the separates fibrous systems cytoplasm is coursed by a multitude of internal membranous structures, the organelles. Cytoplasmic organelles performed specialized tasks: Generation of energy in the form of ATP molecules in Mitochondria; formation and storage of carbohydrates in plastids; protein synthesis in rough endoplasmic reticulum; lipid synthesis in soft endoplasmic reticulum; secretion by Golgi complex; Regulation of all cellular activities by nucleus.

A. Endoplasmic Reticulum (ER): Within the cytoplasm of most animals cells in an extensive network of membrane – limited channels, collectively called Endoplasmic reticulum. The outer surface of rough endoplasmic reticulum has attached ribosomes, where as smooth endoplasmic reticulum don‘t have. Functions of smooth ER include lipid metabolism (Both catabolism and anabolism) glycogenolysis (degradation of glycogen) and drug detoxification.

On their membranes, rough ER contain certain ribosome‘s – specific, transmembrane glycoprotein‘s called ribophorins I & II, to which are attached the ribosome‘s while engaged in polypeptide synthesis. Rough ER pinches off certain tiny protein- filled vesicles which ultimately get fused to Cis-Golgi. RER also synthesize membrane and glycoprotein‘s which are co translationally inserted into rough ER membranes. Thus ER is the site of biogenesis of cellular membranes‘.

General features

1. The ER is a system of membranous tubules and sacs
2. The primary function of the ER is to act as an internal transport system, allowing molecules to move from one part of the cell to another
3. The quantity of ER inside a cell fluctuates, depending on the cell's activity. Cells with a lot include secretory cells and liver cells
4. The rough ER is studded with 80s ribosomes and is the site of protein synthesis. It is an extension of the outer membrane of the nuclear envelope, so allowing mRNA to be transported swiftly to the 80s ribosomes, where they are translated in protein synthesis
5. The smooth ER is where polypeptides are converted into functional proteins and where proteins are prepared for secretion. It is also the site of lipid and steroid synthesis, and is associated with the Golgi apparatus. Smooth ER has no 80s ribosomes and is also involved in

the regulation of calcium levels in muscle cells, and the breakdown of toxins by liver cells

6. Both types of ER transport materials throughout the cell.

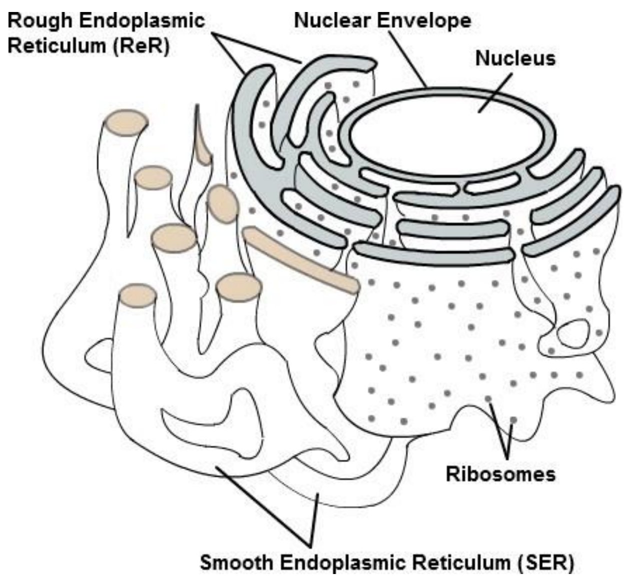


Fig.1.10- Ultra structure of Endoplasmic reticulum

B. Golgi Apparatus: It is cup shaped organelle which is located near the nucleus in many type of cells. Golgi apparatus consists of a set of smooth cisternae (i.e. close fluid –filled flattened membranous sacs or vesicles) which often are stacked together in parallel rows. It is surrounded by spherical membrane bound vesicles which appear to transport proteins to and from it.

Golgi apparatus consist of at least three distinct classes of cisternae: Cis Golgi, Median Golgi and Trans Golgi. Synthesized proteins appear to move in following direction: Rough ER → Cis Golgi → Median Golgi → Trans Golgi → Secretory Vesicles → Cortical Granules.

Plant cells may contain freely distributed subunits of Golgi apparatus, called Dictyosome.

Generally, Golgi apparatus perform the following functions:

1. Packaging of secretory materials.

2. Synthesis of certain polysaccharides and glycolipids.
3. Formation of acrosome of the spermatozoa.

General features

1. The Golgi apparatus is the processing, packaging and secreting organelle of the cell, so it is much more common in glandular cells.
2. The Golgi apparatus is a system of membranes, made of flattened sac-like structures called cisternae.
3. It works closely with the smoother, to modify proteins for export by the cell.

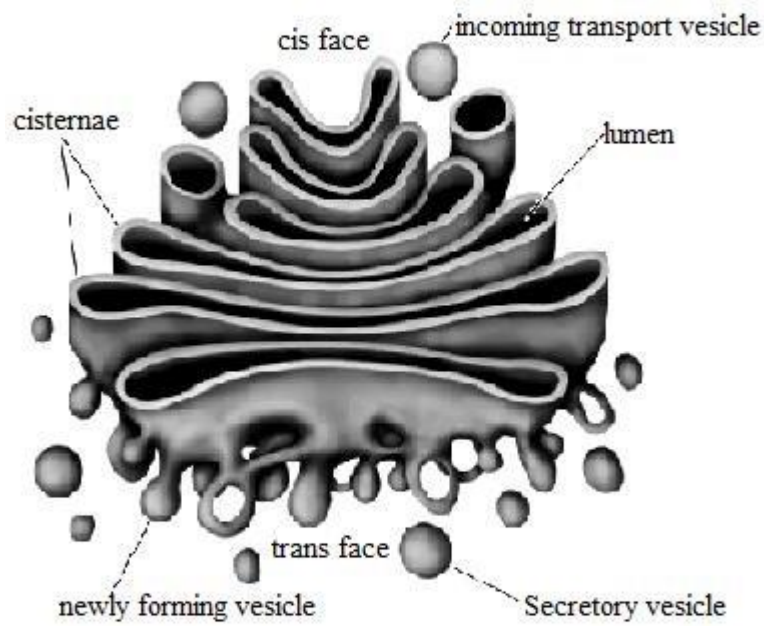


Fig.1.11- Structure of Golgi apparatus

C. Lysosomes: The cytoplasm of animals cells contains many tiny, spherical or irregular shape, membrane bounded vesicles known as lysosomes. They digest the material taken in by endocytosis, part of cells and extra cellular substances. Lysosomes have a high acidic medium (pH 5) and its acidification depends upon ATP dependent proton pumps which are present in lysosomes membrane. Lysosomes exhibits great polymorphism i.e. there is following four types of lysosomes: primary lysosomes (storage granules) secondary lysosomes (digestive vacuoles); residual bodies. The lysosomes of plant cells are membrane bounded storage granules containing hydrolytic digestive enzymes‘ large vacuoles of parenchymatous cells of corn seedlings, proteins or aleurone bodies and other seeds.

General features

1. Lysosomes are small spherical organelles that enclose hydrolytic enzymes within a single membrane

2. Lysosomes are the site of protein digestion – thus allowing enzymes to be re-cycled when they are no longer required. They are also the site of food digestion in the cell, and of bacterial digestion in phagocytes
3. Lysosomes are formed from pieces of the GoIgi apparatus that break off
4. Lysosomes are common in the cells of Animals, Protoctista and even Fungi, but rare in plants.

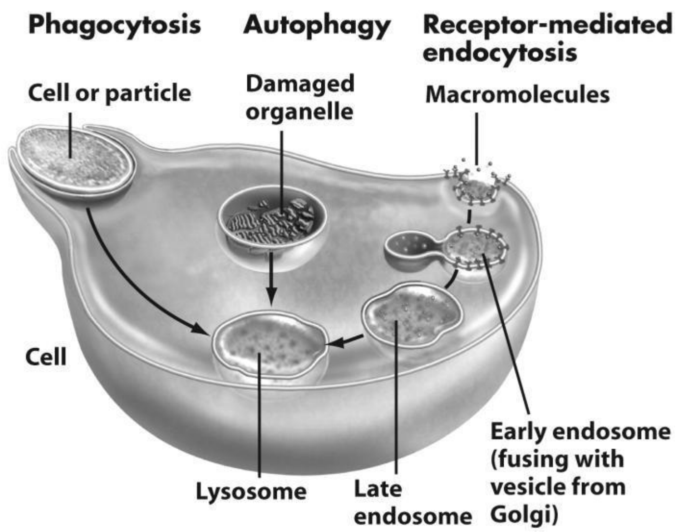


Fig.1.12- Type of formations of Lysosomes

D. Cytoplasmic Vacuoles: The cytoplasm of many plant and some animals‘ cell contain numerous small or large-sized hollow, liquid-filled structures, the vacuoles .The vacuoles of animals are bounded by a lipoproteinous membrane and their function is the storage, transmission of the materials and the maintenance of internal pressure of cell. The vacuoles of plants are bounded by a single, semi permeable membrane known as Tonoplast.

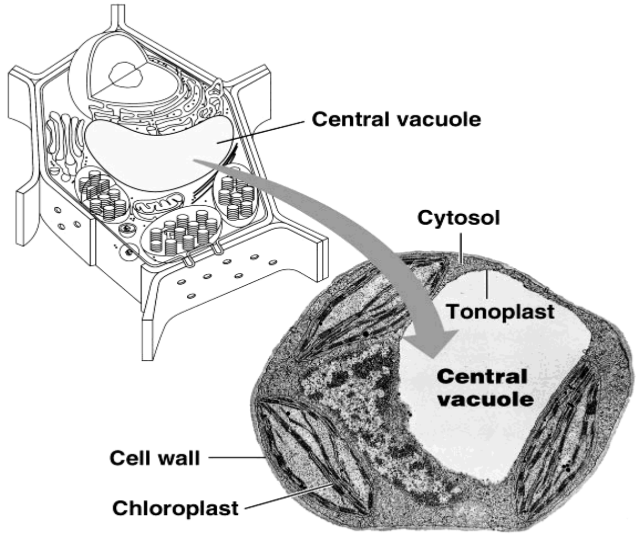


Fig.1.13- Structure of Vacuole

E. Peroxisomes: These are tiny circular membrane bound organelles containing a crystal core of enzymes. These enzymes are required by peroxisomes in detoxification activity. i.e., in the metabolism or production and decomposition, of hydrogen peroxide or H_2O_2 molecules which are produced during neutralization of certain superoxides- the end products of mitochondrial or cytosolic reactions. In green leaves of plants peroxisomes carry out the process of photorespiration.

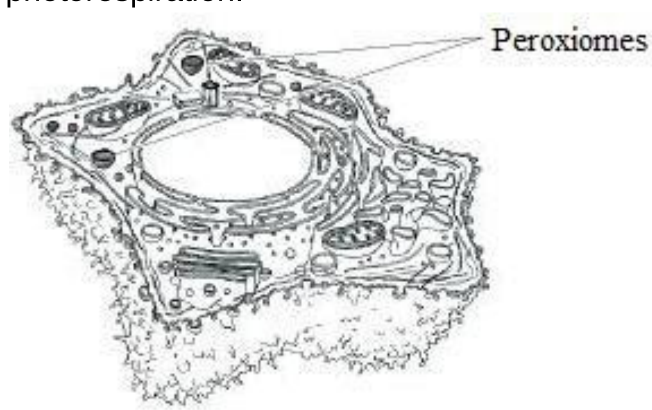


Fig.1.14- Structure of cell showing Peroxisomes

F. Glyoxysomes: These organelles develop in a germinating plant seed to utilize stored fat of the seed. Glyoxysomes consist of an amorphous protein matrix surrounded by a limited membrane. The membrane of Glyoxysomes originates from the ER and their enzymes are synthesized in the free ribosomes in the cytosol, Enzymes of Glyoxysomes are used to transform the fat stores of the seed into carbohydrates by the way Glyoxylate cycle.

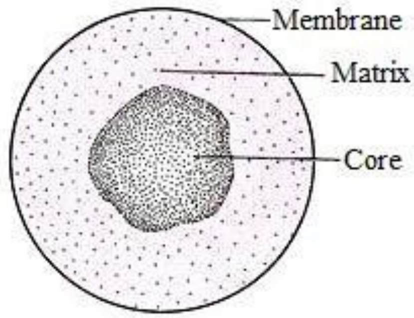


Fig.1.15- Structure of Glyoxysomes

G. **Mitochondria:** Mitochondria are oxygen consuming ribbon shaped cellular organelles of immense importance. Each Mitochondria is bounded by two unit membranes, the outer Mitochondria membrane resembles more with the plasma membrane in structure and chemical composition. It contains Porins, proteins that render the membrane permeable to molecule having molecular weight as high as 10,000. Inner Mitochondrial membrane is rich in many enzymes, coenzymes another component of electron transport chain. It also contain proton pumps and many Permease proteins for the transport of various molecules so such as citrates, ADP, Phosphate & ATP.

Inner Mitochondria membrane gives out finger-like out growths (Cristae) towards the lumen of Mitochondrion. Mitochondrial matrix which is the liquid (colloidal) area in circled by the inner membrane contains the soluble enzyme of Krebs cycle which completely oxidized the acetyl-CoA to produce CO_2, H_2O, hydrogen ions. Hydrogen ions reduce the molecules of NAD and FAD, both of which can pass on hydrogen ions to reparatory or electron transport chain where oxidative phosphorylation takes place to generate energy rich molecules. Mitochondria act as the **"Power House of Cells"**. Since Mitochondria can synthesize 10% of their proteins in their own protein –synthetic machinery, they are considered as semi autonomous organelles.

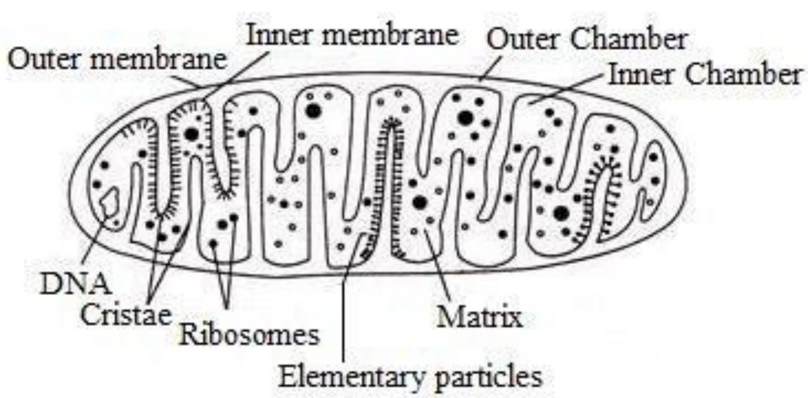


Fig.1.16 - Structure of Mitochondria

General features

1. Mitochondria are found scattered throughout the cytosol, and are relatively large organelles (second only to the nucleus and chloroplasts).

2. Mitochondria are the sites of aerobic respiration, in which energy from organic compounds is transferred to ATP. For this reason they are sometimes referred to as the ‗powerhouse‘ of the cell. 3. ATP is the molecule that most cells use as their main energy ‗currency‘.

4. Mitochondria are more numerous in cells that have a high energy requirement - our muscle cells contain a large number of mitochondria, as do liver, heart and sperm cells.

5. Mitochondria are surrounded by two membranes, indicating that they were once free-living organisms that have become mutualistic and then a part of almost every eukaryotic cell (not

RBC‘s and xylem vessels).

a) The smooth outer membrane serves as a boundary between the mitochondria and the cytosol.
b) The inner membrane has many long folds, known as Cristae, which greatly increase the surface area of the inner membrane, providing more space for ATP synthesis to occur.

6. Mitochondria have their own DNA, and new mitochondria arise only when existing ones grow and divide. They are thus "*semi-autonomous organelles*".

H. Plastids: Plastids are double membrane organelles which are found in plant cells only. They are usually spherical or discoidal in shape and their average size is 4 to 6 µm. A plastid shows two distinct regions-grana and stroma. Grana are stacks of membrane-bound, flattened, discoid sacs containing chlorophyll molecules. These molecules are responsible for the production of food by the process of photosynthesis.

They are, therefore, called "*Kitchen of the cell*". They are the main functional units of the chloroplast. The homogenous matrix in which Grana are embedded is known as Stroma. A variety of photosynthetic enzymes and starch grains are present in the Stroma. The Stroma is colourless, whereas the Grana contain the pigments. Plastids are living and multiply by division of the pre-existing plastids called Proplastids.

Plastids are of three types:

1. **Leucoplasts** are colorless plastids. They store the food of the plant body in the form of starch, protein and lipids. They occur most commonly in the storage cells of roots and underground stems.
2. **Chloroplasts** are green plastids because of the presence of chlorophyll. Chloroplasts occur abundantly in green leaves, and also to some extent in green parts of the shoot.
3. **Chromoplasts** are variously colored plastids. They are mostly present in flowers and fruits.

One form of plastid can change into another. For example, leucoplasts can change into chloroplasts when the former are exposed to light for a long period.

Functions

1. By trapping solar energy, green plastids manufacture food through photosynthesis.
2. Chromoplasts provide colored to various flowering parts.
3. Leucoplasts help in storage of protein, starch and oil.

I. Ribosomes: They are dense, rounded, granular and smallest known electron microscopic Ribonucleoprotein (RNP) particles attached either on RER or floating freely in the cytoplasm. These are the site of protein synthesis. They may exist either in free state in cytosol or attached to RER. Ribosomes in eukaryotes have sedimentation coefficient of about 80S and are composed of 2 subunits namely 40S and 60S, and prokaryotes have 70S and are composed of 2 subunits namely 30S and 50S.

