Introduction

The word biology is derived from the Greek words

Bio- Life

Logos- Study of

Therefore Biology is the study of living things.

Living things are broadly categorized into two forms: plants and animals.

The study of plants is called Botany while that of animals is Zoology.

This grouping is based on the displayed features that are easily observed or noticed

However, within this broad categorization exists other forms of life, some which could not be seen with naked eyes.

Within the discovery of microscope by Anton Van Leeuwenhoek scientists got a peek into the world of organisms that cannot be seen with the naked eyes thus a new field emerged. Considering that a vast majority of organisms fall into this group, a third group that encompasses all others that cannot be seen was created and termed Microbiology.

Within these categories (3), a vast majority of sub-categories have been explored and ventured into. These subcategories are as follow:

- Cytology- the study of cells: structure and functions.
- Histology- the study of detailed structure of tissues.
- Embryology- the study of development of zygote into matured organisms.
- Morphology- the study of general forms and features of organisms.
- Anatomy- the study of internal structure of organisms.
- Physiology- the study of functions of internal structure of organism.
- Genetics- the study of heredity and variations.
- Ecology- the study of interrelationship between organisms and their environment.
- Biochemistry- the study of chemistry of biological molecules of life.
- Taxonomy- the study of description, identification, naming and classification of organisms.
- Bacteriology- the study of bacteria.
- Virology- the study of viruses.
- Protozology- the study of protozoans (single celled organism).
- Entomology- the study of insects.
- Parasitology- the study of parasites
- Pathology- the study of diagnosis, cure and prevention of diseases
- Epidemiology- the study of causes and spread of diseases
- Bryology- the study of bryophytes
- Phycology- the study of algae
- Mycology- the study of fungi
- Pharmacognosy- the study of medical plants
- Palaelobotany- the study of fossils of plants.

Concept of living things (Biotics) and Nonliving things (Abiotics)

Our Earth, which was formed billions and trillions of years ago, has many things. For Example - The trees, the river, the mountains, the plants, the land, the rock, the birds, the animals, etc. These are all part of our surroundings. We come in contact with them in our day to day lives. These things around us are differentiated into two types.

a) Living things

b) Non-living things

Everything that has life is called a living thing and everything that does not possess life is called a non-living thing. There are many factors that differentiate living things from nonliving things. This differentiating factor is not necessarily activities like moving, running, eating but much more. As we know, there are many things on Earth which do not move, run or eat but they are living things. Plants, for example, are not mobile. They do not eat, but plants have a life. Bacteria that are not even visible to naked eyes is believed to be the first kind of living thing on Earth. So, what are living and nonliving things and how do we differentiate between them?

1. Living Things

All living things have life. They eat, breathe, feel, grow, and reproduce. They carry out chemical reactions within their body, which generates energy. This energy within the body is then used to carry out various activities. Imagine, what would happen without energy being generated inside the body of a living thing. The living thing's capability to perform various tasks will end and the living being will cease to exist.

Most often, living things also show the capability to move which is called locomotion.

Every living thing that has life, shows the presence of the cell. Inside the cells, there are chemicals that carry out various chemical reactions. These chemical reactions lead to a number of processes. There are unicellular organisms living organisms with single cells and multicellular organisms- living organisms with multiple cells living on Earth. Multicellular organisms also possess tissues, organs, and organ systems, and thus, such organisms have various cells to carry out various functions.

Characteristics of Living things

The characteristics listed below are shown by all living organisms. These characteristics make up a living thing. These factors show the presence of life in these things. All living organisms take birth, grow, reproduce, and ultimately die. This is the life cycle of every living thing on Earth.

1. Cellular organization- As stated above, all living things must possess a cellular organization. A living thing can be unicellular or multicellular but without the presence of cells, living things cannot exist. And, inside the cell, various activities function as operating systems of various tasks. The generation of energy for instance mostly takes place by cellular respiration. It is the process of absorbing nutrients from food and then turning it into energy.

2. Respiration- Respiration is the second basic process that ensures continuity of life. Respiration is the process of exchanging gases. The goal of respiration is to generate energy. This process also leaves living organisms with waste products that should be eliminated from the body.

3. Nutrition- Proteins, carbohydrates, fats the building blocks of our body. Living organisms derive these nutrients from food. Thus, the process of nutrition is the absorption of nutrients from raw materials or food.

4. Growth- Various stages of development are included in a life cycle of living things. This is called growth. All living things grow. Thus, growth is a very important characteristic of living organisms.

5. Locomotion- Most of the living things can move. Animals can move on their own. Example- Leopards, cats, dogs can run. In the case of plants, they move towards the sun, as sunlight is essential for growth.

6. Response to stimulus- All living things respond to stimulus from the surrounding. They show sensitivity to touch and respond according to their surroundings.

7. Excretion- Various chemical processes taking place in the body of living things generate a bi-product which is not useful. This is waste and it has to be eliminated from the body.

The process of elimination of waste generated in the body is called excretion. Excretion is also a characteristic only possessed by living things.

8. Reproduction- Only living things have the capability to produce o□spring, which carry forward their generation. They have a fragment of genetic material from the parent and also show genetic variation due to the mixing of the genes. Thus, another important characteristic of living things is reproduction.

Non-Living things

Non-living things do not live. They exist on Earth, right from the time, Earth has formed. They can't eat, breathe, live, grow, reproduce, or die. They remain in nature as it is. Although, over the course of evolution, they get degraded from their original form. But they can't die and cease to exist on Earth. Unlike living things, whose continuity depends on the number of factors. Non-Living things are not dependent on such processes.

Characteristics of Non-Living things

1. Non-living things are lifeless. They do not have life. Hence, they do not need cells to carry out different processes. So, non-living things do not have cells, which is the basic unit of life.

2. Due to the absence of cells, tissues, organs, there are no metabolic activities going inside them. No metabolic activity means, no production of energy.

3. Non-living things do not show locomotion. They cannot move on their own. An external force has to be applied to move non-living things from one place to another.

4. They do not require nutrition, as they do not show any life processes. They do not need food to produce energy. They do not grow. They do not produce o□spring. So, there is no process of reproduction involved in their life cycle.

5. Non-living things do not die. They cannot vanish on their own. They do not age. An external force can only destroy them. Example- mountain, car, ship, water, house, etc.

Differences between Living and Non-Living things

All things which possess life are living things. Non-living things do not possess life. The basic unit of life is cells Non-living things do not have cells.

Living things carry out metabolic activities inside their bodies to generate energy. Non-living things cannot generate energy and have no metabolic activities going inside their bodies.

Living things respire and respiration ensures continuity of life. Non-living things do not need to respire.

They show locomotion or movement on their own. They cannot move on their own unless moved by an external force.

Living things show growth from within, Non-living things do not grow on their own.

Living things can reproduce and produce offspring of their own. Non-living things cannot reproduce and neither can they produce their offspring.

Living things die due to age, disease Non-living things never cease to exist or cell death, organ failure, etc. unless they are destroyed by an external force.

Living things eliminate waste from their body through the process of excretion. Non-living things neither eat food nor produce waste. Therefore, they do not show the process of excretion.