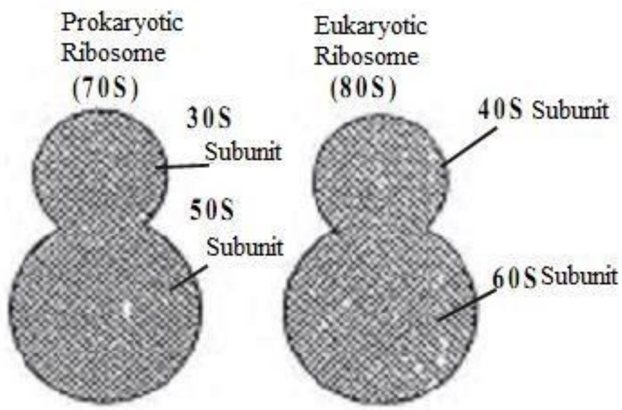


Fig.1.17- Ribosomes, Prokaryotic and Eukaryotic

General features

1. Unlike most other organelles, ribosomes are not surrounded by a membrane.
2. Ribosomes are the site of protein synthesis in a cell.
3. They are the most common organelles in almost all cells.
4. Some are free in the cytoplasm (Prokaryotes) others line the membranes of rough endoplasmic reticulum (rough ER).
5. They exist in two sizes: 70S are found in all Prokaryotes, chloroplasts and mitochondria, suggesting that they have evolved from ancestral Prokaryotic organisms. They are freefloating. While 80S found in all eukaryotic cells – attached to the rough ER (they are rather larger). Here "S" stand as a *Svedberg coefficient* or unit.
6. Groups of 80s ribosomes, working together, are known as a Polysome.

J. Cytoskeletal Structures: Many eukaryotes have long slender motile cytoplasmic projections, called flagella, or similar structures called cilia. Flagella and cilia are sometimes referred to as undulipodia, and are variously involved in movement, feeding, and sensation. They are composed mainly of tubulin. These are entirely distinct from prokaryotic flagella. They are supported by a bundle of microtubules arising from a basal body, also called a Kinetosome or Centrioles, characteristically arranged as nine doublets surrounding two singlets. Flagella also may have hairs, or Mastigoneme, and scales connecting membranes and internal rods. Their interior is continuous with the cell's cytoplasm.

Microfilament structures composed of actin and actin binding proteins, e.g., α-actinin, fimbrin, filamin are present in submembranous cortical layers and bundles, as well. Motor proteins of microtubules, e.g., dynein or kinesin and actin, e.g., myosins provide dynamic character of the network.

Centrioles are often present even in cells and groups that do not have flagella, but conifers and flowering plants have neither. They generally occur in groups of one or two, called kinetids that give rise to various microtubular roots. These form a primary component of the cytoskeletal structure, and are often assembled over the course of several cell divisions, with one flagellum retained from the parent and the other derived from it. Centrioles may also be associated in the formation of a spindle during nuclear division.

The significance of cytoskeletal structures is underlined in the determination of shape of the cells, as well as their being essential components of migratory responses like chemo-taxis and Chemokinesis. Some protists have various other microtubule-supported organelles. These include the radiolaria and heliozoa, which produce axopodia used in flotation or to capture prey, and the haptophytes, which have a peculiar flagellum-like organelle called the haptonema.

General features

1. Just as your body depends on your skeleton to maintain its shape and size, so a cell needs structures to maintain its shape and size.
2. In animal cells, which have no cell wall, an internal framework called the cytoskeleton maintains the shape of the cell, and helps the cell to move.
3. The cytoskeleton consists of two structures: a) microfilaments (contractile). They are made of actin, and are common in motile cells. b) microtubules (rigid, hollow tubes – made of tubulin).
4. Microtubules have three functions:
   (a) To maintain the shape of the cell.
   (b) To serve as tracks for organelles to move along within the cell.
   (c) They form the Centrioles.

K. Nucleus: The nucleus is a membrane-enclosed organelle found in eukaryotic cells.

Eukaryotes usually have a single nucleus, but a few cell types, such as mammalian red blood cells, have no nuclei, and a few others have many.

Cell nuclei contain most of the cell's genetic material, organized as multiple long linear DNA molecules in complex with a large variety of proteins, such as histones, to form chromosomes. The genes within these chromosomes are the cell's nuclear genome and are structured in such a way to promote cell function. The nucleus maintains the integrity of genes and controls the activities of the cell by regulating gene expression—the nucleus is, therefore, the control center of the cell. The main structures making up the nucleus are the nuclear envelope, a double membrane that encloses the entire organelle and isolates its contents from the cellular cytoplasm, and the nuclear matrix (which includes the nuclear lamina), a network within the nucleus that adds mechanical support, much like the cytoskeleton, which supports the cell as a whole.

Because the nuclear membrane is impermeable to large molecules, nuclear pores are required that regulate nuclear transport of molecules across the envelope. The pores cross both nuclear membranes, providing a channel through which larger molecules must be actively transported by carrier proteins while allowing free movement of small molecules and ions. Movement of large molecules such as proteins and RNA through the pores is required for both gene expression and the maintenance of chromosomes. Although the interior of the nucleus does not contain any membrane-bound sub compartments, its contents are not uniform, and a number of sub-nuclear bodies exist, made up of unique proteins, RNA molecules, and particular parts of the chromosomes. The best-known of these is the nucleolus, which is mainly involved in the assembly of ribosomes. After being produced in the nucleolus, ribosomes are exported to the cytoplasm where they translate mRNA.

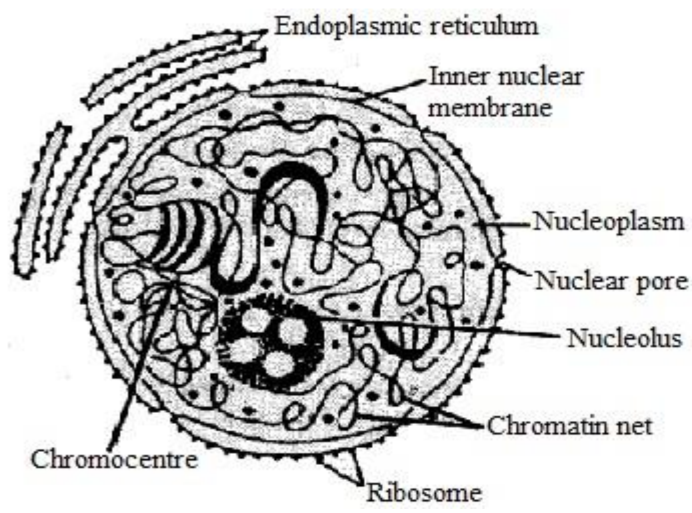


Fig.1.18- Eukaryotic Nucleus

General features

1. The Nucleus is normally the largest organelle within a Eukaryotic cell.
2. Prokaryotes have no nucleus, having a nuclear body instead. This has no membrane and a loop of DNA (and no chromatin proteins).
3. The nucleus contains the cell‘s chromosomes (human 46, fruit fly 6, fern 1260) which are normally uncoiled to form a chromatin network, which contain both linear DNA and proteins, known as histones. These

proteins coil up (dehydrate) at the start of nuclear division, when the chromosomes first become visible.

4. Whilst most cells have a single nucleus some cells (macrophages, phloem companion cells) have more than one.
5. Fungi have many nuclei in their cytoplasm, they are coenocytic (common cytoplasm throughout).
6. The nucleus is surrounded by a double membrane called the nuclear envelope.
7. The nuclear envelope has many nuclear pores through which mRNA, and proteins can pass.
8. Most nuclei contain at least one nucleolus (plural, nucleoli). The nucleoli are, where ribosomes are synthesized. Ribosomes translate mRNA into proteins.
9. When a nucleus prepares to divide, the nucleolus disappears.

The following table featuring different organelles of cell with their location, description and functions.

ORGANELLE	LOCATION	DESCRIPTION	FUNCTION
Cell wall	Plant, not animal	Outer layer rigid, strong, stiff made of cellulose	Support (grow tall) protection allows H_2O, O_2, CO_2 to pass into and out of cell
Cell membrane	Both plant/animal	Plant - inside cell wall animal - outer layer; cholesterol selectively permeable	Support protection controls movement of materials in/out of cell barrier between cell and its environment maintains homeostasis
Nucleus	Both plant/animal	Large, oval	Controls cell activities
Nuclear membrane	Both plant/animal	Surrounds nucleus selectively permeable	Controls movement of materials in/out of nucleus
Cytoplasm	Both plant/animal	Clear, thick, jellylike material and organelles found inside cell membrane	Supports /protects cell organelles
Endoplasmic reticulum (E.R.)	Both plant/animal	Network of tubes or membranes	Carries materials through cell
Ribosome	Both plant/animal	Small bodies free or attached to E.R.	Produces proteins
Mitochondrion	Both plant/animal	Bean-shaped with inner membranes	Breaks down sugar molecules into energy

Vacuole	Plant - few/large animal - small	Fluid-filled sacs	Store food, water, waste (plants need to store large amounts of food)
Lysosome	Plant - uncommon animal - common	Small, round, with a membrane	Breaks down larger food molecules into smaller molecules digests old cell parts
Chloroplast	Plant, not animal	Green, oval usually containing chlorophyll (green pigment)	Uses energy from sun to make food for the plant (photosynthesis)

Differences among Eukaryotic Cells

There are many different types of eukaryotic cells, though animals and plants are the most familiar eukaryotes, and thus provide an excellent starting point for understanding eukaryotic structure. Fungi and many protists have some substantial differences, however.

Animal Cell

All animals consist of eukaryotic cells. Animal cells are distinct from those of other eukaryotes, most notably plants, as they lack cell walls and chloroplasts and have smaller vacuoles. Due to the lack of a cell wall, animal cells can adopt a variety of shapes. A phagocytic cell can even engulf other structures. There are many other types of cell. For instance, there are approximately 210 distinct cell types in the adult human body.

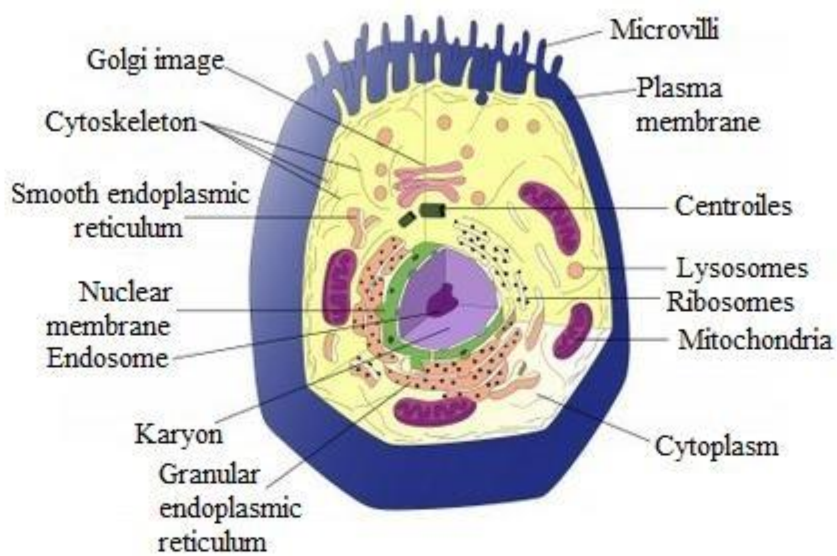


Fig.1.19 Structure of a typical animal cell

Plant Cell

1. Most of the organelles and other parts of the cell are common to all Eukaryotic cells. Cells from different organisms have an even greater difference in structure

2. Plant cells have three additional structures not found in animal cells:
   (a) Cellulose cell walls
   (b) Chloroplasts (and other plastids)
   (c) A Central Vacuole

Cellulose cell wall

1. One of the most important features of all plants is presence of a cellulose cell wall.
2. Fungi such as Mushrooms and Yeast also have cell walls, but these are made of chitin.
3. The cell wall is freely permeable (porous), and so has no direct effect on the movement of molecules into or out of the cell.
4. The rigidity of their cell walls helps both to support and protect the plant.
5. Plant cell walls are of two types:

(a) Primary (cellulose) cell wall - While a plant cell is being formed, a middle lamella made of pectin, is formed and the cellulose cell wall develops between the middle lamella and the cell membrane. As the cell expands in length, more cellulose is added, enlarging the cell wall. When the cell reaches full size, a secondary cell wall may form.

(b) Secondary (lignified) cell wall - The secondary cell wall is formed only in woody tissue (mainly xylem). The secondary cell wall is stronger and waterproof and once a secondary cell wall forms, a cell can grow no more – it is dead.

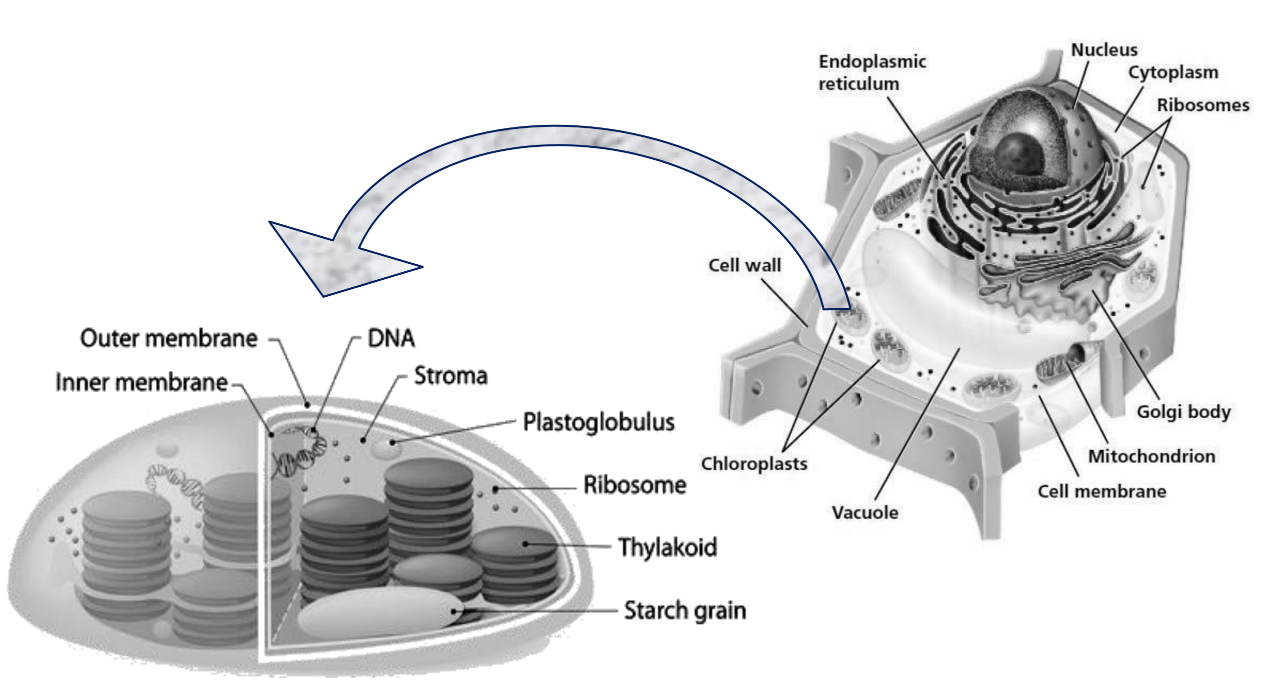
Vacuoles

1. The most prominent structure in plant cells is the large vacuole.
2. The vacuole is a large membrane-bound sac that fills up much of most plant cells.
3. The vacuole serves as a storage area, and may contain stored organic molecules as well as inorganic ions.
4. The vacuole is also used to store waste. Since plants have no kidney, they convert waste to an insoluble form and then store it in their vacuole - until autumn.
5. The vacuoles of some plants contain poisons (e.g. tannins) that discourage animals from eating their tissues.
6. Whilst the cells of other organisms may also contain vacuoles, they are much smaller and are usually involved in food digestion.

Chloroplasts (and other plastids)

1. A characteristic feature of plant cells is the presence of plastids that make or store food.
2. The most common of these are chloroplasts – the site of photosynthesis.
3. Each chloroplast encloses a system of flattened, membranous sacs called thylakoids, which contain chlorophyll.
4. The thylakoids are arranged in stacks called Grana.

5. The space between the Grana is filled with cytoplasm-like Stroma.
6. Chloroplasts contain cp DNA and 70S ribosomes and are semi-autonomous organelles.
7. Other plastids store reddish-orange pigments that colour petals, fruits,



and some leaves.

Fig.1.20- Structure of a Chloroplast and a typical plant cell

Plant cells are quite different from the cells of the other eukaryotic organisms. Their distinctive features are:

1. A large central vacuole (enclosed by a membrane, the Tonoplast), which maintains the cell's turgor and controls movement of molecules between the cytosol and sap.

2. A primary cell wall containing cellulose, hemicellulose and pectin, deposited by the protoplast on the outside of the cell membrane; this contrasts with the cell walls of fungi, which contain chitin, and the cell envelopes of prokaryotes, in which peptidoglycans are the main structural molecules.
3. The plasmodesmata, linking pores in the cell wall that allow each plant cell to communicate with other adjacent cells; this is different from the functionally analogous system of gap junctions between animal cells.
4. Plastids, especially chloroplasts that contain chlorophyll, the pigment that gives plants their green color and allows them to perform photosynthesis.
5. Bryophytes and seedless vascular plants lack flagella and centrioles except in the sperm cells. Sperm of cycads and Ginkgo are large, complex cells that swim with hundreds to thousands of flagella.
6. Conifers (Pinophyta) and flowering plants (Angiospermae) lack the flagella and centrioles that are present in animal cells.

1.7 SUMMARY

1-All living organisms are made up of one or numerous coordinated compartments called cells.

2- Robert Hooke (1665) was first to discover and use the term cell.

3- Cell Theory was proposed by M.J Schleiden and T. Schwann in 1838.

4- PPLO is the smallest cell.

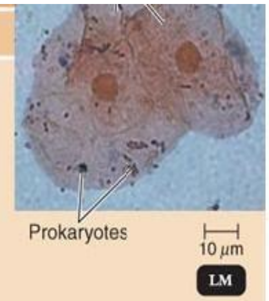
5- Viruses do not have cellular structures.

6-Nucleolus is absent in prokaryotic cells.

7-Complexcity of cell increases from prokaryotes to eukaryotes.

8-Nuclear material of bacteria is also known as Bacterial chromosome.

9-Difference between prokaryotic and eukaryotic cell:

Characteristic	Prokaryotic	Eukaryotic
		 
Size of Cell	Typically 0.2–2.0 μm in diameter	Typically 10–100 μm in diameter
Nucleus	No nuclear membrane or nucleoli	True nucleus, consisting of nuclear membrane and nucleoli
Membrane-Enclosed Organelles	Absent	Present; examples include lysosomes, Golgi complex, endoplasmic reticulum, mitochondria, and chloroplasts
Flagella	Consist of two protein building blocks	Complex; consist of multiple microtubules
Glycocalyx	Present as a capsule or slime layer	Present in some cells that lack a cell wall
Cell Wall	Usually present; chemically complex (typical bacterial cell wall includes peptidoglycan)	When present, chemically simple (includes cellulose and chitin)
Plasma Membrane	No carbohydrates and generally lacks sterols	Sterols and carbohydrates that serve as receptors
Cytoplasm	No cytoskeleton or cytoplasmic streaming	Cytoskeleton; cytoplasmic streaming
Ribosomes	Smaller size (70S)	Larger size (80S); smaller size (70S) in organelles
Chromosome (DNA)	Usually single circular chromosome; typically lacks histones	Multiple linear chromosomes with histones
Cell Division	Binary fission	Involves mitosis
Sexual Recombination	None; transfer of DNA only	Involves meiosis

10. Difference between animal and plant cell:

S.No	Animal cell	Plant cell
1.	Animal cells are generally small in size.	Plant cells are larger than animal cells.
2.	Cell wall is absent.	The plasma membrane of plant cells is surrounded by a rigid cell wall of cellulose.
3.	Except the protozoan *Euglena* no animal cell possesses plastids.	Plastids are present.
4.	Vacuoles in animal cells are many and small.	Most mature plant cells have a large central sap vacuole.
5.	Animal cells have a single highly complex Golgi	Plant cells have many simpler units of and prominent Golgi apparatus. apparatus, called dictyosomes.
6.	Animal cells have centrosome and centrioles.	Plant cells lack centrosome and centrioles.

1.8 GLOSSARY

Aleurone: Protein stored as granules in the cells of plant seeds.
Autotroph: Any organism capable of self-nourishment by using inorganic materials as a source of nutrients and using photosynthesis or chemosynthesis as a source of energy, as most plants and certain bacteria and protists.
Cell Biology: Sub-discipline of biology that focuses on the study of the basic unit of life, the cell.
Cell theory: All organisms consist of one or more cells, the cell is the smallest unit of organization still displaying the properties of life, and life's continuity arises directly from growth and division of single cells.
Cell wall: Of many cells (not animal cells), a semi-rigid but permeable structure that surrounds the plasma membrane; helps a cell retain its shape and resist rupturing.
Cell: Smallest unit that still displays the properties of life; it has the capacity to survive and reproduce on its own.
Central vacuole: In many mature, living plant cells, an organelle that stores amino acids, sugars, and some wastes; when it enlarges during growth, it forces the cell to enlarge and increase its surface area.
Chemokinesis: Increased activity of an organism due to a chemical substance.
Chloroplast: A plastid containing chlorophyll.
Chromoplast: A plastid containing coloring matter other than chlorophyll.

Chromosome: A long, stringy aggregate of genes that carries heredity information (DNA) and is formed from condensed chromatin.

Cilium: A cilium (plural cilia) is an organelle found in eukaryotic cells. It is a hair-like extensions from the cell membrane that allow some cells to "*sweep*" materials across their surfaces.

Cisternae: A cisterna (plural cisternae) is a flattened membrane disk of the endoplasmic reticulum and Golgi apparatus.

Colicin: Any bacteriocin produced by certain strains of Escherichia coli and having a lethal effect on strains other than the producing strain.

Cristae: Each of the partial partitions in a mitochondrion formed by infolding of the inner membrane.

Cytoplasm: Consists of all of the contents outside of the nucleus and enclosed within the cell membrane of a cell.

Cytoskeleton: A network of fibers throughout the cell's cytoplasm that helps the cell maintain its shape and gives support to the cell.

Cytosol: Semi-fluid component of a cell's cytoplasm.

Detoxification: The metabolic process by which toxins are changed into less toxic or more readily excretable substances.

Dictyosome: The set of flattened membranes in a Golgi body, resembling a stack of plates.

Ectoplasm: The outer portion of the cytoplasm of a cell.

Endocytosis: The taking in of matter by a living cell by invagination of its membrane to form a vacuole.

Endoplasm: The more fluid, granular inner layer of the cytoplasm in amoeboid cells.

Endoplasmic reticulum: The endoplasmic reticulum is a type of organelle in eukaryotic cells that forms an interconnected network of flattened, membrane-enclosed sacs or tube-like structures known as cisternae.

Eukaryote: Any organism whose cells have a cell nucleus and other organelles enclosed within membranes. Eukaryotes belong to the domain Eukaryota, and can be single-celled or multicellular.

Flagella: A long, lash-like appendage serving as an organ of locomotion in protozoa, sperm cells, etc.

Glyoxysomes: Are specialized peroxisomes found in plants (particularly in the fat storage tissues of germinating seeds) and also in filamentous fungi.

Golgi Bodies: A complex of vesicles and folded membranes within the cytoplasm of most eukaryotic cells, involved in secretion and intracellular transport.

Granum: One of the structural units of a chloroplast in vascular plants, consisting of layers of thylakoids.

Heredity: It is the process by which features and characteristics are passed on from parents to their children before the children are born.

Heterotrophic: Capable of utilizing only organic materials as a source of food.

Histone: Any of a group of five small basic proteins, occurring in the nucleus of eukaryotic cells, that organize DNA strands into nucleosomes by forming molecular complexes around which the DNA winds.

Homeostasis: It refers to the ability of the body to maintain a stable internal environment despite changes in external conditions.

Kinetosome: A structure in some flagellate protozoans which forms the base of the flagellum, consisting of a circular arrangement of microtubules.

Leucoplast: A colourless organelle found in plant cells, used for the storage of starch or oil. **Lysosome:** An organelle in the cytoplasm of eukaryotic cells containing degradative enzymes enclosed in a membrane.

Mastigoneme: They are lateral "hairs" found covering the flagella of heterokont and cryptophyte algae.

Mycoplasma: It is a genus of bacteria that lack a cell wall around their cell membrane. Without a cell wall, they are unaffected by many common antibiotics such as penicillin or other β-lactam antibiotics that target cell wall synthesis.

Nucleoid: The nucleoid (meaning nucleus-like) is an irregularly shaped region within the cell of a prokaryote that contains all or most of the genetic material, called genophore.

Nucleus: A dense organelle present in most eukaryotic cells, typically a single rounded structure bounded by a double membrane, containing the genetic material.

Parasite: An organism that lives on or in an organism of another species, known as the host, from the body of which it obtains nutriment.

Parenchyma: The fundamental tissue of plants, composed of thin-walled cells able to divide. **Pectin:** Pectin is a structural hetero-polysaccharide contained in the primary cell walls of terrestrial plants.

Phloem: The part of a vascular bundle , in vascular plants, phloem is the living tissue that transports the soluble organic compounds made during photosynthesis, in particular the sugar sucrose, to parts of the plant where needed.

Photorespiration: The oxidation of carbohydrates in many higher plants in which they get oxygen from light and then release carbon dioxide, somewhat different from photosynthesis. **Plasmid:** A plasmid is a small, circular, double-stranded DNA molecule that is distinct from a cell's chromosomal DNA. Plasmids naturally exist in bacterial cells, and they also occur in some eukaryotes.

Plasmodesma: Any of many minute strands of cytoplasm that extend through plant cell walls and connect adjoining cells.

Plastid: The plastid is a major double-membrane organelle found in the cells of plants, algae, and some other eukaryotic organisms. Plastids are the site of manufacture and storage of important chemical compounds used by the cell.

Polymorphism: The existence of an organism in several form or color varieties.

Porins: They are beta barrel proteins that cross a cellular membrane and act as a pore, through which molecules can diffuse.

Prokaryote: A prokaryote is a unicellular organism that lacks a membrane-bound nucleus, mitochondria, or any other membrane-bound organelle.

Proteins: Proteins are large biomolecules, or macromolecules, consisting of one or more long chains of amino acid residues. It performs a vast array of functions within organisms, including catalyzing metabolic reactions, DNA replication, responding to stimuli, and transporting molecules from one location to another.

Ribosome: A tiny, somewhat mitten-shaped organelle occurring in great numbers in the cell cytoplasm either freely, in small clusters, or attached to the outer surfaces of endoplasmic reticulum, and functioning as the site of protein manufacture.

Rotifers: The rotifers (wheel animals) make up a phylum of microscopic and near-microscopic pseudo-coelomate animals.

Saprophytes: Any organism that lives on dead organic matter, as certain fungi and bacteria.

Spermatozoa: Spermatozoa (sperm) are the male sex cells that carry a man's genetic material. **Stroma:** The matrix of a chloroplast, containing various molecules and ions. The supporting framework or matrix of a cell.

Superoxide: A compound containing the univalent ion O 2 −.

Thylakoid: A flattened sac or vesicle lined with a pigmented membrane that is the site of photosynthesis, in plants and algae occurring in interconnected stacks constituting a granum of the chloroplast, and in other photosynthesizing organisms occurring either singly or as part of the cell membrane or other structure.

Tonoplast: A membrane separating a vacuole from the surrounding cytoplasm in a plant cell.

Unicellular: Having or consisting of a single cell.

Vacuole: A membrane-bound cavity within a cell, often containing a watery liquid or secretion. **Vesicle:** It is a small structure within a cell, or extracellular, consisting of fluid enclosed by a lipid bilayer. Vesicles form naturally during the processes of secretion (exocytosis), uptake (endocytosis) and transport of materials within the cytoplasm.

Xylem: A compound tissue in vascular plants that helps provide support and that conducts water and nutrients upward from the roots, consisting of tracheids, vessels, parenchyma cells, and woody fibers.

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UNIT-2 STRUCTURES AND FUNCTIONS OF CELL ORGANELLES

2.2 INTRODUCTION

Our natural world originated the principle of form following function, especially in cell biology, and this will become clear as we explore eukaryotic cells. Unlike prokaryotic cells, eukaryotic cells have: (1) a membrane-bound nucleus; (2) numerous membrane-bound organelles—such as the endoplasmic reticulum, Golgi apparatus, chloroplasts, mitochondria, and others; and (3) several, rod-shaped chromosomes. Because a eukaryotic cell‘s nucleus is surrounded by a membrane, it is often said to have a —*true nucleus*‖. The word —*organelle*‖ means —*little organ*,‖ and, organelles have specialized cellular functions, just as the organs of your body have specialized functions.

Cells are the smallest units of life. They are a closed system, can self-replicate, and are the building blocks of our bodies. In order to understand how these tiny organisms work, we will look at a cell‘s internal structures. We will focus on eukaryotic cells, cells that contain a nucleus. A cell consists of two major regions, the cytoplasm and the nucleus. The nucleus is surrounded by a nuclear envelope and contains DNA in the form of chromosomes. The cytoplasm is a fluid matrix that usually surrounds the nucleus and is bound by the outer membrane of the cell. Organelles are small structures within the cytoplasm that carry out functions necessary to maintain homeostasis in the cell. They are involved in many processes, for example energy production, building proteins and secretions, destroying toxins, and responding to external signals.

Organelles are considered either membranous or non-membranous. Membranous organelles possess their own plasma membrane to create a lumen separate from the cytoplasm. This may be the location of hormone synthesis or degradation of macromolecules. Nonmembranous organelles are not surrounded by a plasma membrane. Most non-membranous organelles are part of the cytoskeleton, the major support structure of the cell. These include: filaments, microtubules, and centrioles.

Ribosomes, as a site for turning RNA code into protein sequences, and *chromosomes*, the DNA storage complex, are examples of non-membrane organelles. These non-membranous organelles are commonly *molecular complexes.* They may have complex functions, but the processes by which those functions are done are usually localized to the surfaces of the complex. They neither require specific isolation nor a large working surface of membrane. Some functional parts of a eukaryote cell are types of extensions of the external membrane. They will be treated here as *cell extension organelles,* although they are not always called "organelles" in some biology books.

The "soup" inside a cell, often so thick that it becomes a gel, has various names. In prokaryotes, its *protoplasm.* In eukaryotes, the material between the cell membrane and the nuclear envelope is usually called *cytoplasm,* which sometimes is further divided as *cytosol* is considered to be just outside the organelles. The material inside the nucleus is usually called *nucleoplasm.* All these organelles along with their structures and functions have been discussed in this unit.

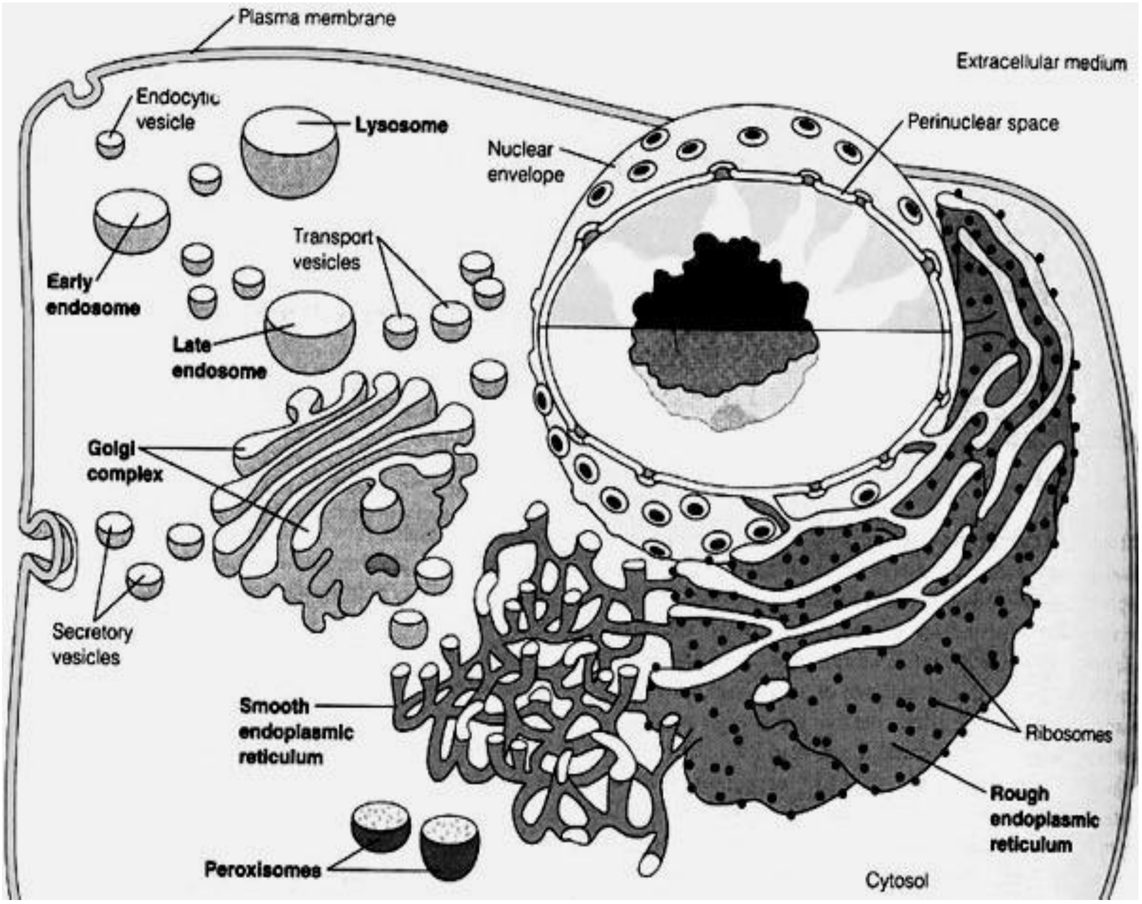

Fig.2.1 Typical Cell Membrane Bound Compartments

2.3 NUCLEUS

Nucleus the most prominent organelle of the cell. The number of nuclei may vary, they may be uninucleate (single nucleus), binucleate (two nuclei) or even multi-nucleate. Certain eukaryotic cells such as the mature sieve tubes of higher plants and mammalian erythrocytes contain no nucleus. Prokaryotic cells lack nucleus and is complemented by nucleoid.