Living things respond to the stimulus from the surrounding, which implies that living things are sensitive. Non-living things do not have this characteristic. They do not fall on their own without external force or have senses and hence, they do not respond to stimulus.

Definition of Plants

Plants fall under kingdom **Plantae** and are kept under **multicellular, photosynthetic eukaryotes** category. The range of the plants varies from one place to other, one climate to other, etc., which includes the angiosperms, gymnosperms, ferns, conifers, mosses, liverworts, hornworts and of course the green algae.

Plants are regarded as the **primary producer** on the ecosystem of Earth. They are said as **autotrophic**, which means they can produce their own food by the process of photosynthesis. If we look at the general structure of a plant, it has a proper root system, and the shoot system. The **root system** includes the part of the plant which is found below the ground, while the **shoot system** comprises the part like flowers, fruits, stem or trunk, leaves, buds, and branches and these are found above the ground. The basic development starts from the cell, which develops into the tissues, these tissues can be ground, dermal or vascular.

Ground tissues are composed of the essential part of the plant. Dermal tissue supports the outer layer of the plant, which has a waxy coat to prevent the loss of water. Maximum plants have the vascular system, which acts as the carrier for transporting of the nutrients, water and hormones from one part of the plants to other, green algae do not have this system.

Plants can be **angiosperms or gymnosperms**; angiosperms are the plants where seeds are found inside the fruit, while gymnosperms are the naked seeds, further there are many subdivisions on the basis of the cotyledons which can be as monocots or dicots. It is estimated that there are around 390,880 species of the plants found till date and there are more in counting.

The study of the plant is called as **botany**, and the person who studies botany is known as a **botanist**. The plants are important in many ways, as they are medicinally used, cultivation of many plants is economically important for many countries; they are scientifically important, major food source, etc. Most important is that they play a critical role in providing oxygen to the atmosphere.

Definition of Animals

Animals fall under the category of **multicellular, eukaryotes** but under the kingdom of the **Animalia**. Likewise the plants, animals also vary from place to place, whether living in water, air or on land. The maximum number of species of animals have bilaterally symmetric body plan or called as Bilateria.

There are many subdivisions of the animals like they can be vertebrates or invertebrates, can be oviparous or viviparous, can be cold-blooded or warm blooded.

Aristotle, Carl Linnaeus, Jean-Baptiste Lamarck, Ernst Haeckel played an important role in creating the hierarchical classification of the animals. The six common groups of animals are Birds, Fish, Reptiles, Amphibians, Mammals, and Insects. Till date there are about **80, 500 species** of the vertebrates found, and 6, 755, 830 invertebrates are there, it is also said that there five million species of insects, among the total number of plants and animals found yet. Rest invertebrates acquire for 1,75 million, and vertebrates are 80,000. The mammals account for the

lesser number of only 5,500. Animals need food, air, water, and shelter for their survival; also they need a proper habitat or environment where they can spend their life and can increase their population. The habitats include the deserts, grasslands, rainforest and arctic tundra, though it depends on the animal that which suits best to them. Animals may variate on the basis of place they live, the food they eat, their living habits, etc.

There are many common characteristics which make the animals unique from other living things. Firstly they are motile; they have many organs and organs to perform various functions of the body like they have well developed respiratory system, digestive system, excretory system, reproductive system and nervous system. Their sense organs are also the critical characters which make them exclusive; these sense organs give special power to animals so that they can smell, taste, hear, visualize and respond to the stimulus.

BASIS FOR COMPARING PLANTS AND ANIMALS

Meaning: Plants are green in colour due to the presence of the chlorophyll and are able to prepare their own food with the help of sunlight, water and air. They are known for providing oxygen to the atmosphere. Animals are the living organisms which feed on the organic material and are known to have a specialized system in their body like the nervous system, reproductive system, sense organs, which make them unique from the other forms of life. Movement Plants do not have the ability to move from one place to another, as plants are rooted into the ground, exceptions are *Volvox* and *Chlamydomonas*. Animals can move from one place to another freely, and exceptions are Sponges and Corals.

Mode of nutrition: Plants have chlorophyll, due to which they have the capability to prepare their own food and are known as autotrophs.

Animals are the heterotrophs, as they depend on plants for their food, either directly or indirectly.

Storage of food: Plants do not have the digestive system, and the storage of food (carbohydrate) takes place in the form of starch. Animals have the proper digestive system which support the food in digesting and absorbing nutrition from it, the food (carbohydrate) is stored in the form of glycogen.

Respiration Plants take in carbon dioxide and release oxygen into the atmosphere, exchange of gases occurs through stomata. Animals take in oxygen and release carbon dioxide into the atmosphere, which occurs through lungs, gills, skin, etc.

Cellular structure: The cellular structure of plants contains the cell wall, chloroplast, plasmodesmata, plastids and other different organelles. The cellular structure of animals does not have cell walls, though other organelles like the tight junction, cilia are present.

Growth: The growth of the plants takes place throughout the life, the meristematic system present in the tip of roots and stems supports the growth. The organs and organ system supports the growth and is definite.

Reproduction: Reproduction of plants takes place asexually like by budding, vegetative methods, spores, wind, or through insects. Some lower animals like algae reproduce asexually while higher animals reproduce sexually.

Response: Plants show the responses to stimuli like touch, light, though are less sensitive due to the absence of the sense organs. They have proper nervous system and response to any stimuli in a fraction of seconds, so they are regarded as highly sensitive.

Key Differences between Plants and Animals

Given below points will present the main features on which plants and animals vary:

1. The **ability of the plants** of preparing their food with the help of sunlight, water and the air is what makes them unique, the green colour pigment called as chlorophyll, and the capacity of providing oxygen, food to the living beings are the characteristics of the plants. The exclusive characters present **in animals** are different types of organs and organ systems, like nervous, reproductive, digestive, etc. They are sensitive and show the quick response to the stimuli. They entirely depend on plants, directly or indirectly for their food.
2. Animals show **movement**, which can be on the ground through legs, underwater through fins or in air through wings, on the contrary plants cannot move from one place to another, as plants are rooted into the ground, an exception is *Volvox* and *Chlamydomonas*. Animals have exceptions like Sponges and Corals.
3. Plants have chlorophyll, due to which they can prepare their food in the presence of air, water and sunlight, and due to this feature, they are termed as **autotrophs**. On other hands, animals are termed as **heterotrophs**, as they depend on plants for their food, either directly or indirectly for their nutrition.
4. **Storage of food** (carbohydrate) is in the form of starch in plants, while in animals the food is stored in the form of glycogen, the animals have the proper digestive system which supports in digesting the food materials.
5. In plants **exchange of gases** occurs through stomata where the plants take in carbon dioxide and release oxygen into the atmosphere, whereas in case of animals it is just opposite as animals take in oxygen and release carbon dioxide into the atmosphere, this process occurs through lungs, gills, skin, etc.
6. As plants and animals are eukaryotic, so they have almost similar **cellular structure**, but few organelles like chloroplast, plasmodesmata, cell wall, plastids, etc. are only found in the plant cell, while in there is no cell wall in the animal cell; instead they have cilia, the tight junction for other functionality.
7. The **growth** of the plants is not restricted and takes place through life in their meristematic regions like roots, stems, the tip of leaves, etc. Animals are confined to grow up to the certain period, and their organs and organ system support the growth.
8. **Reproduction** of plants takes place asexually like by budding, vegetative methods, spores, wind, or through insects, whereas some lower animals like algae reproduce asexually while higher animals reproduce sexually and give birth to the young ones.
9. Plants **response to stimuli** like touch, light, though are less sensitive due to the absence of the sense organs, animals have the proper nervous system and the sense organs too due to which they respond to any stimuli in a fraction of seconds.