The contents of the nucleus are DNA genome, RNA synthetic apparatus, and a fibrous matrix. It is surrounded by two membranes, each one a phospholipid bilayer containing many different types of proteins. The inner nuclear membrane defines the nucleus itself. In most cells, the outer nuclear membrane is continuous with the rough endoplasmic reticulum, and the space between the inner and outer nuclear membranes is continuous with the lumen of the rough endoplasmic reticulum. The two nuclear membranes appear to fuse at nuclear pores, the ring-like complexes composed of specific membrane proteins through which material moves between the nucleus and the cytosol. It contains cell's genetic material, organized as multiple long linear DNA molecules in complex with histones, to form chromosomes. The genes within these chromosomes are the cell's nuclear genome. The function is to maintain the integrity of the genes that controls the activities of the cell by regulating gene expression.

History

Nucleus was the first cell organelle to be discovered. **Antonie von Leeuwenhoek** (1632 - 1723) observed lumen (nucleus) in the red blood cells of salmon. The nucleus was also described in 1804 by **Franz Bauer** (14 March 1758 – 11 December 1840) an Austrian microscopist & botanical artist, and, in more detail in 1831 by Scottish botanist **Robert Brown (21 December 1773 – 10 June 1858)** in a talk at the *Linnean Society of London*. Brown was studying orchids under microscope when he observed an opaque area, which he called the "*areola*" or "*nucleus*", in the cells of the flower's outer layer. It was discovered and named by Robert Brown in 1833 in the plant cells and is recognized as a constant feature of all animal and plant cells.

Nucleus Definition

In cell biology, the nucleus (plural-nuclei; from Latin *nucleus* or *nuculeus*, meaning kernel or seed) is a membrane-enclosed organelle found in eukaryotic cells. Eukaryotes usually have a single nucleus, but a few cell types, such as mammalian red blood cells, have no nuclei, and a few others have many. Human skeletal muscle cells have more than one nucleus, as do eukaryotes like fungi. Cell nuclei contain most of the cell's genetic material, organized as multiple long linear DNA molecules in complex with a large variety of proteins, such as histones, to form chromosomes. The genes within these chromosomes are the cell's nuclear genome and are structured in such a way to promote cell function. The nucleus maintains the integrity of genes and controls the activities of the cell by regulating gene expression—the nucleus is, therefore, the control center of the cell.

2.3.1- Origin

A study of the comparative genomics, evolution and origins of the nuclear membrane led to the proposal that the nucleus emerged in the primitive eukaryotic ancestor (the ―prekaryote‖), and was triggered by the archaeo-bacterial symbiosis. Several ideas have been proposed for the evolutionary origin of the nuclear membrane. These ideas include the invagination of the plasma membrane in a prokaryote ancestor, or the formation of a genuine new membrane system following the establishment of proto-mitochondria in the archaeal-host. The adaptive function of the nuclear membrane may have been to serve as a barrier to protect the genome from reactive oxygen species (ROS) produced by the cells' pre-mitochondria.

2.3.2- Nucleus Structure

The nucleus is the largest organelle of the cell. It occupies about 10% of the total volume of the cell. In mammalian cells the average diameter of the nucleus is approximately 6 micrometers. The viscous liquid within it is called nucleoplasm (karyolymph), and is similar in composition to the cytosol found outside the nucleus. Generally there is a single nucleus per cell (Mononucleate conditions), but more than one nucleus (Polynucleate condition) may be found in certain special cases. There are many nuclei in a syncytium which is formed due to fusion of cells. A similar multinucleate situation is found in coenocytes commonly found in plants. A coenocyte results by repeated nuclear divisions without cytokinesis.

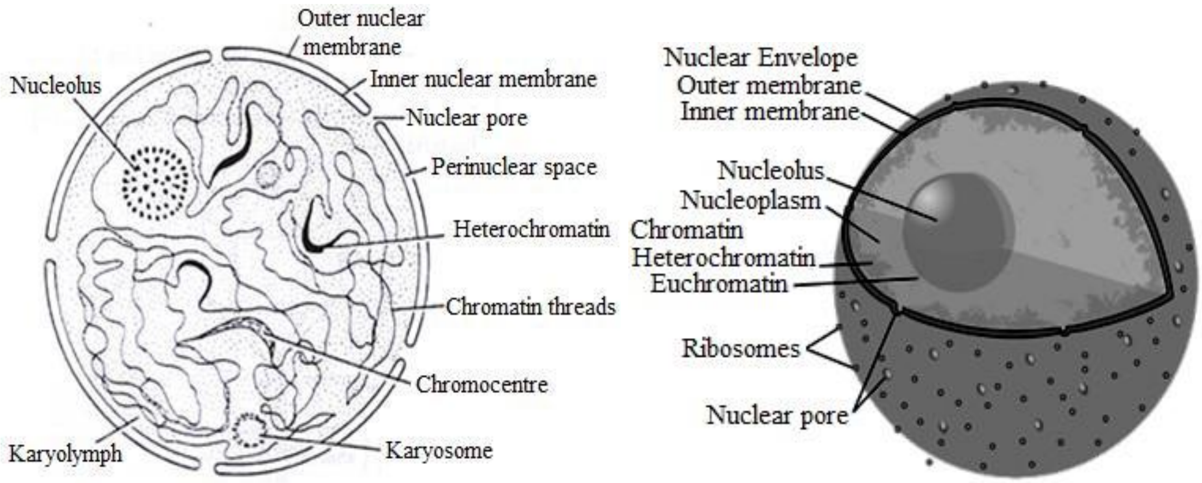

Fig.2.2 The schematic representation of nucleus

There are also variations with respect to shape and size of nucleus. It may be spherical oval to flattened lobe or irregular in shape. Shape of nucleus also depends on the cell. The spheroid, cuboid or polyhedral cells, nucleus is usually spheroid. In cylindrical, prismatic or fusiform cells, nucleus is ellipsoid.

Nuclear Envelope

1. The nuclear envelope is also known as the nuclear membrane.
2. It is made up of two membranes the outer membrane and the inner membrane.
3. The outer membrane of the nucleus is continuous with the membrane of the rough endoplasmic reticulum.
4. The space between these layers is known as the Perinuclear space.
5. The nuclear envelope encloses the nucleus and separates the genetic material of the cell from the cytoplasm of the cell.
6. It also serves as a barrier to prevent passage of macro-molecules freely between the nucleoplasm and the cytoplasm.

Nuclear Pore

1. The nuclear envelope is perforated with numerous pores called nuclear pores.
2. The nuclear pores are composed of many proteins known as nucleoproteins.

3. The nuclear pores regulate the passage of the molecules between the nucleus and cytoplasm.
4. The pores allow the passage of molecules of only about 9nm wide. The larger molecules are transferred through active transport.
5. Molecules like of DNA and RNA are allowed into the nucleus. But energy molecules (ATP), water and ions are permitted freely.

Chromosomes (Chromatin structure)

1. The nucleus of the cell contains majority of the cells genetic material in the form of multiple linear DNA molecules.
2. These DNA molecules are organized into structures called chromosomes.
3. The DNA molecules are in complex with a large variety of proteins (histones) which form the chromosome.
4. In the cell they are organized in a DNA-protein complex known as chromatin.
    a. Chromatin = DNA + Histone + DNA binding proteins.
    b. Two type of chromatin are present.
        (i) Euchromatin
        (ii) Heterochromatin
5. During cell-division the chromatin forms well-defined chromosomes.
6. The genes within the chromosomes consists of the cells nuclear genome.
7. Mitochondria of the cell also contains a small fraction of genes.
8. Human cells has nearly 6 feet of DNA, which is divided into 46 individual molecules.

Nucleolus

1. The nucleolus is not surrounded by a membrane, it is a densely stained structure found in the nucleus.
2. The nucleoli are formed around the nuclear organizer regions.
3. It synthesizes and assembles ribosomes and r-RNA.
4. The number of nucleoli is different from species to species but within a species the number is fixed.
5. During cell division, the nucleolus disappears.
6. Studies suggest that nucleolus may be involved in cellular aging and senescence.

In the nucleolus seems to proceed from center to periphery 3 distinct region are:

i) **Fibriller Center (FC):** Where r-RNA genes of nucleolus organizer region (NOR) are located, the transcription of r-RNA genes also takes place in this region.

ii) **Dense Fibriller Component (DFC):** Which surround the fibriller genes and where RNA synthesis progress. The 80S ribosomal proteins also bind to the transcripts in this region.

iii) **Cortical Granular Component(CGC):** It is the inner-most region and where processing and maturation of pre ribosomal particles occurs. Therefore, these region roles in —ribosome formation.

2.3.3- Functions of the Nucleus

Speaking about the functions of a cell nucleus, it controls the hereditary characteristics of an organism. This organelle is also responsible for the protein synthesis, cell division, growth, and differentiation. Some important functions carried out by a cell nucleus are:

1. Storage of hereditary material, the genes in the form of long and thin DNA (deoxyribonucleic acid) strands, referred to as chromatins.
2. Storage of proteins and RNA (ribonucleic acid) in the nucleolus.
3. It is responsible for protein synthesis, cell division, growth and differentiation.
4. Nucleus is a site for transcription in which messenger RNA (mRNA) are produced for the protein synthesis.
5. It controls the heredity characteristics of an organism. Exchange of hereditary molecules (DNA and RNA) between the nucleus and rest of the cell.
6. During the cell division, chromatins are arranged into chromosomes in the nucleus.
7. Production of ribosomes (protein factories) in the nucleolus.
8. Selective transportation of regulatory factors and energy molecules through nuclear pores.
9. It also regulates the integrity of genes and gene expression.

Animal Cell Nucleus

Animal cell nucleus is a membrane bound organelle. It is surrounded by double membrane. The nucleus communicates with the surrounding cell cytoplasm through the nuclear pores. The DNA in the nucleus is responsible for the hereditary characteristics and protein synthesis. The active genes on the DNA are similar, but some genes may be turned on or off depending on the specific cell type. This is the reason why a muscle cell is different from a liver cell. Nucleolus is a prominent structure in the nucleus. This aids in ribosomes production and protein synthesis.

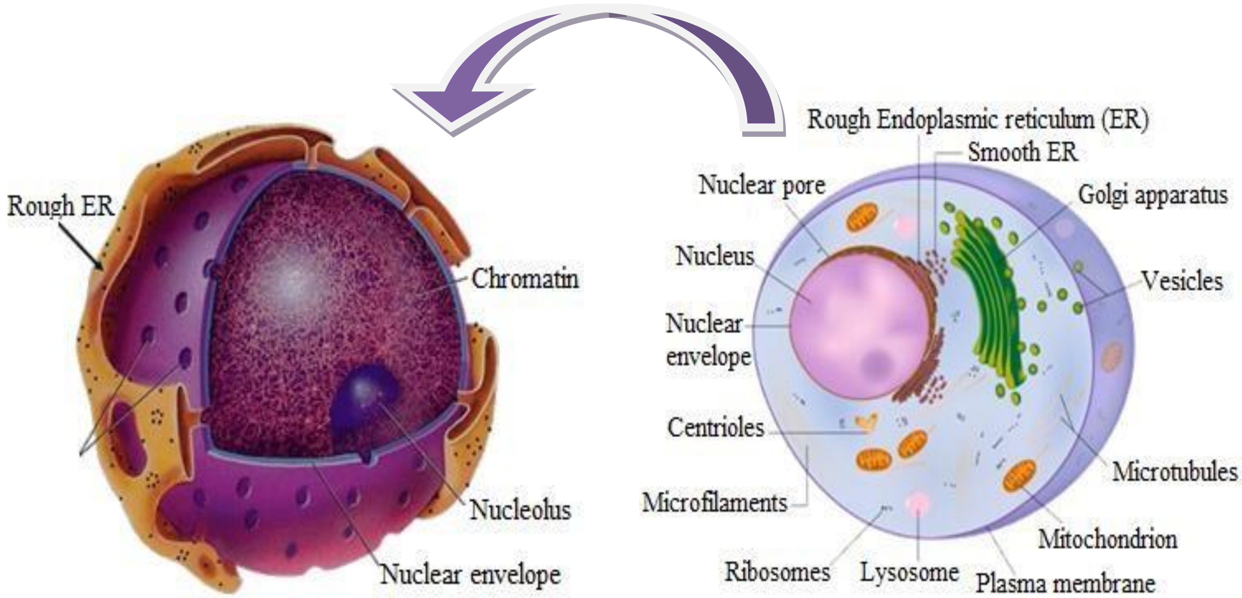

Fig. 2.3 Structure of a typical Animal cell nucleus

Plant Cell Nucleus

Plant cell nucleus is a double-membrane bound organelle. It controls the activities of the cell and is known as the master mind or the control center of the cell. The plant cell wall has two layers - the outer membrane and the inner membrane, which encloses a tiny space known as perinuclear space. The nucleus communicates to the cell cytoplasm through the nuclear pores present in the nuclear membrane. The nuclear membrane is continuous with the endoplasmic reticulum. The
DNA is responsible for cell division, growth and protein synthesis.

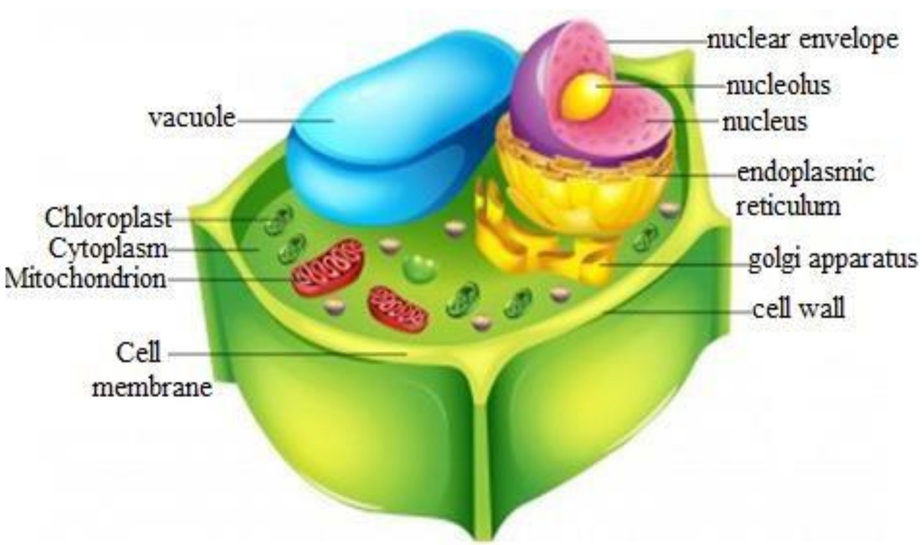

Fig. 2.4 Structure of typical Plant cell with nucleus

Bacterial Cell Nucleus

Bacteria are minute single-celled microorganisms under the domain Prokaryota. Interestingly, they are believed to be the direct descendants of the first ever organisms that thrive on Earth about 3.5 billion years ago.

While they seem to be invisible with the naked eye, under powerful microscopes, the structures within bacteria can be observed.

The bacterial cell does not contain any nucleus. The bacterial chromosome is not enclosed in a membrane bound nucleus. The bacterial chromosome is circular and located in the cytoplasm.

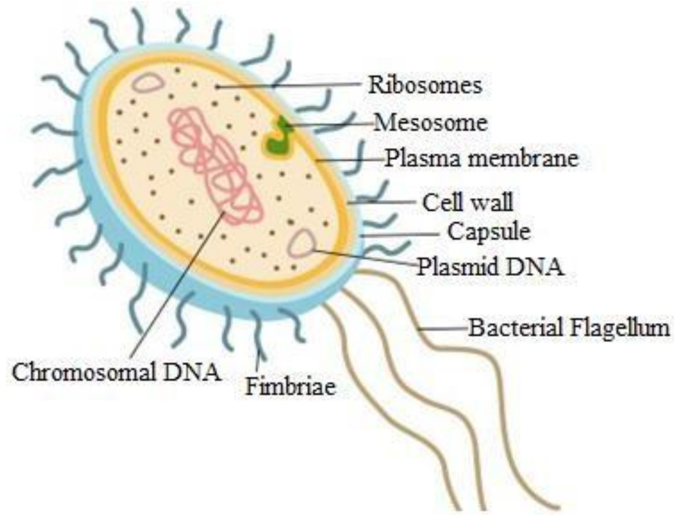

Fig. 2.5 Structure of a typical bacterial cell

2.4 RIBOSOME

Proteins are necessary for the cells to perform cellular functions. Ribosomes are the cellular components that make proteins from all amino acids. Ribosomes are made from complexes of RNAs and proteins. The number of ribosomes in a cell depends on the activity of the cell. Ribosomes are freely suspended in the cytoplasm or attached to the endoplasmic reticulum forming the rough endoplasmic reticulum. On an average in a mammalian cell there can be about 10 million ribosomes.

When the ribosomes are attached to the same mRNA strand, this structure is known as Polysome. The existence of ribosomes is temporary, after the synthesis of polypeptide the two sub-units separate and is reused or broken up. Amino acids are joined by the ribosomes at a rate of 200 per minute. Therefore small proteins can be made quickly but two or three hours are needed for proteins which are as large as 30,000 amino acids.

The ribosomes present in the prokaryotes function differently in protein production than the ribosomes of the eukaryote organisms. The ribosomes of bacteria, archaea and eukaryotes differ significantly from each other in structure and RNA sequences. The differences in the ribosomes allows the antibiotic to kill the bacterial ribosome by inhibiting the activity of the bacterial ribosomes, the human ribosome remain unaffected. The ribosomes of the eukaryotic cells are similar to the ribosomes of the bacterial cells, showing the evolutionary origin of the organelle.