Similarities

They respond to stimuli.
They breathe, reproduce, and grow.
They try to adapt according to changes in the environment.
The basic unit of their structure is the eukaryotic cell.
They both require air and water to survive.
They proper grow and develop.

CELLS - STRUCTURE AND FUNCTION

A cell is the smallest functioning unit of all living organisms on our planet earth, which is capable of performing life activities. Hence it can also be defined as a fundamental unit of life.

The term cell was first observed and identified by an English physicist, Robert Hook in the year 1665. There were many theories developed for cell. Later in the year 1839, a two German scientist – Schwann and Schleiden provided few basic principles of cell.

Cell Structures

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 (eukaryotic cells). The size and the shape of the cell range from microns to millimeter, 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 these cells can only be seen under the microscope.

Important Events in the Discovery of Cells

- 1665 - Robert Hooke looked at cork under a microscope. Called the chambers he saw"cells"
- 1665 - 75 Anton van Leeuwenhoek was incorrectly given credit for the invention of the microscope (actually, he was just damned good at making and using them, and his scopes soon became the standard, and history gave him credit as the inventor of the microscope), studied organisms living in pond water. He called them "Animalcules."
- 1830 - German scientists Schleiden and Schawann summarize the findings of many scientists and concluded that all living organisms are made of cells. This formed the basis of the Cell Theory of Biology .

The Cell Theory of Biology

- All organisms are composed of cells
- The cell is the structural unit of life - units smaller than cells are not alive
- Cells arise by division of preexisting cells - spontaneous generation does not exist
- Cells can be cultured to produce more cells
    - *in vitro* = outside organism or cell
    - *in vivo* = inside organism or cell

PROPERTIES OF CELLS

Cells are complex and highly organized

- They contain numerous internal structures
- Some are membrane bound (organelles) while others are not.

Cells contain a genetic blueprint and machinery to use it

- Genes are instructions for cells to create specific proteins
- All cells use the same types of information
    - The genetic code is universal
    - The machinery used for synthesis is interchangeable

- However, for this to function properly, information transfer must be error free
    - Errors are called *mutations*

Cells arise from the division of other cells

- Daughter cells inherit the genes from the mother cells
- Binary fission – cell division in bacteria
- Mitosis - the genetic complement of each daughter cell is identical to the other and to the mother cell. This is asexual reproduction
- Meiosis - the genetic complement of each daughter cell is reduced by half and each daughter cell is genetically unique. This is used in sexual reproduction
- Daughter cells inherit cytoplasm and organelles from the mother cells
    - Asexual - organelles from mother cell
    - Sexual - organelles predominantly from one parent
        - In eukaryotes, the chloroplasts and mitochondria come from the egg cell
        - This can be used to trace the evolutionary origin of the organism

Cells acquire and utilize energy

- Plant cells undergo photosynthesis
    - convert light energy and CO_2 to chemical energy (ATP and glucose)
- Most cells respire
    - release energy found in organic compounds
    - convert organic compounds to CO_2 and O_2
    - make ATP

Cells can perform a variety of chemical reactions

- **Transform simple organic molecules into complex molecules (anabolism)**
- **Breakdown complex molecules to release energy (catabolism)**
- Metabolism = all reactions performed by cells

Cells can engage in mechanical activities

- Cells can move
- Organelles can move
- Cells can respond to stimuli
    - chemotaxis - movement towards chemicals
    - phototaxis - movement towards light
    - hormone responses
    - touch responses

Cells can regulate activities

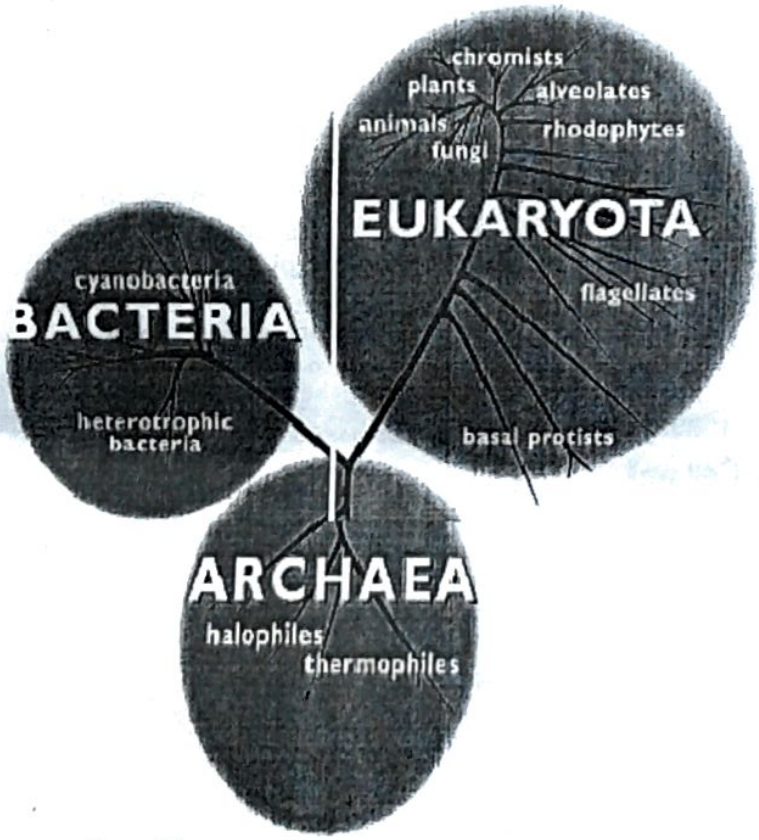
- Cells control DNA synthesis and cell division
- Gene regulation - cells make specific proteins only when needed

- Turn on and off metabolic pathways

Cells contain the following structures:

- Plasma membrane - separates the cell from the external environment
- Cytoplasm - fluid-filled cell interior
- Nuclear material - genetic information stored as DNA

Types of Cells



Source: TutorVista.com

Figure 1: Types of cells

Prokaryotes

- Pro = before; karyon = nucleus
- relatively small - 5 to 10 μm
- lack membrane-bound organelles
- earliest cell type

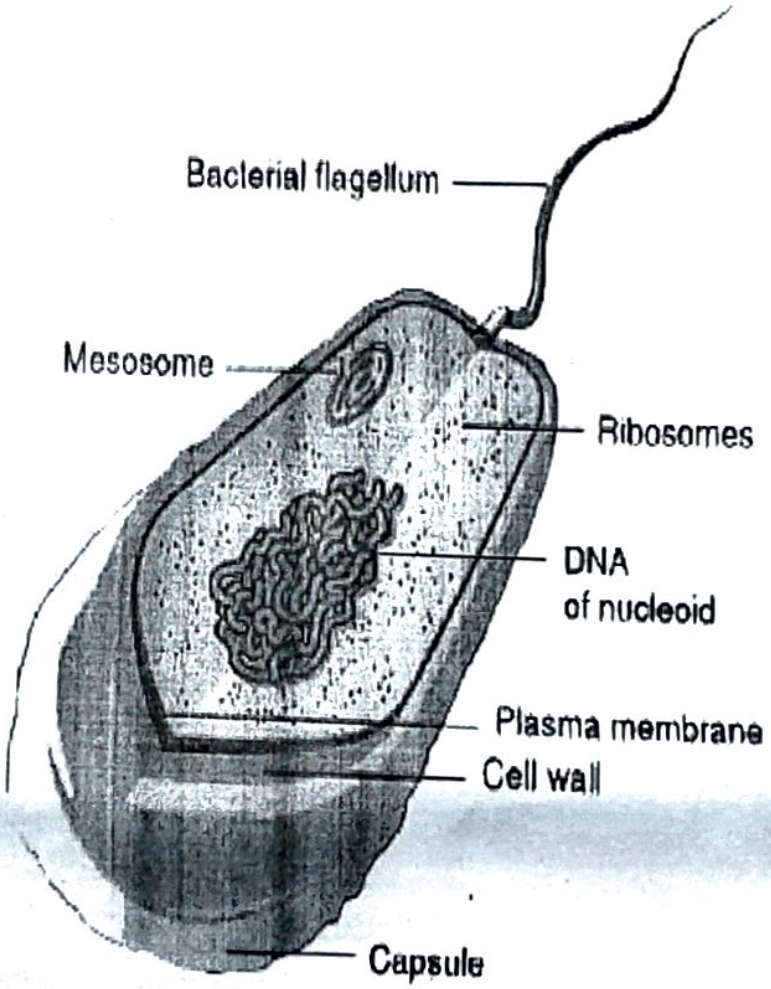
Archaea

- Originally thought to be prokaryotes
- relatively small - 5 to 10 μm
- lack membrane-bound organelles
- Usually live in extreme environments (thermophiles, halophiles, etc)

Eukaryotes

- Eu = true; karyon = nucleus
- contain membrane-bound organelles
- Evolved from prokaryotes by endosymbiotic association of two or more prokaryotes
- Include Protists, Fungi, Animals, and Plants

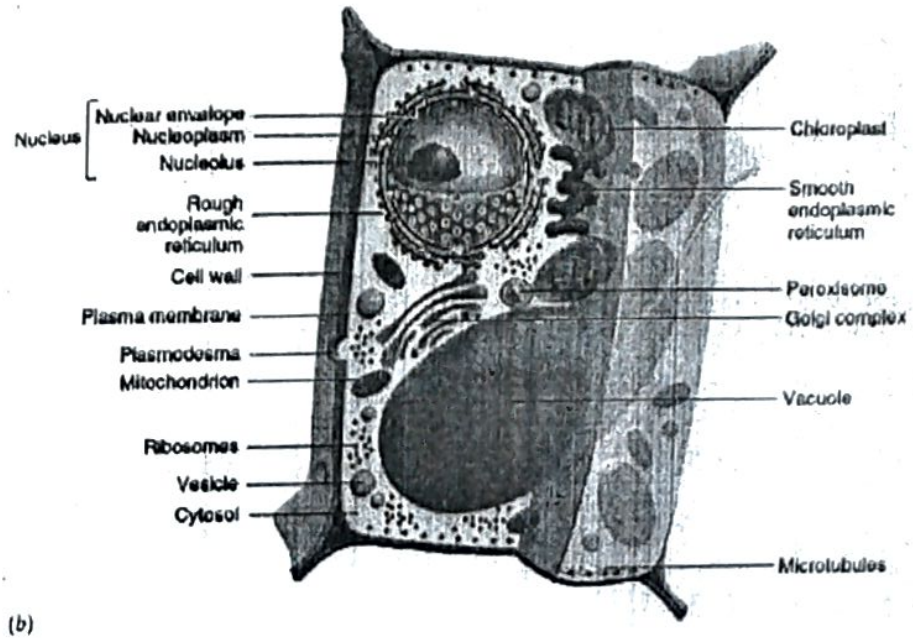
Features of Prokaryotic Cells



- Capsule - outer sticky protective layer
- Cell wall - rigid structure which helps the bacterium maintain its shape
    - this is in no way the same as the cell wall of a plant cell
- Plasma membrane - separates the cell from the environment
- Mesosome - infolding of plasma membrane to aid in compartmentalization
- Nucleoid - region where naked DNA is found
- Cytoplasm
    - semi-fluid cell interior
    - no membrane-bound organelles
    - location for metabolic enzymes
    - location of ribosomes for protein synthesis

Source: TutorVista.com (2016)

Figure 2: Diagram of a typical Prokaryotic Cell



(b)

Figure 2: Diagram of A Plant Cell

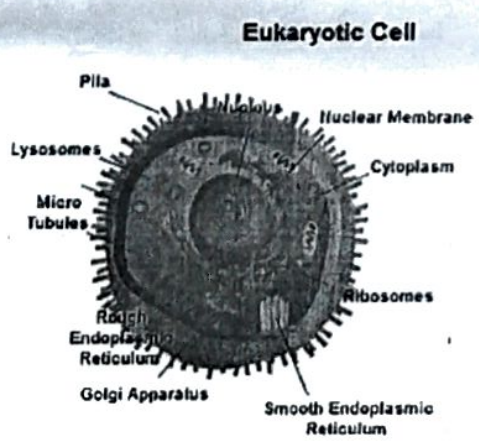


Figure 3: Diagram of Animal Cell

- Features shared with Prokaryotic cells
  - Rigid cell wall
    - Plant cells, some Fungi, some Protists
    - Animal cells lack cell wall

- Plasma membrane
- Cytoplasm with ribosomes
- Nuclear material

- **Cytoskeleton** - flexible tubular scaffold of microfilaments
  - maintains cell shape and provides support
  - anchors organelles & enzymes to specific regions of the cell
  - contractility and movement (amoeboid movement)
  - intracellular transport - tracks for vesicle and organelle movement by motor proteins
- Cytoskeleton components
  - Microfilaments
    - solid protein (actin) which is assembled at one end and disassembled at the other end
  - Intermediate filaments - rope-like fibrous proteins
    - provide structural reinforcement
    - anchor organelles
    - keep nucleus in place
  - Microtubules - hollow tubes of tubulin (a globular protein)
    - maintains cell shape
    - anchor organelles
    - movement of organelles
    - track for motor proteins
- **Cilia and Flagella** - involved in cellular movement
  - composed of microtubules
  - cilia - short, numerous, complex
  - flagella - longer, fewer, less complex
  - both arranged in a 9+2 pattern with dynein arms projecting outward
- **Nucleus**
  - Double membrane with pores
  - Outer membrane continuous with endoplasmic reticulum
  - Nuclear matrix - protein-containing fibrilar network
  - Nucleoplasm - the fluid substance in which the solutes of the nucleus are dissolved
  - Chromosomes - protein and DNA complexes
  - Nucleolus - involved in the synthesis and assembly of ribosomes
- **Endomembrane System**
  - **Endoplasmic Reticulum** - an extensive membranous network continuous with the outer nuclear membrane.
    - Rough ER - has ribosomes and is involved in secreted protein synthesis
    - Smooth ER - lacks ribosomes and is involved in membrane lipid synthesis
  - **Golgi Apparatus**
    - Flattened vesicles in stacks which receive protein from ER
    - Form secretory vesicles to transport proteins to different parts of the cell (vacuole, lysosome, etc) or for secretion
    - *cis* face - "receiving" side of Golgi apparatus
    - *trans* face - "shipping" side of Golgi apparatus