Ribosomes Definition

Ribosomes are small particles, present in large numbers in all the living cells. They are sites of protein synthesis. The ribosome word is derived - '*ribo'* from ribonucleic acid and '*somes*' from the Greek word '*soma*' which means '*body'*. The ribosomes link amino acids together in the order that is specified by the messenger RNA molecules.

The ribosomes are made up of two subunits - a small and a large subunit. The small subunit reads the mRNA while the large subunit joins the amino acids to form a chain of polypeptides. Ribosomal subunits are made of one or more rRNA (ribosomal RNA) molecules and various proteins. The ribosomes and associated molecules are also known as the translational apparatus.

Ribosomes were first observed in the mid-1950s by Romanian-American cell biologist **George Emil Palade**, using an electron microscope, as dense particles or granules. The term "ribosome" was proposed by scientist **Richard B. Roberts** in the end of 1950s.

Types of Ribosomes

Ribosomes are classified into two types based on their sedimentation coefficient, 70S and 80S. S stands for "Svedberg unit" and related to sedimentation rate (sedimentation depends on mass and size). Thus, the value before S indicates size of ribosome.

2.4.1- Origin

The ribosome may have first originated in an RNA world, appearing as a self-replicating complex that only later evolved the ability to synthesize proteins when amino acids began to appear. Studies suggest that ancient ribosomes constructed solely of rRNA could have developed the ability to synthesize peptide bonds. In addition, evidence strongly points to ancient ribosomes as self-replicating complexes, where the rRNA in the ribosomes had informational, structural, and catalytic purposes because it could have coded for tRNAs and proteins needed for ribosomal self-replication.

In the prokaryotes, the ribosome originates in the cytoplasm as there is no nucleolus, but in eukaryotes, the ribosome is partly nucleolar (rRNA) and partly cytoplasmic (proteins) in origin.

2.4.2- Structure

1. Ribosomes are tiny particles about 200 Ã. Ribosomes in a cell are located in two regions of the cytoplasm. They are found scattered in the cytoplasm and some are attached to the endoplasmic reticulum.
2. When the ribosomes are bound to the ER there are known as the Rough Endoplasmic Reticulum (RER). The bound and the free ribosomes are similar in structure and are involved in protein synthesis.
3. Ribosomes are composed of both RNA and proteins. About 37 - 62% of RNA are made up of RNA and the rest is proteins.

4. Ribosome is made up of two subunits. The subunits of ribosomes are named according to their ability of sedimentation on a special gel which the Svedberg Unit.
5. Prokaryotes have 70S ribosomes, each subunit consisting of small subunit is of 30S and the large subunit is of 50S. Eukaryotes have 80S ribosomes, each consisting of small (40S) and large (60S) subunit.
6. The ribosomes found in the chloroplasts of mitochondria of eukaryotes consists of large and small subunits bound together with proteins into one 70S particle.
7. The ribosomes share a core structure which is similar to all ribosomes despite differences in its size.
8. The RNA is organized in various tertiary structures. The RNA in the larger ribosomes are into several continuous insertion as they form loops out of the core structure without disrupting or changing it.
9. The catalytic activity of the ribosome is carried out by the RNA, the proteins reside on the surface and stabilize the structure.
10. The differences between the ribosomes of bacterial and eukaryotic are used to create antibiotics that can destroy bacterial infection without harming human cells.

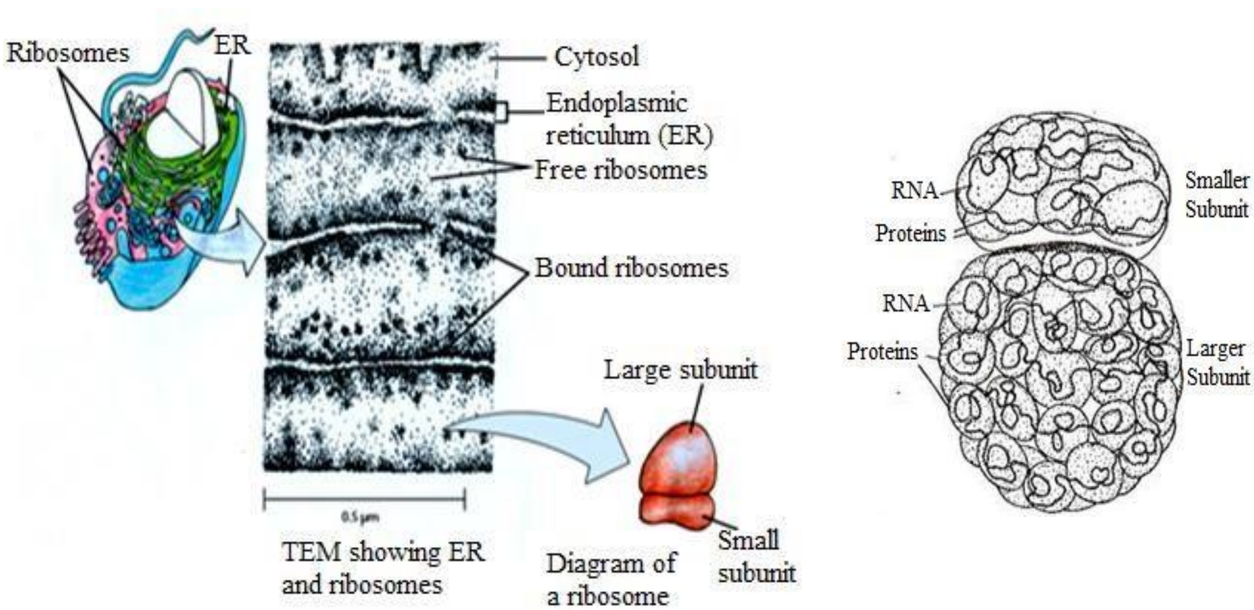

Fig: 2.6 Schematic representation of the ribosome

2.4.3-Function

1. Nearly all the proteins required by cells are synthesized by ribosomes. Ribosomes are found

   ‗free' in the cell cytoplasm and also attached to rough endoplasmic reticulum.
2. Ribosomes receive information from the cell nucleus and construction materials from the cytoplasm.

3. Ribosomes translate information encoded in messenger ribonucleic acid (mRNA).
4. They link together specific amino acids to form polypeptides and they export these to the cytoplasm.
5. A mammalian cell may contain as many as 10 million ribosomes, but each ribosome has only a temporary existence.
6. Ribosomes can link up amino acids at a rate of 200 per minute.
7. Ribosomes are formed from the locking of a small sub-unit on to a large sub-unit. The subunits are normally available in the cytoplasm, the larger one being about twice the size of the smaller one.
8. Each ribosome is a complex of Ribonucleoprotein with two-thirds of its mass is composed of ribosomal RNA and about one-third ribosomal protein.
9. Protein production takes place in three stages: (1) Initiation, (2) elongation, and (3) termination.
10. During peptide production the ribosome moves along the mRNA in an intermittent process called translocation.
11. Antibiotic drugs such as streptomycin can be used to attack the translation mechanism in prokaryotes. This is very useful. Unfortunately some bacterial toxins and viruses can also do this.
12. After they leave the ribosome most proteins are folded or modified in some way. This is

    called ‗post translational modification'.

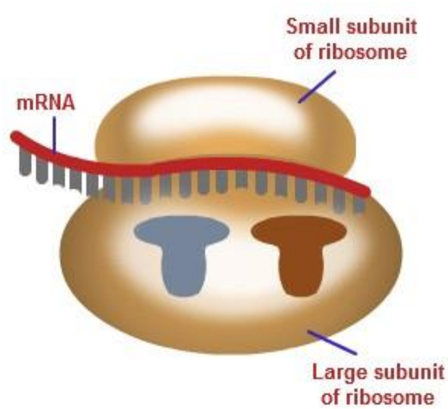

Fig. 2.7 Ribosome as a site of protein synthesis

2.5 NUCLEOPLASM

The nucleus of most cells contains a substance that suspends structures inside the nuclear membrane. Just like the cytoplasm found inside a cell, the nucleus contains nucleoplasm, also known as **Karyoplasm**.

The nucleoplasm is a type of protoplasm that is made up mostly of water, a mixture of various molecules, and dissolved ions. It is completely enclosed within the nuclear membrane or nuclear envelope. It is a highly gelatinous, sticky liquid that supports the chromosomes and nucleoli. The soluble, fluid component of the nucleoplasm is called the **Nucleosol** or **Nuclear Hyaloplasm**. The nucleoplasm includes the chromosomes and nucleoli. Many substances such as nucleotides (necessary for purposes such as the replication of DNA) and enzymes (which direct activities that take place in the nucleus) are dissolved in the nucleoplasm.

The term "*nucleoplasm*" was coined by embryologist, cytologist and marine biologist **Edouard van Beneden** (1875), while "*karyoplasm*" was by **Walther Flemming** (1878) a German biologist and a founder of Cytogenetics.

2.5.1- Origin

It arises from the nuclear content and chromatin content contained in a cell nucleus.

2.5.2- Structure

The nucleoplasm consists of a viscous mix of water, in which various substances and structures are dissolved or carried, and an underlying intranuclear ultrastructure. The nucleoplasm is especially rich in protein enzymes and protein constituents involved in the synthesis of deoxyribonucleic acid (DNA) and the various types of ribonucleic acid (RNA), the precursor molecules of RNA, and the nucleotides from which they are assembled. Some of these proteins direct initial transcription, while others function in the further modification of the RNA molecules for packaging and transport to the cytoplasm.

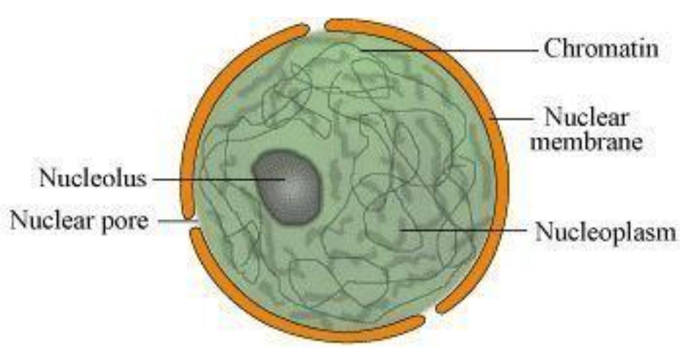

Fig. 2.8 Structure of Nucleus showing Nucleoplasm

Prominent structures located within the interphase nucleoplasm (the resting cell or the non replicating cell) include organelles called nucleoli and the unwound DNA, called chromatin. The nucleoli resemble miniature nuclei and are the sites of synthesis of precursor RNA molecules and their assembly.

The other major components in nucleoplasm include the DNA chromosomes seen during mitosis. During cell interphase most of the DNA chromosomes exist as unwound chromatin that extend through the nucleoplasm. Two distinct types of chromatin are recognized. Diffuse, or uncondensed, chromatin is called Euchromatin and exists as thin threads that extend throughout much of the nucleoplasm.

2.5.3- Function

1. The nucleoplasm acts as a suspension medium for components of the nucleus including the nucleolus, and chromatin.
2. Nucleotides required for DNA replication and enzymes involved in other nuclear processes are also found dissolved within the nucleoplasm.
3. The nucleoplasm plays a role in the maintenance of the shape and structure of the nucleus.
4. The nuclear matrix is present within the nuclear hyaloplasm, the liquid component of the nucleoplasm.
5. One other function is that it is responsible for the transport of materials that are vital to metabolism and cell function.

2.6 MITOCHONDRIA

Mitochondria are well-defined cytoplasmic organelles of the cell which take part in a variety of cellular metabolic functions. Survival of the cells requires energy to perform different functions. The mitochondria are important as the fact that these organelles supply all the necessary biological energy of the cell, and they obtain this energy by oxidizing the substrates of the Krebs cycle. Energy of the cell is got from the enzymatic oxidation of chemical compounds in the mitochondria. Hence, the mitochondria re referred to as the "***power houses of the cell***". Almost all the eukaryotic cell have mitochondria, though they are lost in the later stages of development of cell like in the red blood cells or in elements of phloem sieve tube.

In 1890, mitochondria were first described by **Richard Altmann** (12 March 1852 – 8 December 1900) an German pathologist and histologist, and he called them as "*bioblasts*". **Carl Benda,** another German scientist (one of the first microbiologists) in the year 1897 coined the term "*mitochondrion"*. In the 1920s, a biochemist Warburg found that oxidative reactions takes place in most tissues in small parts of the cell.

Mitochondria Definition

Mitochondria is a membrane bound cellular structure and is found in most of the eukaryotic cells. The term 'mitochondrion' is derived from a Greek word *mitos* which means "thread" and *chondrion* which means "granule" or "grain-like". Mitochondria are commonly between 0.75 and 3 μm in diameter but vary considerably in size and structure. The mitochondria are sometimes described as power plants of the cells. These organelles generate most of the energy of the cell in the form of adenosine triphosphate (ATP) and it is used a source of chemical energy. The mitochondria also involved in other cellular activities like signaling, cellular differentiation, cell senescence and also control of cell cycle and cell growth. Mitochondria also affect human health, like mitochondrial disorder and cardiac dysfunction and they also play important role in the aging process.

2.6.1- Origin

There are two hypotheses about the origin of mitochondria: endosymbiotic and autogenous. The endosymbiotic hypothesis suggests that mitochondria were originally prokaryotic cells, capable of implementing oxidative mechanisms that were not possible for eukaryotic cells; they became endosymbionts living inside the eukaryote. In the autogenous hypothesis, mitochondria were born by splitting off a portion of DNA from the nucleus of the eukaryotic cell at the time of divergence with the prokaryotes; this DNA portion would have been enclosed by membranes, which could not be crossed by proteins. Since mitochondria have many features in common with bacteria, the endosymbiotic hypothesis is more widely accepted.

Unlike any other organelle, except for chloroplasts, mitochondria appear to originate only from other mitochondria. They contain their own DNA, which is circular as is true with bacteria, along with their own transcriptional and translational machinery. Mitochondrial ribosomes and transfer RNA molecules are similar to those of bacteria, as are components of their membrane.

2.6.2- Structure

A mitochondrion contains outer and inner membranes composed of phospholipid bilayers and proteins. The two membranes have different properties. Because of this double-membraned organization, there are five distinct parts to a mitochondrion.

1. Outer mitochondrial membrane,
2. Intermembrane space (the space between the outer and inner membranes),
3. Inner mitochondrial membrane,
4. Cristae space (formed by infoldings of the inner membrane), and
5. Matrix (space within the inner membrane).

Mitochondria stripped of their outer membrane leaving the inner membrane intact are called Mitoplasts.

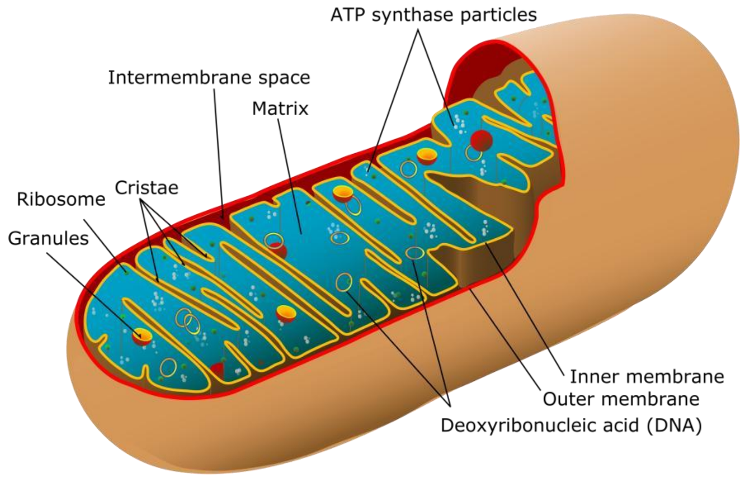

Fig.2.9 Structure of Mitochondria

Outer Membrane

1. It is smooth and is composed of equal amounts of phospholipids and proteins.
2. It has a large number of special proteins known as the Porins.
3. The Porins are integral membrane proteins and they allow the movement of molecules that are of 5000 daltons or less in weight to pass through it.
4. The outer membrane is freely permeable to nutrient molecules, ions, oxygen, pyruvate, energy molecules like the ATP and ADP molecules.

Intermembrane Space

1. It is the space between the outer and inner membrane of the mitochondria, it has the same composition as that of the cell's cytoplasm.
2. It has a high proton concentration. This is due to the electron transport system of the inner mitochondrial membrane.

Inner Membrane

1. The inner membrane of mitochondria is more complex in structure.
2. It has many invaginations and is known as the Cristae.
3. This folding help to increase the surface area inside the organelle.
4. Many of the chemical reactions that take place within mitochondria occur on the inner membrane. It contains the electron transport system and the ATPase complex:

(i) Electron transport system - generates a proton gradient.

(ii) ATPase complex - uses proton gradient to produce adenosine triphosphate (ATP) from adenosine diphosphate (ADP).

5. Hence the inner mitochondrial membrane is the site of oxidative phosphorylation.

6. Unlike the outer membrane, the inner membrane is strictly permeable, it is permeable only to oxygen, ATP and it also helps in regulating transfer of metabolites across the membrane.

Cristae Space

The inner mitochondrial membrane is compartmentalized into numerous Cristae, which expand the surface area of the inner mitochondrial membrane, enhancing its ability to produce ATP. Cristae are covered with many tiny "*stalked particles*" called inner membrane spheres that are also known as simply "*spheres*" or "*knobs*".

Matrix Space

The matrix of the mitochondria is a complex mixture of proteins and enzymes. These enzymes are important for the synthesis of ATP molecules, mitochondrial ribosomes, tRNAs and mitochondrial DNA.