- **Lysosome**
  - found only in animal cells
  - contain enzymes for use in the hydrolytic breakdown of macromolecules
- **Peroxisome**
  - Eukaryotic organelle that degrades fatty acids and amino acids
  - Also degrades the resulting hydrogen peroxide

- **Plant Central Vacuole** - major storage space in center of plant cell with many functions
  - Digestive - break down of macromolecules
  - Storage - ions, sugars, amino acids, toxic waste
  - Maintain cell rigidity - high ionic concentration generates high water potential

- **Mitochondria**
  - Found in all eukaryotic cells (yes, even in plant cells)
  - Site of aerobic respiration
    - sugars + O_2 - - > ATP + CO_2 + H_2O
  - Contain DNA which codes for mitochondrial proteins, ribosomes, etc.
  - Divide by a process similar to binary fission when cell divides
  - Enclosed in a double membrane system
    - Inner Membrane forms the Cristae (invaginations into interior region)
      - Site of energy generation
    - Matrix is the soluble portion of the mitochondria
      - Site of carbon metabolism
      - Location of mDNA
      - Site of mitochondrial protein synthesis

- **Chloroplasts**
  - Found only in plant cells
  - Site of photosynthesis
    - conversion of solar energy to chemical energy in the form of ATP and sugars
  - Contain DNA which codes for chloroplast proteins, ribosomes, etc.
  - Divide when plant cell divides
  - Enclosed in a double membrane envelope that does not invaginate into the chloroplast
  - Thylakoid is a third internal membrane system
    - contains membrane-bound photosynthetic pigments
    - site of photochemistry (the conversion of light energy to ATP)
    - site of O_2 generation
  - Stroma is soluble portion of chloroplast
    - site of CO_2 fixation
    - site of sugar synthesis (carbon metabolism)
    - location of cpDNA
    - site of chloroplast protein synthesis
- **Ribosomes**
  - Technically not an organelle, since there is no membrane, but they are prominent cellular structures and usually lumped in with the organelles
  - The "factories" of the cell - involved in protein synthesis

- Facilitate the specific coupling of tRNA anticodons with mRNA codons during protein synthesis
- May either be free or bound to ER
- Made up of two subunits, the large and the small subunit
- Both subunits are constructed out of protein and RNA (called rRNA)
- The ribosomes of prokaryotes and eukaryotes vary slightly with regard to size and shape

Genetic Variation

Genetic variation refers to differences in the genetic makeup of individuals in a population. Genetic variation is necessary in **natural selection**. In natural selection, organisms with environmentally selected traits are better able to adapt to the environment and pass on their genes. Major causes of variation include mutations, gene flow, and sexual reproduction.

DNA mutation causes genetic variation by altering the genes of individuals in a population.

Gene flow leads to genetic variation as new individuals with different gene combinations migrate into a population.

Sexual reproduction promotes variable gene combinations in a population leading to genetic variation. Examples of genetic variation include eye color, blood type, camouflage in animals, and leaf modification in plants. Genetic variation occurs mainly through DNA mutation, gene flow (movement of genes from one population to another), and sexual reproduction. Due to the fact that environments are unstable, populations that are genetically variable will be able to adapt to changing situations better than those that do not contain genetic variation.

DNA Mutation: A mutation is a change in the DNA sequence. These variations in gene sequences can sometimes be advantageous to an organism. Most mutations that result in genetic variation produce traits that confer neither an advantage or disadvantage. Mutations lead to genetic variation by altering genes and alleles in a population. They may impact an individual gene or an entire chromosome.Although mutations change an organism's genotype (genetic makeup), they may not necessarily change an organism's phenotype.

Gene Flow: Also called gene migration, gene flow introduces new genes into a population as organisms migrate into a new environment. New gene combinations are made possible by the availability of new alleles in the gene pool. Gene frequencies may also be altered by the emigration of organisms out of a population. The immigration of new organisms into a population may help organisms better adapt to changing environmental conditions. The migration of organisms out of a population could result in a lack of genetic diversity.

Sexual Reproduction: Sexual reproduction promotes genetic variation by producing different gene combinations. Meiosis is the process by which sex cells or gametes are created. Genetic variation occurs as alleles in gametes are separated and randomly united upon fertilization. The genetic recombination of genes also occurs during crossing over or the swapping of gene segments in homologous chromosomes during meiosis.

Genetic Variation Examples

Favorable genetic traits in a population are determined by the environment. Organisms that are better able to adapt to their environment survive to pass on their genes and favorable traits. Sexual selection is commonly seen in nature as animals tend to select mates that have traits that are favorable. As females mate more often with males considered having more favorable traits, these genes occur more often in a population over time. A person's skin color, hair color, dimples, freckles, and blood type are all examples of genetic variations that can occur in a

human population. Examples of genetic **variation in plants** include the modified leaves of carnivorous plants and the development of flowers that resemble insects to lure plant pollinators. Gene variation in plants often occurs as the result of gene flow. Pollen is dispersed from one area to another by the wind or by pollinators over great distances.
Examples of genetic variation in animals include albinism, cheetahs with stripes, snakes that fly, animals that play dead, and animals that mimic leaves. These variations enable the animals to better adapt to conditions in their environments.

Evolution

In biology, evolution is the change in the characteristics of a species over several generations and relies on the process of natural selection. The theory of evolution is based on the idea that all are related and gradually change over time.
Evolution relies on there being in a population which affects the physical characteristics (phenotype) of an organism. Some of these characteristics may give the individual an advantage over other individuals which they can then pass on to their offspring.

Different types of evolution

1. Covergent evolution

When the same adaptations evolve independently, under similar selection pressures. For example, flying insects, birds and bats have all evolved the ability to fly, but independently of each other.

2. Co-evolution

When two species or groups of species have evolved alongside each other where one adapts to changes in the other. For example, flowering plants and pollinating insects such as bees.

3. Adaptive evolution

When a species splits into a number of new forms when a change in the environment makes new resources available or creates new environmental challenges For example, finches on the Galapagos Islands have developed different shaped beaks to take advantage of the different kinds of food available on different islands.

Four MainTheories of Evolution

Main theories of evolution are:

(I) Lamarckism or Theory of Inheritance of Acquired characters.
(II) Darwinism or Theory of Natural Selection.
(III) Mutation theory of De Vries.
(IV) Neo-Darwinism or Modern concept or Synthetic theory of evolution.