Plant Cell Mitochondria

Like in other eukaryotic cells, the mitochondria in plants play an important role in the production of ATP via the process of oxidative phosphorylation. Mitochondria also play essential roles in other aspects of plant development and performance. It also has various properties which allows the mitochondria to interact with special features of metabolism in plant cell.

Animal Cell Mitochondria

Mitochondria are known as "power houses" of the cells, they are unusual organelles and are surrounded by a double membrane. These organelles have their own small genome. They divide independently by simple fission. The division of the mitochondria is a result of the energy demand, so the cells with high need of energy have greater number of mitochondria. A typical animal cell may have about 1000 to 2000 mitochondria. The process creating energy for the cell is known as cellular respiration. Most of the chemical reactions of this process happen in the mitochondria.

2.6.3- Function

Functions of mitochondria depend on the cell type in which they are present.

1. The most important function of the mitochondria is to produce energy. The simpler molecules of nutrition are sent to the mitochondria to be processed and to produce charged molecules. These charged molecules combine with oxygen and produce ATP molecules. This process is known as oxidative phosphorylation.
2. Mitochondria help the cells to maintain proper concentration of calcium ions within the compartments of the cell.

3. The mitochondria also help in building certain parts of blood and hormones like testosterone and estrogen.
4. The liver cells mitochondria have enzymes that detoxify ammonia.
5. The mitochondria also play important role in the process of apoptosis or programmed cell death. Abnormal death of cells due to the dysfunction of mitochondria can affect the function of organ.

2.7 CHLOROPLAST

The word chloroplast is derived from the Greek word *chloros* meaning "green" and *plastes* meaning "the one who forms". Chloroplasts are organelles, specialized compartments, in plant and algal cells. Their discovery inside plant cells is usually credited to Julius von Sachs (1832–1897), an influential botanist and author of standard botanical textbooks - sometimes called "The Father of Plant Physiology".

Chloroplasts are organelles present in plant cells and some eukaryotic organisms. Chloroplasts are the most important plastids found in plant cells. It is the structure in a green plant cell in which photosynthesis occurs. Chloroplast is one of the three types of plastids. The chloroplasts take part in the process of photosynthesis and it is of great biological importance. Animal cells do not have chloroplasts. All green plant take part in the process of photosynthesis which converts energy into sugars and the byproduct of the process is oxygen that all animals breathe. This process happens in chloroplasts. The distribution of chloroplasts is homogeneous in the cytoplasm of the cells and in certain cells chloroplasts become concentrated around the nucleus or just beneath the plasma membrane. A typical plant cell might contain about 50 chloroplasts per cell.

2.7.1- Origin

Chloroplasts are unique organelles and are said to have originated as endosymbiotic bacteria. They develop from colourless precursors, called Proplastids or Eoplasts. They are semi autonomous in nature and arise from pre existing chloroplast as they have their own machinery to synthesize the required proteins. This is very clear in algae, where one chloroplast divides into two during cell division. In higher plants, the division of chloroplasts is very difficult to observe as. the number of chloroplast is very high. Still, some-times the dividing chloroplast is seen under the phase contrast microscope as in Spinach.

2.7.2- Structure

1. Chloroplasts found in higher plants are generally biconvex or planoconvex shaped. In different plants chloroplasts have different shapes, they vary from spheroid, filamentous saucer-shaped, discoid or ovoid shaped.

2. They are vesicular and have a colorless center. Some chloroplasts are in shape of club, they have a thin middle zone and the ends are filled with chlorophyll. In algae a single huge chloroplast is seen that appears as a network, a spiral band.
3. The size of the chloroplast also varies from species to species and it is constant for a given cell type. In higher plants, the average size of chloroplast is 4-6 microns in diameter and 1- o microns in thickness.

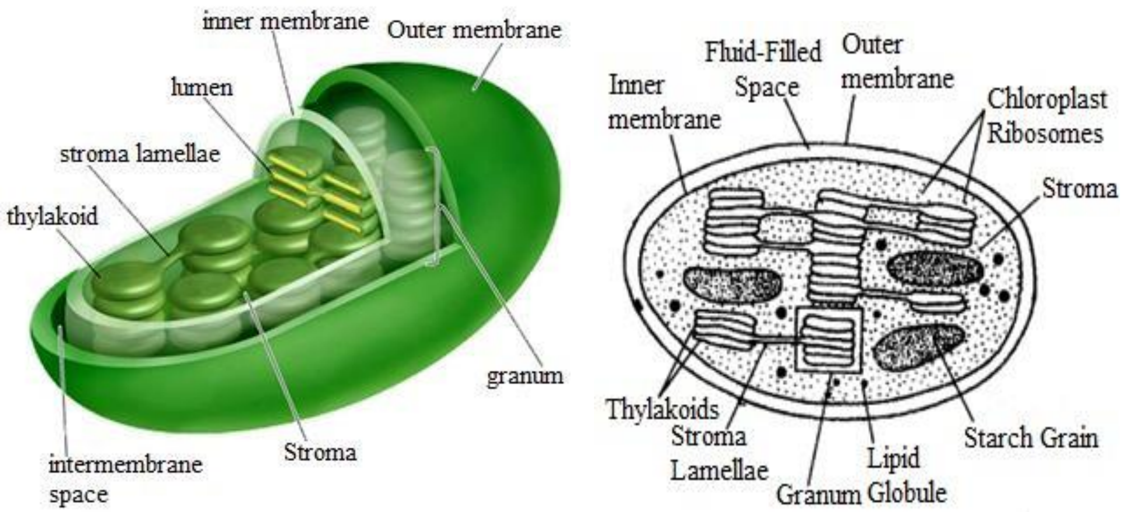

Fig.2.10 Structure of Chloroplast

4. The chloroplasts are double membrane bound organelles and are the site of photosynthesis. The chloroplasts have a system of three membranes: The Outer Membrane, The Inner Membrane and The Thylakoid system. The outer and the inner membrane of the chloroplast enclose a semigel-like fluid known as the Stroma. This stroma makes up much of the volume of the chloroplast, the thylakoids system floats in the stroma.

Components of Chloroplast

Outer Membrane: It is a semi-porous membrane and is permeable to small molecules and ions, which diffuses easily. The outer membrane is not permeable to larger proteins.

Intermembrane Space: It is usually a thin intermembrane space about 10-20 nanometers and it is present between the outer and the inner membrane of the chloroplast.

Inner Membrane: The inner membrane of the chloroplast forms a border to the stroma. It regulates passage of materials in and out of the chloroplast. In addition of regulation activity, the fatty acids, lipids and carotenoids are synthesized in the inner chloroplast membrane.

Stroma: Stroma is a alkaline, aqueous fluid which is protein rich and is present within the inner membrane of the chloroplast. The space outside the thylakoid space is called the stroma. The chloroplast DNA, chloroplast ribosomes and the thylakoid system, starch granules and many proteins are found floating around the stroma.

Thylakoid System: It is suspended in the stroma. The Thylakoid system is a collection of membranous sacks called thylakoids. The chlorophyll is found in the thylakoids and is the sight for the process of light reactions of photosynthesis to happen. The thylakoids are arranged in stacks known as Grana. Each granum contains around 10-20 thylakoids.

General Features of Thylakoid System

1. Thylakoids are interconnected small sacks, the membranes of these thylakoids is the site for the light reactions of the photosynthesis to take place. The word thylakoid is derived from the Greek word "*thylakos"* which means 'sack'.
2. Important protein complexes which carry out light reaction of photosynthesis are embedded in the membranes of the thylakoids. The Photosystem I and the Photosystem II are complexes that harvest light with chlorophyll and carotenoids, they absorb the light energy and use it to energize the electrons.
3. The molecules present in the thylakoid membrane use the electrons that are energized to pump hydrogen ions into the thylakoid space, this decrease the pH and become acidic in nature. A large protein complex known as the ATP synthase controls the concentration gradient of the hydrogen ions in the thylakoid space to generate ATP energy and the hydrogen ions flow back into the stroma.
4. Thylakoids are of two types - Granal Thylakoids and Stromal Thylakoids. Granal thylakoids arranged in the grana, are pancake shaped circular discs, which are about 300-600 nanometers in diameter. The Stromal thylakoids are in contact with the stroma and are in the form of helicoid sheets.
5. The Granal thylakoids contain only Photosystem II protein complex, this allows them to stack tightly and form many granal layers with granal membrane. This structure increases stability and surface area for the capture of light.
6. The Photosystem I and ATP synthase protein complexes are present in the stroma. These protein complexes act as spacers between the sheets of Stromal thylakoids.

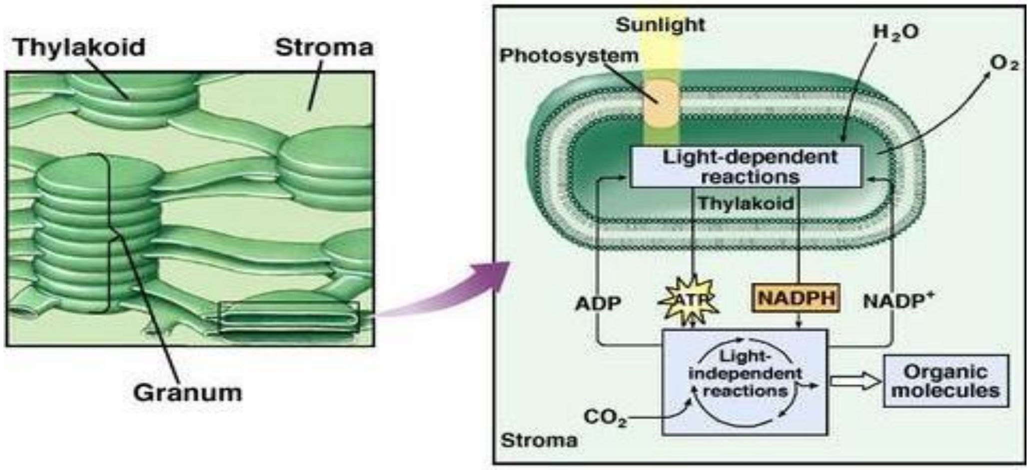

Fig. 2.11 Light reaction of photosynthesis in thylakoid

Transport of proteins into Chloroplast

1. For import of protein across double membrane, the chloroplast seems to employ ATP hydrolysis.
2. Signal peptide on chloroplast, proteins can be recognized by receptor on chloroplast membrane.
3. In first step the protein passes through chloroplast double membrane to reach stroma.
4. From where in the second step they are transported to Thylakoid space.
5. After the protein reaches the stroma, the chloroplast signal peptide cleaved by Stromal peptidase which facilitates transport to Thylakoid.

2.7.3- Functions of Chloroplast

1. In plants all the cells participate in plant immune response as they lack specialized immune cells. The chloroplasts with the nucleus and cell membrane and ER are the key organelles of pathogen defense.
2. The most important function of chloroplast is absorption of light energy and conversion of it into biological energy, making food by the process of photosynthesis. Food is prepared in the form of sugars. The chloroplast is very important as it is the cooking place for all the green plants.
3. During the process of photosynthesis sugar and oxygen are made using light energy, water, and carbon dioxide. Conversion of PGA (phosphoglyceric acid) into different sugars and store as starch.
4. Like the mitochondria, Chloroplasts use the potential energy of the H+ ions or the hydrogen ion gradient to generate energy in the form of ATP.
5. Light reactions takes place on the membranes of the thylakoids. Production of $NADPH_2$ and evolution of oxygen through the process of photolysis of water.
6. The dark reactions also known as the Calvin cycle takes place in the stroma of chloroplast.
7. Enzymes for carbon dioxide fixation and other dark reactions are present in the stroma and the enzymes for light reactions are present in

the thylakoids. Two separate ways for carbon dioxide fixation are observed in higher plants which are broadly classified into C3 and C4 plants.

8. Breaking of 6-carbon atom compound into two molecules of phosphoglyceric acid by the utilization of assimilatory powers ($NADPH_2$ and ATP).

2.8 TYPES OF PLASTID

Plastids are double membraned organelles which are found in plant cells only. They are usually spherical or discoidal in shape and their average size is 4-6 µm. A plastid shows two distinct regions- Grana and Stroma. Grana are stacks of membrane-bound, flattened, discoid sacs containing chlorophyll molecules. These molecules are responsible for the production of food by the process of photosynthesis. They are, therefore, called "*Kitchen of the cell*". They are the main functional units of the chloroplast. The homogenous matrix in which grana are embedded is known as Stroma. A variety of photosynthetic enzymes and starch grains are present in the stroma. The stroma is colourless, whereas the grana contain the pigments. Plastids are living and multiply by division of the pre-existing plastids called Proplastids.

Types of Plastids

1. **Leucoplasts:** These are colorless plastids. They store the food of the plant body in the form of starch, protein and lipids. They occur most commonly in the storage cells of roots and underground stems.
2. **Chloroplasts**: These are green plastids because of the presence of chlorophyll. Chloroplasts occur abundantly in green leaves, and also to some extent in green parts of the shoot.
3. **Chromoplasts**: These are variously colored plastids. They are mostly present tin flowers and fruits.

One form of plastid can change into another. For example, leucoplasts can change into chloroplasts when the former are exposed to light for a long period.

Functions of Plastids:

1. By trapping solar energy, green plastids manufacture food through photosynthesis **2.** Chromoplasts provide colored to various flowering parts.
3. Leucoplasts help in storage of protein, starch and oil.

On the basis of presence of pigments, the plastids are of two types:
1. Chromoplasts: The chromoplasts may be further divided on the basis of colour of the pigment and these are of the following types-

A. Chloroplasts: It is the most common plastid which contains chlorophyll a and b pigments, and DNA and RNA. Chloroplasts are found mainly in the cells of the leaves of higher plants and algae. It is the most biologically important plastid. By the process of photosynthesis, they produce oxygen and the most of the chemical energy used by living organisms.

B. Phaeoplast: These are yellow or brown plastids found in brown algae, diatoms and dinoflagellates. Fucoxanthin is a carotenoid pigment which masks the colour of chlorophyll a, which is also present. It also absorbs light and transfer the energy to chlorophyll a.

C. Rhodoplasts: These are red coloured plastids. It is found in red algae and its red colour is due to phycoerythrin. It also absorbs light.

D. Chromatophores: These are present in the blue-green algae. The term chromatophore is used instead of plastid, since the pigments are not organized within a discrete plastid body but are often arranged on lamellar structures in concentric rings or plates within algal cell. Blue-green colour of this algae is due to phycocyanin and phycobilins. These accessory pigments do not participate in photosynthesis.

Non-photosynthetic chromoplasts:

(i) A variety of accessory pigments is also found which do not appear to be directly involved in photosynthesis or energy transfer.

(ii) Chromoplasts may develop from chloroplasts by accumulation of non-photosynthetic pigments, e.g., red carotenoid, Lycopene in tomatoes. Genes for synthesis of pigments lie in the nucleus.

2. Leucoplasts: These plastids are devoid of pigment and are membranous structures.

They serve to store starches, oils and proteins. These are of the following types-

A. **Amyloplasts:** These are food storage cells and store starch. These are generally found in storage tubers, cotyledons and endosperm. These are found in regions of little or no illumination.

Amyloplasts have nucleoids and ribosomes.

B. **Elaioplasts**: These are found in certain monocotyledons and their function is to store oils.

C. **Proteinoplasts:** Also known as Aleuroneplasts. These are found in seeds of Ricinus and Brazil nut, and store proteins. Epidermal cells of Helleborus also possess Proteinoplast.

- Plastid differentiation depends upon the metabolic requirements of the cell. The chloroplasts may develop from leucoplasts, and chromoplasts, which are considered end forms of plastid differentiation, may develop from either leucoplasts or chloroplasts.

- Proplastids can differentiate into one of three types of plastids and since, in certain cases, one type of plastid can differentiate into another, it has been generally assumed that all plastids are essentially the same in structure, having the ability to differentiate in various ways, depending upon the requirements of the cells.

2.9 GOLGI COMPLEX

Golgi apparatus or Golgi complex is a cytoplasmic organelle of smooth membranes sac or cisternae, tubules and vesicles. It was identified in 1897 by the Italian scientist **Camillo Golgi,** in the nerve cells of barn owl and cat by means of impregnation method, and named after him in 1898. With the aids of special staining techniques the Golgi bodies were seen as densely stained region of the cytoplasm under the optical microscope. Under the electron microscope the Golgi apparatus is seen to be composed of stacks of flattened structures which contains numerous vesicles containing secretory granules.

The Golgi apparatus is the processing, packaging and secretion organelle of the cell. It is found in all eukaryotic cells with the exception of mammalian erythrocytes, sieve tube elements. Prokaryotic cell do not contain the apparatus. In plants Golgi apparatus is formed of a number of unconnected units called Dictyosomes. The newly synthesized proteins, found in the channels of the rough endoplasmic reticulum are moved to the Golgi body where the carbohydrates are added to them and these molecules are enveloped in a part of the Golgi membrane and then the enveloped molecules leave the cell. The Golgi apparatus hence acts as the assembly factory of the cell where the raw materials are directed to the Golgi apparatus before being passed out from the cell.

Golgi apparatus Definition

An organelle, consisting of layers of flattened sacs, that takes up and processes secretory and synthetic products from the endoplasmic reticulum and then either releases the finished products into various parts of the cell cytoplasm or secretes them to the outside of the cell. The Golgi complex is responsible inside the cell for packaging of the protein molecules before they are sent to their destination. This organelles helps in processing and packaging the macromolecules like proteins and lipids that are synthesized by the cell, sometimes referred as "*post office"* of the cell.

Origin

The intracellular origin of Golgi bodies has been a hotly debated subject for many years. Among the proposed sources of new Golgi bodies are:

(i) Vesicles dis-patched from the endoplasmic reticulum,

(ii) Vesicles dispatched from the outer membrane of the nuclear envelope, (iii) Vesicles formed by invaginations of the plasma membrane, and (iv) Division of Golgi bodies al-ready present in the cell.

The most widely accepted view is that Golgi bodies are formed from vesicles dis-patched from the ER. These vesicles are called transi-tion vesicles Transition vesicles migrate to the forming face of the Golgi body, fuse there with existing cisterna membranes, and in so doing contribute to the organelle's growth.

Structure

Shape and size of Golgi complex is largely dependent upon type of cell and its physiological state. It is small in muscle cell but it is well developed in secretary cells. Further, it can be compact stack of fenestrated saccules or a diffuse network of lamellae. It posses four types of components: cisternae, tubules, vesicles and vacuoles.

1. The Golgi apparatus is a major organelle in most of the eukaryotic cells. They are membrane bound organelles, which are sac-like. They are found in the cytoplasm of plant and animal cells.

2. The Golgi complex is composed of stacks of membrane-bound structures, these structures are known as the cisternae. An individual stack of the cisternae is sometimes referred as Dictyosome.

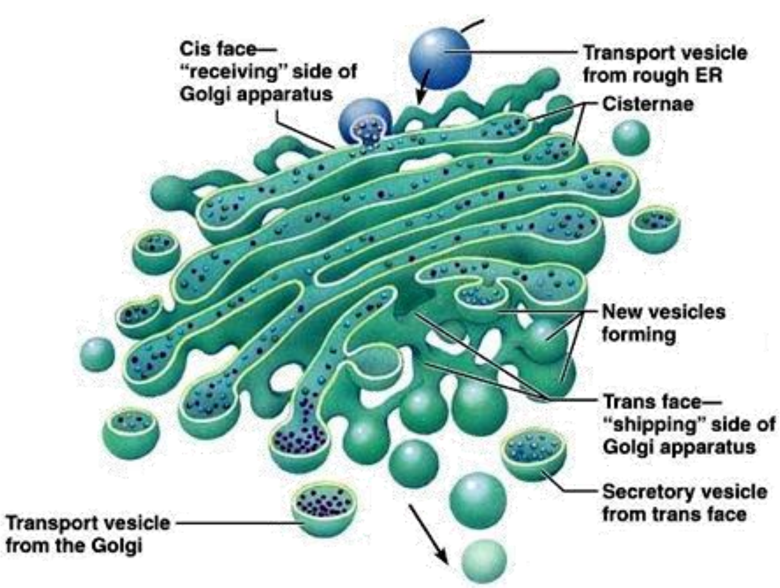

Fig.2.12 Structure of Golgi complex

3. In a typical animal cell, there are about 40-100 stacks. In a stack there are about four to eight cisternae. Each cisternae is a disc enclosed in a membrane, it possess special enzymes of the Golgi which help to modify and transport of the modified proteins to their destination.

4. The flat sacs of the cisternae are stacked and is bent and semicircular in shape. Each group of stacks is membrane bound and its insides are separated from the cytoplasm of the cell. The interaction in the Golgi membrane in responsible for the unique shape of the apparatus.

5. The Golgi complex is polar in nature. The membranes of one end of the stack is different in composition and thickness to the membranes at the other end.

6. One end of the stack is known as the **Cis-face**, it is the "receiving department" while the other end is the **Trans-face** and is the "shipping department". The Cis-face of the Golgi apparatus is closely associated with the endoplasmic reticulum.

Golgi apparatus Function

1. The cell synthesizes a huge amount of variety of macromolecules. The main function of the Golgi apparatus is to modify, sort and package the macromolecules that are synthesized by the cells for secretion purposes or for use within the cell.
2. It is involved in the formation of lysosomes and other enzyme-containing cellular inclusions, and in the formation of secretory granules in cells such as those found in the pancreas, pituitary and mammary glands, and mucous-secreting glands of the intestine and in many other cell types.
3. They are also involved in the transport of lipid molecules around the cell. The Golgi complex is thus referred as post office where the molecules are packaged, labeled and sent to different parts of the cell.
4. It mainly modifies the proteins that are prepared by the rough endoplasmic reticulum. The enzymes in the cisternae have the ability to modify proteins by the addition of carbohydrates and phosphate by the process of glycosylation and phosphorylation respectively.
5. Carbohydrates are synthesized in the Golgi body. The process of carbohydrate synthesis involves production of polysaccharides and glycosaminoglycans (GAGs).
6. The long, unbranched polysaccharides and GAGs are attached to proteins in order to form proteoglycans, the molecules that are present in the extracellular matrix of the animal cells.
7. Sulfation process of certain molecules is an important task carried out by the Golgi body. The sulfating of substances passing through the lumen of Golgi body is carried out with the help of sulfotransferases.

8. To carry out the glycosylation and phosphorylation processes, nucleotide sugars and ATP are imported by the Golgi apparatus from cytosol.
9. Golgi apparatus plays an important role in the prevention of destruction of cells (or apoptosis). The Bcl-2 genes present in the Golgi are used for this purpose.

Functions (Secretion) of Golgi complex in different types of cells

S.No.	Cell Type	Golgi body Functions
1	Plant cells	Secretion of protein and cellulose.
2	Exocrine cells of Pancreas	Secretion of Zymogen (Digestive enzymes-protease, lipase)
3	Goblet cells of intestinal mucosa	Secretion of mucus and Zymogens
4	Paneth cells of intestine	Secretion of proteins
5	Brunner‘s gland cell or duodenum and ileum	Secretion of mucopolysaccharides (Glycosaminoglycan)
6	Hepatic cells of liver	Transformation and secretion of lipids
7	Follicle cells of thyroid gland	Prothyroglobulins
8	Plasma cells of blood	Immunoglobulins
9	Cells of alveolar epithelium (mammary glands)	Secretion of milk proteins

2.10 ENDOPLASMIC RETICULUM

Endoplasmic reticulum is a continuous membrane, which is present in both plant cells, animal cells and absent in prokaryotic cells. It is the membrane of network tubules and flattened sacs, which serves a variety of functions within the cell. The space, which is present in the endoplasmic reticulum, is called as the Lumen.

The word reticulum, which means "*network*", was applied to describe the fabric of membranes. It can be defined as a eukaryotic organelle, which forms a network of tubules, vesicles and cisternae within the cells. There are two regions of the Endoplasmic reticulum, which differ in both structure and function. One region is called as Rough Endoplasmic Reticulum, as it contains ribosome attached to the cytoplasmic side of the membrane and they are the series of flattened sacs. The other region is called as Smooth Endoplasmic Reticulum as it lacks the attached ribosome and they are tubule network.

The electron microscope reveals an extensive membrane system in the cytoplasm called Endoplasmic reticulum (ER). It was first reported by **Keith R. Porter** (a Canadian-American cell biologist) in 1945. This continuous membrane system joins the nuclear membrane on one end and the cell membrane on the other.

Types of Endoplasmic Reticulum

Two types of ER, such as smooth walled and rough walled, have been recognized. They may be present in the same or different types of cells.

(i) **Smooth Endoplasmic Reticulum (SER):** The surface of this type of reticulum is smooth as ribosomes not attached. Smooth ER is present in cells, which are actively engaged in steroid synthesis, carbohydrate metabolism, pigment production etc.

(ii) **Rough Endoplasmic Reticulum:** The rough ER have ribosomes attached throughout the surface. These are present in cells, which are active in protein synthesis.

Plant Cell Endoplasmic Reticulum

In plant cell, the endoplasmic reticulum acts as a port for the entry of proteins into the membrane. It also plays a vital role in the biosynthesis and storage of lipids. There are number of soluble membrane, which are associated with the enzymes and the molecular chaperones. The general functions of the endoplasmic reticulum in plant cell are protein synthesis and maturation. Endoplasmic reticulum of plant cell possesses some additional functions, which is not found in animal cells. The additional function involves cell to cell communication between specialized cells and also it serves as a storage site for proteins. Endoplasmic reticulum of plant cell contains enzymes and structural proteins, which are involved in the process of oil body biogenesis and lipid storage. In plants, the endoplasmic reticulum is connected between the cells via the plasmodesmata.

Animal Cell Endoplasmic Reticulum

In animal cells, the endoplasmic reticulum is a network of sacs, which play a vital role in manufacturing, processing and transporting different types of chemical compounds for use of both inside and outside of the cell. It is connected to the double-layered nuclear envelope, which provides the pipeline between the nucleus and the cytoplasm of a cell. In animal cells, the endoplasmic reticulum is a multifunctional organelle, which synthesis the membrane lipids, proteins and also regulates the intracellular calcium.

Endoplasmic Reticulum Structure

1. Endoplasmic reticulum is an extensive membrane network of cisternae (sac-like structures), which are held together by the cytoskeleton. The phospholipid membrane encloses a space, the lumen from the cytosol, which is continuous with the Perinuclear space.
2. The surface of the rough endoplasmic reticulum is studded with the protein manufacturing ribosome, which gives it a rough appearance. Hence it is referred as a rough endoplasmic reticulum.

3. The smooth endoplasmic reticulum consists of tubules, which are located near the cell periphery. This network increases the surface area for the storage of key enzymes and the products of these enzymes.
4. Rough endoplasmic reticulum synthesizes proteins, while smooth endoplasmic reticulum synthesizes lipids and steroids. It also metabolizes carbohydrates and regulates calcium concentration, drug detoxification, and attachment of receptors on cell membrane proteins.
5. Endoplasmic reticulum varies extensive extending from the cell membrane through the cytoplasm and forming a continuous connection with the nuclear envelope.

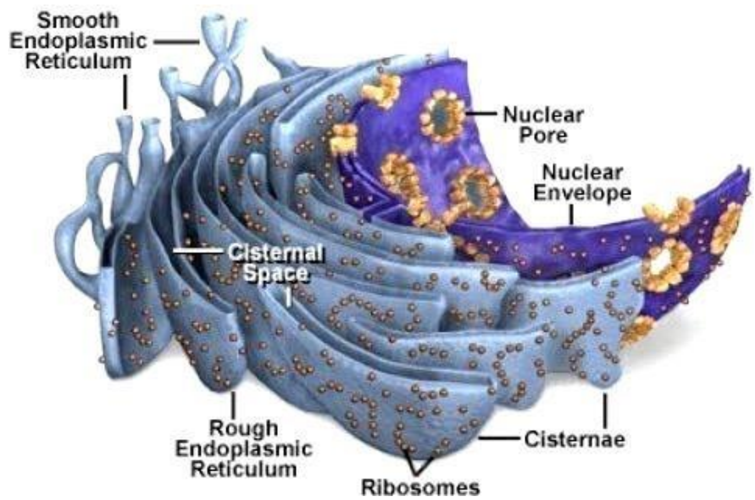

Fig.2.10 Structure of Endoplasmic reticulum

The Major Functions of Endoplasmic reticulum

(1)Common to both Endoplasmic Reticulum:

(i) Forms the skeletal framework.
(ii) Active transport of cellular materials.
(iii) Metabolic activities due to presence of different enzymes.
(iv) Provides increased surface area for cellular reactions.
(v) Formation of nuclear membrane during cell division.

(2) Function of Smooth Endoplasmic Reticulum:

(i) Lipid synthesis.
(ii) Glycogen synthesis.
(iii) Steroid synthesis like cholesterol, progesterone, testosterone, etc.
(iv) Metabolism of carbohydrates.
(v) Detoxification function.
(vi) Major storage and released site of inter cellular calcium ions.

(3) Function of Rough Endoplasmic Reticulum:

(i) It provides site for protein synthesis.
(ii) Protein translocation, folding and transport of protein.

(iii) Glycosylation (this is the relation of a saccharides group with a hydroxyl or amino functional group to form a glucoside).

(iv) Disulfide bond formation (disulfide bonds stabilize the tertiary and quaternary structures of many proteins). (v) Membrane synthesis.

2.11 SUMMARY

A cell is enclosed by a plasma membrane, which forms a selective barrier that allows nutrients to enter and waste products to leave. The interior of the cell is organized into many specialized compartments, or organelles, each surrounded by a separate membrane. One major organelle, the **nucleus**, contains the genetic information necessary for cell growth and reproduction. Each cell contains only one nucleus, whereas other types of organelles are present in multiple copies in the cellular contents, or cytoplasm.

Organelles include **mitochondria**, which are responsible for the energy transactions necessary for cell survival; **lysosomes**, which digest unwanted materials within the cell; and the **endoplasmic reticulum** and the **Golgi apparatus**, which play important roles in the internal organization of the cell by synthesizing selected molecules and then processing, sorting, and directing them to their proper locations. In addition, plant cells contain **chloroplasts**, which are responsible for photosynthesis, whereby the energy of sunlight is used to convert molecules of carbon dioxide (CO2) and water (H2O) into carbohydrates. Between all these organelles is the space in the cytoplasm called the **cytosol**. The cytosol contains an organized framework of fibrous molecules that constitute the **cytoskeleton**, which gives a cell its shape, enables organelles to move within the cell, and provides a mechanism by which the cell itself can move. The cytosol also contains more than 10,000 different kinds of molecules that are involved in cellular biosynthesis, the process of making large biological molecules from small ones.

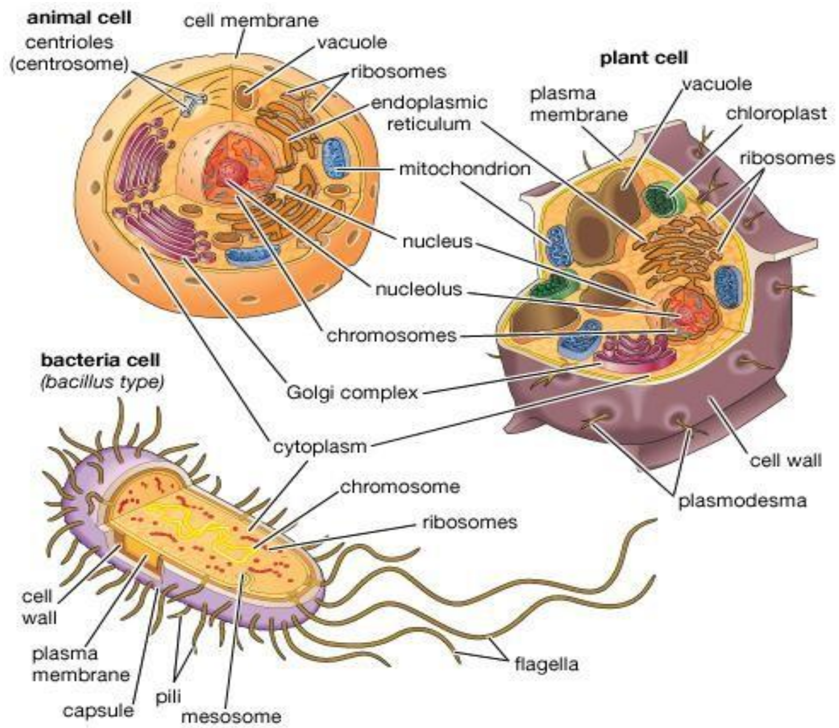

Fig.2.11 Structure of some typical cells

2.12 GLOSSARY

Aleurone: Protein stored as granules in the cells of plant seeds.

Carotenoid: Any of a group of red and yellow pigments, chemically similar to carotene, contained in animal fat and some plants.

Cell Biology: Sub-discipline of biology that focuses on the study of the basic unit of life, the cell.

Cell wall: Of many cells (not animal cells), a semi-rigid but permeable structure that surrounds the plasma membrane; helps a cell retain its shape and resist rupturing.

Cell: Smallest unit that still displays the properties of life; it has the capacity to survive and reproduce on its own.

Central vacuole: In many mature, living plant cells, an organelle that stores amino acids, sugars, and some wastes; when it enlarges during growth, it forces the cell to enlarge and increase its surface area.

Centrioles: a small, cylindrical cell organelle, seen near the nucleus in the cytoplasm of most eukaryotic cells, that divides in perpendicular fashion during mitosis, the new pair of centrioles moving ahead of the spindle to opposite poles of the cell as the cell divides: identical in internal structure to a basal body.

Chloroplast: A plastid containing chlorophyll. Organelle of photosynthesis in plants and algae.

Chromatin: All of the DNA molecules and associates proteins in a nucleus.

Chromatin: The readily stainable substance of a cell nucleus, consisting of DNA, RNA, and various proteins, that forms chromosomes during cell division.

Chromoplast: A plastid containing coloring matter other than chlorophyll.

Chromosome: A long, stringy aggregate of genes that carries heredity information (DNA) and is formed from condensed chromatin.

Cisternae: A cisterna (plural cisternae) is a flattened membrane disk of the endoplasmic reticulum and Golgi apparatus.

Coenocytes: An organism made up of a multinucleate, continuous mass of protoplasm enclosed by one cell wall, as in some algae and fungi.

Cristae: Each of the partial partitions in a mitochondrion formed by infolding of the inner membrane.

Cytokinesis: The division of the cell cytoplasm that usually follows mitotic or meiotic division of the nucleus.

Cytoplasm: Consists of all of the contents outside of the nucleus and enclosed within the cell membrane of a cell.

Cytoskeleton: A network of fibers throughout the cell's cytoplasm that helps the cell maintain its shape and gives support to the cell.