I. Lamarckism:

It is also called "Theory of inheritance of acquired characters" and was proposed by a great French naturalist, Jean Baptiste de Lamarck in 1809 A.D. in his famous book "Philosphic Zoologique". This theory is based on the comparison between the contemporary species of his time to fossil records. His theory is based on the inheritance of acquired characters which are defined as the changes (variations) developed in the body of an organism from normal characters, in response to the changes in environment, or in the functioning (use and disuse) of organs, in their own life time, to fulfill their new needs. Thus Lamarck stressed on adaptation as means of evolutionary modification.

A. Postulates of Lamarckism:

Lamarckism is based on following four postulates:

1. New needs:

Every living organism is found in some kind of environment. The changes in the environmental factors like light, temperature, medium, food, air etc. or migration of animal lead to the origin of new needs in the living organisms, especially animals. To fulfill these new needs, the living organisms have to exert special efforts like the changes in habits or behaviour.

2. Use and disuse of organs:

The new habits involve the greater use of certain organs to meet new needs, and the disuse or lesser use of certain other organs which are of no use in new conditions. This use and disuse of organs greatly affect the form, structure and functioning of the organs. Continuous and extra use of organs make them more efficient while the continued disuse of some other organs lead to their degeneration and ultimate disappearance. So, Lamarckism is also called "Theory of use and disuse of organs." So the organism acquires certain new characters due to direct or indirect environmental effects during its own life span and are called Acquired or adaptive characters.

3. Inheritance of acquired characters:

Lamarck believed that acquired characters are inheritable and are transmitted to the offsprings so that these are born fit to face the changed environmental conditions and the chances of their survival are increased.

4. Speciation:

Lamarck believed that in every generation, new characters are acquired and transmitted to next generation, so that new characters accumulate generation after generation. After a number of generations, a new species is formed. So according to Lamarck, an existing individual is the sum total of the characters acquired by a number of previous generations and the speciation is a gradual process.

Summary of four postulates of Lamarckism:

1. Living organisms or their component parts tend to increase in size.
2. Production of new organ is resulted from a new need.
3. Continued use of an organ makes it more developed, while disuse of an organ results in degeneration.
4. Acquired characters (or modifications) developed by individuals during their own lifetime are inheritable and accumulate over a period of time resulting a new species.

B. Evidences in favour of Lamarckism:

1. Phylogenetic studies of horse, elephant and other animals show that all these increase in their evolution from simple to complex forms.

2. Giraffe

Development of present day long-necked and long fore-necked giraffe from deer-like ancestor by the gradual elongation of neck and forelimbs in response to deficiency of food on the barren ground in dry deserts of Africa. These body parts were elongated so as to eat the leaves on the tree branches. This is an example of effect of extra use and elongation of certain organs.

3. Snakes:

Development of present day limbless snakes with long slender body from the limbed ancestors due to continued disuse of limbs and stretching of their body to suit their creeping mode of

locomotion and fossorial mode of living out of fear of larger and more powerful mammals. It is an example of disuse and degeneration of certain organs.

4. Aquatic birds:

Development of aquatic birds like ducks, geese etc. from their terrestrial ancestors by the acquired characters like reduction of wings due to their continued disuse, development of webs between their toes for wading purposes. These changes were induced due to deficiency of food on land and severe competition. It is an example of both extra use (skin between the toes) and disuse (wings) of organs. Development of flightless birds like ostrich from flying ancestors due to continued disuse of wings as these were found in well protected areas with plenty of food.

6. Horse:

The ancestors of modem horse (Equus caballus) used to live in the areas with soft ground and were short legged with more number of functional digits (e.g. 4 functional fingers and 3 functional toes in Dawn horse-Eohippus). These gradually took to live in areas with dry ground. This change in habit was accompanied by increase in length of legs and decrease in functional digits for fast running over hard ground.

C. Criticism of Lamarckism:

A hard blow to Lamarckism came from a German biologist, August Weismann who proposed the "Theory of continuity of germplasm" in 1892 A.D. This theory states that environmental factors do affect only somatic cells and not the germ cells. As the link between the generations is only through the germ cells and the somatic cells are not transmitted to the next generation so the acquired characters must be lost with the death of an organism so these should have no role in evolution. He suggested that germplasm is with special particles called "ids" which control the development of parental characters in offsprings. Weismann mutilated the tails of mice for about 22 generations and allowed them to breed, but tailless mice were never born. Pavlov, a Russian physiologist, trained mice to come for food on hearing a bell. He reported that this training is not inherited and was necessary in every generation. Mendel's laws of inheritance also object the postulate of inheritance of acquired characters of Lamarckism.

Similarly, boring of pinna of external ear and nose in Indian women; tight waist, of European ladies circumcising (removal of prepuce) in certain people; small sized feet of Chinese women etc are not transmitted from one generation to another generator. Eyes which are being used continuously and constantly develop defects instead of being improved. Similarly, heart size does not increase generation after generation though it is used continuously.

Presence of weak muscles in the son of a wrestler was also not explained by Lamarck. Finally, there are a number of examples in which there is reduction in the size of organs e.g. among Angiosperms, shrubs and herbs have evolved from the trees. So, Lamarckism was rejected.

D. Significance:

1. It was first comprehensive theory of biological evolution.
2. It stressed on adaptation to the environment as a primary product of evolution.

Neo-Lamarckism:

Long forgotten Lamarckism has been revived as Neo-Lamarckism, in the light of recent findings in the field of genetics which confirm that environment does affect the form, structure; colour, size etc. and these characters are inheritable. Main scientists who contributed in the evolution of Neo- Lamarckism are: French Giard, American Cope, T.H. Morgan, Spencer, Packard, Bonner, Tower, Naegali, Mc Dougal, etc. Term neo-Lamarckism was coined by Alphaeus S. Packard.

Neo-Lamarckism states: 1. Germ cells may be formed from the somatic cells indicating similar nature of chromosomes and gene make up in two cell lines e.g.

(a) Regeneration in earthworms.
(b) Vegetative propagation in plants like Bryophyllum (with foliar buds).
(c) A part of zygote (equipotential egg) of human female can develop into a complete baby (Driesch).

2. Effect of environment on germ cells through the somatic cells e.g. Heslop Harrison found that a pale variety of moth, *Selenia bilunaria,* when fed on manganese coated food, a true breeding melanic variety of moth is produced.

3. Effect of environment directly on germ cells. Tower exposed the young ones of some potato beetles to temperature **UK Jobs** | Sponsored fluctuation and found that though beetles remained unaffected with no somatic change but next generation had marked changes in body colouration.

Muller confirmed the mutagenic role of X-rays on Drosophila while C. Auerbach *et al.* confirmed the chemical mutagens (mustard gas vapours) causing mutation in *Drosophila melanogaster*, so neo-Lamarckism proved:

(a) Germ cells are not immune from the effect of environment.
(b) Germ cells can carry somatic changes to next progeny (Harrison's experiment).
(c) Germ cells may be directly affected by the environmental factors (Tower's experiment).

II. Darwinism (Theory of Natural Selection):

A. Introduction:

Charles Darwin (Fig. 7.36) (1809- 1882 A.D.), an English naturalist, was the most dominant figure among the biologists of the 19th century. He made an extensive study of nature for over 20 years, especially in 1831-1836 when he went on a voyage on the famous ship "H.M.S. Beagle" and explored South America, the Galapagos Islands and other islands. He collected the observations on animal distribution and the relationship between living and extinct animals. He found that existing living forms share similarities to varying degrees not only among themselves but also with the life forms that existed millions of years ago, some of which have become extinct. He stated that every population has built in variations in their characters. From the analysis of his data of collection and from Malthus's Essay on Population, he got the idea of struggle for existence within all the populations due to continued reproductive pressure and limited resources and that all organisms, including humans, are modified descendents of previously existing forms of life. In 1858 A.D., Darwin was highly influenced by a short essay entitled "On the Tendency of Varieties to Depart Indefinitely from the Original Type" written by another naturalist, Alfred Russel Wallace (1812-1913) who studied biodiversity on Malayan archipelago and came to similar conclusions. Darwin and Wallace's views about evolution were presented in the meeting of Linnean Society of London by Lyell and Hooker on July1, 1858. Darwin's and Wallace's work was jointly published in "Proceedings of Linnean Society of London" in 1859. So it is also called Darwin-Wallace theory. Darwin explained his theory of evolution in a book entitled "On the Origin of Species by means of Natural Selection". It was published on 24th Nov., 1859. In this theory, Charles Darwin proposed the concept of natural selection as the mechanism of evolution.

B. Postulates of Darwinism:

Main postulates of Darwinism are:

1. Geometric increase.
2. Limited food and space.
3. Struggle for existence.
4. Variations.

5. Natural selection or Survival of the fittest.
6. Inheritance of useful variations.
7. Speciation.

1. Geometric increase:

According to Darwinism, the populations tend to multiply geometrically and the reproductive powers of living organisms (biotic potential) are much more than required to maintain their number e.g., Paramecium divides three times by binary fission in 24 hours during favourable conditions. At this rate, a Paramecium can produce a clone of about 280 million Paramecia in just one month and in five years, can produce Paramecia having mass equal to 10,000 times than the size of the earth.

Other rapidly multiplying organisms are: Cod (one million eggs per year); Oyster (114 million eggs in one spawning); Ascaris (70, 00,000 eggs in 24 hours); housefly (120 eggs in one laying and laying eggs six times in a summer season); a rabbit (produces 6 young ones in a litter and four litters in a year and young ones start breeding at the age of six months).

Similarly, the plants also reproduce very rapidly e.g., a single evening primrose plant produces about 1, 18,000 seeds and single fern plant produces a few million spores.

Even slow breeding organisms reproduce at a rate which is much higher than required e.g., an elephant becomes sexually mature at 30 years of age and during its life span of 90 years, produces only six offsprings. At this rate, if all elephants survive then a single pair of elephants can produce about 19 million elephants in 750 years. These examples confirm that every species can increase manifold within a few generations and occupy all the available space on the earth, provided all survive and repeat the process. So the number of a species will be much more than can be supported on the earth.

2. Limited food and space:

Darwinism states that though a population tends to increase geometrically, the food increases only arithmetically. So two main limiting factors on the tremendous increase of a population are: limited food and space which together form the major part of carrying capacity of environment. These do not allow a population to grow indefinitely which are nearly stable in size except for seasonal fluctuation.

3. Struggle for existence:

Due to rapid multiplication of populations but limited food and space, there starts an everlasting competition between individuals having similar requirements. In this competition, every living organism desires to have an upper hand over others.

This competition between living organisms for the basic needs of life like food, space, mate etc., is called struggle for existence which is of three types:

(a) Intraspecific: Between the members of same species e.g. two dogs struggling for a piece of meat.

(b) Interspecific: Between the members of different species e.g. between predator and prey.

(c) Environmental or Extra specific:

Between living organisms and adverse environmental factors like heat, cold, drought, flood, earthquakes, light etc. Out of these three forms of struggle, the intraspecific struggle is the strongest type of struggle as the needs of the individuals of same species are most similar e.g., sexual selection in which a cock with a more beautiful comb and plumage has better chances to win a hen than a cock with less developed comb.

Similarly, cannabilism is another example of intraspecific competition as in this; individuals eat upon the members of same species. In this death and life struggle, the majority of individuals die

before reaching the sexual maturity and only a few individuals survive and reach the reproductive stage. So struggle for existence acts as an effective check on an ever-increasing population of each species. The nature appears saying, "They are weighed in the balance and are found wanting." So the number of offsprings of each species remains nearly constant over long period of time.

4. Variations:

Variation is the law of nature. According to this law of nature, no two individuals except identical (monozygotic) twins are identical. This everlasting competition among the organisms has compelled them to change according to the conditions to utilize the natural resources and can survive successfully. Darwin stated that the variations are generally of two types—
continuous variations or fluctuations and discontinuous variations.

On the basis of their effect on the survival chances of living organisms, the variations may be neutral, harmful and useful. Darwin proposed that living organisms tend to adapt to changing environment due to useful continuous variations {e.g., increased speed in the prey; increased water conservation in plants; etc.), as these will have a competitive advantage.

5. Natural selection or Survival of the fittest:

Darwin stated that as many selects the individuals with desired characters in artificial selection; nature selects only those individuals out of the population which are with useful continuous variations and are best adapted to the environment while the less fit or unfit individuals are rejected by it. Darwin stated that if the man can produce such a large number of new species/varieties with limited resources and in short period of time by artificial selection, then natural selection could account for this large biodiversity by considerable modifications of species with the help of unlimited resources available over long span of time.

Darwin stated that discontinuous variations appear suddenly and will mostly be harmful, so are not selected by nature. He called them "sports". So the natural selection is an automatic and self going process and keeps a check on the animal population. **This sorting out of the individuals with useful variations from a heterogeneous population by the nature was called Natural selection by Darwin and Survival of the fittest by Wallace. So natural selection acts as a restrictive force and not a creative force.**

6. Inheritance of useful variations:

Darwin believed that the selected individuals pass their useful continuous variations to their offsprings so that they are born fit to the changed environment.

7. Speciation:

According to Darwinism, useful variations appear in every generation and are inherited from one generation to another. So the useful variations go on accumulating and after a number of generations, the variations become so prominent that the individual turns into a new species. So according to Darwinism, evolution is a gradual process and speciation occurs by gradual changes in the existing species.

Thus the two key concepts of Darwinian Theory of Evolution are:

1. Branching Descent, and 2. Natural Selection.

C. Evidences in favour of Darwinism:

1. There is a close parallelism between natural selection and artificial selection.
2. The remarkable cases of resemblance e.g. mimicry and protective colouration can be achieved only by gradual changes occurring simultaneously both in the model and the mimic.