Cytosol: Semi-fluid component of a cell's cytoplasm.

Detoxification: The metabolic process by which toxins are changed into less toxic or more readily excretable substances.

Dictyosome: The set of flattened membranes in a Golgi body, resembling a stack of plates. **Dictyosomes:** Are stacks of flat, membrane-bound cavities (cisternae) that together comprise the Golgi apparatus.

Endocytosis: The taking in of matter by a living cell by invagination of its membrane to form a vacuole.

Endo-membrane system: Endoplasmic reticulum, Golgi bodies, and transport vesicles concerned with modification of many new proteins, lipid assembly, and their transport within the cytoplasm or to the plasma membrane for export.

Endoplasm: The more fluid, granular inner layer of the cytoplasm in amoeboid cells.

Endoplasmic reticulum: The endoplasmic reticulum is a type of organelle in eukaryotic cells that forms an interconnected network of flattened, membrane-enclosed sacs or tube-like structures known as cisternae.

Endosymbiosis: Symbiosis in which one symbiont lives within the body of the other.

Euchromatin: The part of a chromosome that condenses maximally during metaphase and contains most of the genetically active material.

Eukaryote: Any organism whose cells have a cell nucleus and other organelles enclosed within membranes. Eukaryotes belong to the domain Eukaryota, and can be single-celled or multicellular.

Flagella: A long, lash-like appendage serving as an organ of locomotion in protozoa, sperm cells, etc.

Genomics: The study of genomes.

Glyoxysomes: Are specialized peroxisomes found in plants (particularly in the fat storage tissues of germinating seeds) and also in filamentous fungi.

Golgi Bodies: A complex of vesicles and folded membranes within the cytoplasm of most eukaryotic cells, involved in secretion and intracellular transport.

Granum: One of the structural units of a chloroplast in vascular plants, consisting of layers of thylakoids.

Heredity: It is the process by which features and characteristics are passed on from parents to their children before the children are born.

Homeostasis: The tendency of a system, especially the physiological system of higher animals, to maintain internal stability, owing to the coordinated response of its parts to any situation or stimulus that would tend to disturb its normal condition or function.

Hyaloplasm: The clear fluid portion of cytoplasm as distinguished from the granular and netlike components. Also called ground substance

Invagination: The action or process of being turned inside out or folded back on itself to form a cavity or pouch.

Leucoplast: A colourless organelle found in plant cells, used for the storage of starch or oil.

Lumen: The cavity that the cell walls enclose.

Lysosome: An organelle in the cytoplasm of eukaryotic cells containing degradative enzymes enclosed in a membrane.

Mitoplast: A mitochondrion that has been stripped of its outer membrane leaving the inner membrane intact.

Mycoplasma: It is a genus of bacteria that lack a cell wall around their cell membrane. Without a cell wall, they are unaffected by many common antibiotics such as penicillin or other β-lactam antibiotics that target cell wall synthesis.

Nuclear Envelope: A double membrane that is the other boundary of the nucleus.

Nucleoid: The nucleoid (meaning nucleus-like) is an irregularly shaped region within the cell of a prokaryote that contains all or most of the genetic material, called genophore.

Nucleolus: In an interphase nucleus, a mass of material from which RNA and proteins are assembled into the subunits of ribosomes.

Nucleoplasm: The protoplasm of the nucleus of a cell.

Nucleus: A dense organelle present in most eukaryotic cells, typically a single rounded structure bounded by a double membrane, containing the genetic material.

Organelles: One of the membrane- bound compartments that carry out specialized metabolic functions in eukaryotic cells; e.g. a nucleus, mitochondria.

Perinuclear space: The space between the membranes.

Phospholipid: Any of a group of fatty compounds, as lecithin, composed of phosphoric esters, and occurring in living cells.

Photolysis: The decomposition or separation of molecules by the action of light.

Photorespiration: The oxidation of carbohydrates in many higher plants in which they get oxygen from light and then release carbon dioxide, somewhat different from photosynthesis.

Photosystems: Are functional and structural units of protein complexes involved in photosynthesis that together carry out the primary photochemistry of photosynthesis: the absorption of light and the transfer of energy and electrons.

Plasmid: A plasmid is a small, circular, double-stranded DNA molecule that is distinct from a cell's chromosomal DNA. Plasmids naturally exist in bacterial cells, and they also occur in some eukaryotes.

Plastid: The plastid is a major double-membrane organelle found in the cells of plants, algae, and some other eukaryotic organisms. Plastids are the site of manufacture and storage of important chemical compounds used by the cell.

Polysome: A complex of ribosomes strung along a single strand of messenger RNA that translates the genetic information coded in the messenger RNA during protein synthesis. **Porins:** Are beta barrel proteins that cross a cellular membrane and act as a pore, through which molecules can diffuse.

Porins: They are beta barrel proteins that cross a cellular membrane and act as a pore, through which molecules can diffuse.

Prokaryote: A prokaryote is a unicellular organism that lacks a membrane-bound nucleus, mitochondria, or any other membrane-bound organelle.

Proteins: Proteins are large biomolecules, or macromolecules, consisting of one or more long chains of amino acid residues. It perform a vast array of functions within organisms, including catalyzing metabolic reactions, DNA replication, responding to stimuli, and transporting molecules from one location to another.

Ribosome: A tiny, somewhat mitten-shaped organelle occurring in great numbers in the cell cytoplasm either freely, in small clusters, or attached to the outer surfaces of endoplasmic reticulum, and functioning as the site of protein manufacture.

Sedimentation: The deposition or accumulation of sediment.

Senescence: No longer capable of dividing but still alive and metabolically active.

Stalked particles: On the inner surface of cristae contain the enzymes required to make ATP from ADP and phosphate.

Stroma: The matrix of a chloroplast, containing various molecules and ions. The supporting framework or matrix of a cell.

Symbiosis: The living together of two dissimilar organisms, as in mutualism, commensalism, amensalism, or parasitism.

Syncytium: A multinucleate mass of cytoplasm that is not separated into cells.

Thylakoid: A flattened sac or vesicle lined with a pigmented membrane that is the site of photosynthesis, in plants and algae occurring in interconnected stacks constituting a granum of the chloroplast, and in other photosynthesizing organisms occurring either singly or as part of the cell membrane or other structure.

Tonoplast: A membrane separating a vacuole from the surrounding cytoplasm in a plant cell.

Vacuole: A membrane-bound cavity within a cell, often containing a watery liquid or secretion. **Vesicle:** It is a small structure within a cell, or extracellular, consisting of fluid enclosed by a lipid bilayer. Vesicles form naturally during the processes of secretion (exocytosis), uptake (endocytosis) and transport of materials within the cytoplasm.

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GENETICS AND HEREDITY

1. Introduction

Epidermolysis bullosa (EB) is a disorder that is genetic, this means that the cause for this is found in the genes of a human. The processes in our genes are complicated and difficult to understand, there are still many unanswered questions. Of course, there are always many questions and misconceptions about inheritance in EB. In this section we'll summarize the complex processes, which play a role in the inheritance, and try to bring you closer to an understanding of the effects of the genetic changes that lead to EB.

Important points in a nutshell

- **Genes are the carriers of our heredity factors.**
- **The cause of EB lies in changes in individual genes. These altered genes can be inherited in different ways Recessive:**
  - **The disease usually occurs in this family as a complete surprise.**
  - **Usually both parents (healthy) are carriers of the gene.**

Dominant:
  - **There usually is already one or more victims in a family.**
  - **A parent usually is affected by EB.**
- **There are a number of exceptions to this rule and cases, even in EB!**
- **A detailed genetic counseling is important for a better understanding of EB.**

2. General information

This section cannot explain all the relationships that play a role in heredity factors to you. These processes are very complex and not yet completely explored. However, it might interest you to know a few basics to better understand the background of a disease like EB.

Basics for understanding the processes involved in hereditary factors:

In biology, heredity is called the transmission of traits from parents to their children. This applies only to material properties (e.g. hair color, body size) but not for skills and knowledge that children learn from their parents.

Genes are the carriers of genetic information; they are like the "base unit" of heredity. They contain so to speak the "blueprint" for certain "building blocks" from which our bodies are built and are distributed on 23 pairs of chromosomes, which are located in the nucleus of every cell in the body. In all body cells, these 23 pairs of chromosomes in humans are included, so 23 x 2 = 46 chromosomes, except egg and sperm cells. These contain 23 chromosomes only once. In the fusion of egg and sperm a complete set of chromosomes with 23 pairs occurs again, with each pair one chromosome from the mother and the other inherited from the father.

The chromosomes 1 - 22 are known as "autosomes" and this denotes that they look the same in men and women. The 23 pairs of chromosomes are the sex chromosomes X and Y. They determine the sex of a person. The human chromosomes are therefore either 46, XX (= female) or 46, XY (= male). Chromosomes are (DNA = Deoxyribonucleic Acid) from the so-called deoxyribonucleic acid that builds the individual genes. A gene is a piece of DNA that is the blueprint for a single protein or protein molecule from which our bodies are built.

Recently, the entire DNA (genome) of humans was entirely decrypted; it is now estimated that there are approximately 30 000 genes on the human chromosomes. So far, the genes responsible for about 16 000 hereditary characteristics are known. They are responsible for the diversity and uniqueness of each person. Hair color, eye color, but also the blood group and many other features are passed on from generation to generation in various combinations. Each person inherits half its genes from their mother and the other half from their father. The genes are constantly being reshuffled, only identical twins have exactly the same genetic information.

Changes in genes are referred to as mutations. They may be relatively unimportant and unnoticed, or can even lead to different diseases. They have currently found for 1300 diseases specific changes in the corresponding genes and in many other diseases gene alterations are also suspected.

The causes and the nature of the inheritance of genetic diseases are generally divided into:

Chromosomal Disease:

There is not only a change to one of or several genes, but a change in the total chromosome number or structure. The most famous example is Down's syndrome, in which there is too many of the same chromosome. Instead of a pair of chromosome No. 21 there are three chromosomes 21 in the cells, that is to say there is a total of 47 chromosomes in each cell instead of 46.

Polygenic Diseases:

These are caused by the interaction of many individual changes of undefined genes on the one hand, and often unknown environmental factors on the other. The occurrence and recurrence risk of polygenic or multifactorial genetic disease cannot be as easily determined as with the monogenic diseases with rules or read from the family tree, but it is known to occur more frequently in some families. These include allergies and diabetes.

Monogenic Disease:

There is a single altered gene responsible for a disease outbreak. This genetic alteration results in the loss or malformation of a particular enzyme or protein molecule. This is the cause in the different forms of EB, but also many other diseases. Seen statistically, about 1 child in 100 babies has a condition that is due to a change in a single gene. Some of these genetic disorders are expressed at birth, others only in the course of life. Thus, metabolic or muscular disorders are often seen already in infancy, while other diseases such as Huntington's chorea ("Saint Vitus' Dance") or even some family tumors don’t show up until adulthood.

Inheritance of Epidermolysis Bullosa:

Epidermolysis bullosa is one of the monogenic diseases, and this means, that the change in a single gene is responsible for the disease. There are now 16 different genes that are known to cause changes in EB, and it may be that more are discovered in the coming years. The genetic modification ensures that certain proteins that are produced are not formed or not changed, which are responsible for the anchoring of the epidermis and the dermis. The result is, that the anchoring of the epidermis does not work properly and it results in blister formation under mechanical stress. These changes are inherited in a legitimate manner, namely with autosomal recessive and autosomal dominant genes.

For the sake of completeness it should be mentioned that there is also other monogenic modes of inheritance, namely those that are tied to the sex chromosomes (X-linked recessive, X-linked dominant) and also those that are bound to the mitochondria (the "power plants cell "). These modes of inheritance are not relevant for EB, so we will not discuss it further.

Please see the chapter for which specific heredity type you or your child with EB is suffering from „EB-subtypes“.

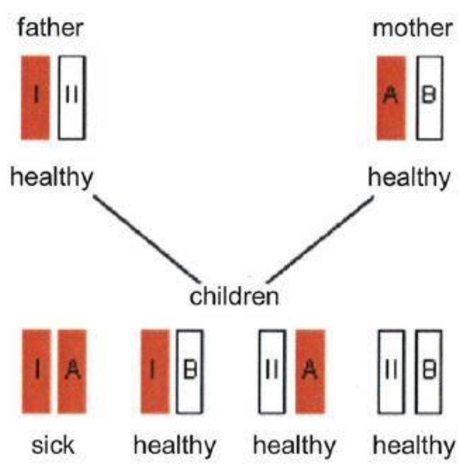
What does an Autosomal Recessive Inheritance mean?

Examples of autosomal recessive forms of EB are: recessive dystrophic EB, EB simplex with muscular dystrophy and all forms of junctional EB.
Recessive could be translated into "oppressed" or "retreating". This means that a change is present in a gene, but it is covered by the second, unmodified gene. The gene on the second chromosome is "healthy" and often able to produce intact functional building blocks. The disease did not break out, even though a gene mutation occurred.
This type of gene mutation that is a gene pair - one of a modified and one normal gene exists - is called heterozygous (roughly translated: "two different"). The carrier of such a gene is even healthy, they also are mostly not aware that they carry the affected gene of this disease with them. It has now been estimated that probably 6 - 8 of these gene mutations are carried by every person on earth, without knowing it and without becoming ill because of it.

How can there be a Disease in this Case EB?

If the parents of a child - by chance or by fate, or whatever you want to say – are both carriers of the same gene mutation, there is a risk of 25% for the child that it inherits two mutated genes and a disease (see figure 1). It may also be, that there are none or they only inherited one of the mutated genes and it is healthy (see figure 1).
Sometimes it is assumed that at a risk of 25% for 4 children therefore one is affected. This is not right, it just means that at every birth there is a 25% chance for that child that it is affected, and a 75% chance that it is not affected. It may be that in this mode of inheritance all children are affected, or even none are affected. The data are purely statistical data, but the genes are shuffled with each pregnancy! The disease is otherwise independent of the sex of the child, since the altered gene in the case of EB is not on the chromosomes that determine the sex.

Figure 1: Autosomal recessive inheritance:



Summary of Autosomal Recessive Inheritance:

- The carrier of an altered gene will have only one healthy gene because the gene function is maintained by the second, non-altered gene.
- Only when two altered genes (one from mom, one from dad) come together in the child, this will result in a disease.
- Both sexes are equally affected.

What is an Autosomal Dominant Inheritance?

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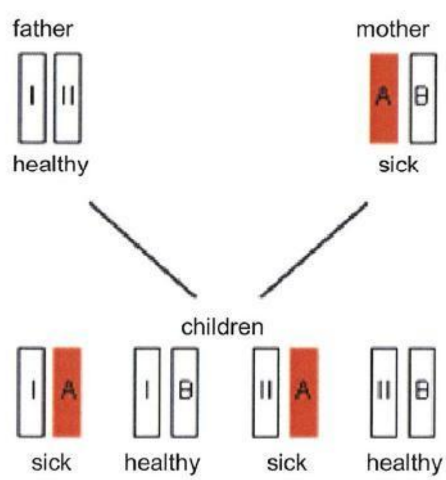
Examples of autosomal dominant forms of EB are: EBS localized, EBS generalized severe and the dominant dystrophy EB form.

Dominant means "prevalent". In these forms, a single gene mutation cannot be compensated by a healthy partner gene. The change is too strong and outweighs the normal gene. The gene on the second chromosome is no longer capable of compensating for the non-functioning of his "neighbor" gene. The carrier of this gene will definitely become ill (see figure 2). The disease forms as soon as a gene is changed. In contrast to the recessive inheritance the disease in the family was already known, there are often more people affected in different successive generations.
Because only one of the two genes (either modified or not-changed) is passed from the affected parent, the children of an affected parent have (in the picture the mother) a 50% chance of getting the altered gene and of developing it. Again, this is a statistic because it is reshuffled again with each pregnancy. It is possible that all children are affected, several or even none.

Figure 2: Autosomal dominant inheritance:



Summary of Autosomal Dominant Inheritance:

- An altered gene from the mother or father is sufficient enough for the disease outbreak.
- The disease-causing gene dominates over the "healthy".
- The disease usually occurs in successive generations.
- Both sexes may be equally affected.
- The attribute does not occur in the offspring of non-diseased persons.

Spontaneous Gene Mutations:

At this point it must be mentioned that there may also be spontaneous changes in a gene regardless of the inherited disease, by genes during fetus development. This can also lead to a disease. One speaks of a "spontaneous mutation" that occurs in a brand new family member, but it can then be passed on in future generations. In this instance parents are healthy, none of them carries the mutated gene, and yet their child may be born with EB. This mostly relates to the dominant forms and it occurs fairly often.

Investigation of the Gene:

Today it is possible to search for genetic disorders in an appropriate laboratory, exploring the underlying genetic mutation. This can help to confirm the diagnosis and in some cases this may find possibilities for the future. So sometimes a prenatal examination is desired, for instance in subsequent pregnancies from the same pair. If necessary, you can also determine if there are more carriers of the disease in the family. Research is making steady progress and if one day there is a possibility to influence genetic diseases directly within the genes and heal it, then it is necessary to allow the gene mutation to be closely examined.
Of course it cannot be said here, whether it is in your case important to know the exact genetic mutation or not. It should also be mentioned that the health insurance plans (which are getting more expensive!) do not cover all costs. So before you decide for or against genetic testing, it is necessary to discuss this in detail with a specialist. In many countries this is also required by law and this is also useful, as the correlations to diseases may be different in each case. As part of a comprehensive genetic counseling you can then sort out all the issues that are important to you and your family.

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