3. Correlation between position of nectaries in the flowers and length of the proboscis of the pollinating insect.

D. Evidences against Darwinism:

Darwinism is not able to explain:

1. The inheritance of small variations in those organs which can be of use only when fully formed e.g. wing of a bird. Such organs will be of no use in incipient or underdeveloped stage.
2. Inheritance of vestigial organs.
3. Inheritance of over-specialised organs e.g. antlers in deer and tusks in elephants.
4. Presence of neuter flowers and sterility of hybrids.
5. Did not differentiate between somatic and germinal variations.
6. He did not explain the causes of the variations and the mode of transmission of variations.
7. It was also refuted by Mendel's laws of inheritance which state that inheritance is particulate.

So this theory explains only the survival of the fittest but does not explain the arrival of the fittest so Darwin himself confessed, "natural selection has been main but not the exclusive means of modification."

Principle of Natural Selection:

It was proposed by Ernst Mayer in 1982. It stems from five important observations and three inferences.This principle demonstrates that natural selection is the differential success in reproduction and enables the organisms to adapt them to their environment by development of small and useful variations. These favourable Variations accumulate over generation after generation and lead to speciation. So natural selection operates through interactions between the environment and inherent variability in the population.

III. Mutation Theory of Evolution:

The mutation theory of evolution was proposed by a Dutch botanist, Hugo de Vries (1848-1935 A.D.) in 1901 A.D. in his book entitled "Species and Varieties, Their Origin by Mutation". He worked on evening primrose (*Oenothera lamarckiana*).

A. Experiment:

Hugo de Vries cultured *O. lamarckiana* in botanical gardens at Amsterdam. The plants were, allowed to self pollinate and next generation was obtained. The plants of next generation were again subjected to self pollination to obtain second generation. Process was repeated for a number of generations.

B. Observations:

Majority of plants of first generation were found to be like the parental type and showed only minor variations but 837 out of 54,343 members were found to be very different in characters like flower size, shape and arrangement of buds, size of seeds etc. These markedly different plants were called primary or elementary species. A few plants of second generation were found to be still more different. Finally, a new type, much longer than the original type, called *O. gigas*, was produced. He also found the numerical chromosomal changes in the variants (e.g. with chromosome numbers 16, 20, 22, 24, 28 and 30) up to 30 (Normal diploid number is 14).

C. Conclusion:

1. The evolution is a discontinuous process and occurs by mutations (L. mutate = to change; sudden and inheritable large differences from the normal and are not connected to normal by intermediate forms). Individuals with mutations are called mutants.
2. Elementary species are produced in large number to increase chances of selection by nature.

3. Mutations are recurring so that the same mutants appear again and again. This increases the chances of their selection by nature.
4. Mutations occur in all directions so may cause gain or loss of any character.
5. Mutability is fundamentally different from fluctuations (small and directional changes).

So according to mutation theory, evolution is a discontinuous and jerky process in which there is a jump from one species to another so that new species arises from pre-existing species in a single generation (macrogenesis or saltation) and not a gradual process as proposed by Lamarck and Darwin.

D. Evidences in favour of Mutation theory:

1. Appearance of a short-legged sheep variety, Ancon sheep from long-legged parents in a single generation in 1791 A.D. It was first noticed in a ram (male sheep) by an American farmer, Seth Wright.
2. Appearance of polled Hereford cattle from horned parents in a single generation in 1889.
3. De Vries observations have been experimentally confirmed by McDougal and Shull in America and Gates in England.
4. Mutation theory can explain the origin of new varieties or species by a single gene mutation e.g. *Cicer gigas*, Nuval orange. Red sunflower, hairless cats, double- toed cats, etc.
5. It can explain the inheritance of vestigial and over-specialized organs.
6. It can explain progressive as well as retrogressive evolution.

E. Evidences against Mutation theory:

1. It is not able to explain the phenomena of mimicry and protective colouration.
2. Rate of mutation is very low, i.e. one per million or one per several million genes.
3. *Oenothera lamarckiana* is a hybrid plant and contains anamolous type of chromosome behaviour.
4. Chromosomal numerical changes as reported by de Vries are unstable.
5. Mutations are incapable of introducing new genes and alleles into a gene pool.

IV. Neo-Darwinism or Modern Concept or Synthetic Theory of Evolution:

The detailed studies of Lamarckism, Darwinism and Mutation theory of evolution showed that no single theory is fully satisfactory. Neo-Darwinism is a modified version of theory of Natural Selection and is a sort of reconciliation between Darwin's and de Vries theories.

Modern or synthetic theory of evolution was designated by Huxley (1942). It emphasises the importance of populations as the units of evolution and the central role of natural selection as the most important mechanism of evolution. The scientists who contributed to the outcome of Neo-Darwinism were: J.S. Huxley, R.A. Fischer and J.B.S. Haldane of England; and S.Wright, Ford, H.J. Muller and T. Dobzhansky of America.

A. Postulates of Neo-Darwinism:

1. Genetic Variability:

Variability is an opposing force to heredity and is essential for evolution as the variations form the raw material for evolution. The studies showed that the units of both heredity and mutations are genes which are located in a linear manner on the chromosomes.

Various sources of genetic variability in a gene pool are:

(i) Mutations:

These are sudden, large and inheritable changes in the genetic material. On the basis of amount of genetic material involved, mutations are of three types:

(a) Chromosomal aberrations:

These include the morphological changes in the chromosomes without affecting the number of chromosomes. These result changes either in the number of genes (deletion and duplication) or in the position of genes (inversion).

There are of four types:

1. Deletion (Deficiency) involves the loss of a gene block from the chromosome and may be terminal or intercalary.
2. Duplication involves the presence of some genes more than once, called the repeat. It may be tandem or reverse duplication.
3. Translocation involves transfer of a gene block from one chromosome to a non-homologous chromosome and may be simpleor reciprocal type.
4. Inversion involves the rotation of an intercalary gene block through 180° and may be paracentric or pericentric.

(b) Numerical chromosomal mutations:

These include changes in the number of chromosomes. These may be euploidy (gain or loss of one or more genomes) or aneuploidy (gain or loss of one or two chromosomes). Euploidy may be haploidy or polyploidy. Among polyploidy, tetraploidy is most common. Polyploidy provides greater genetic material for mutations and variability. In haploids, recessive genes express in the same generation. Aneuploidy may be hypoploidy or hyperploidyl Hypoploidy may bemonosomy (loss of one chromosome) or nullisomy (loss of two chromosomes). Hyperploidy may be trisomy (gain of one chromosome) or tetrasomy (gain of two chromosomes).

(c) Gene mutations (Point mutations):

There are invisible changes in chemical nature (DNA) of a gene and are of three types:

1. Deletion involves loss of one or more nucleotide pairs.
2. Addition involves gain of one or more nucleotide pairs.
3. Substitution involves replacement of one or more nucleotide pairs by other base pairs. These may be transition or transversion type. These changes in DNA cause the changes in the sequence of amino acids so changing the nature of proteins and the phenotype.

(ii) Recombination of genes:

Thousands of new combinations of genes are produced due to crossing over, chance arrangement of bivalents at the equator during metaphase – I and chance fusion of gametes during fertilization.

(iii) Hybridization:

It involves the interbreeding of two genetically different individuals to produce 'hybrids'. (iv) Physical mutagens (e.g. radiations, temperature etc.) and chemical mutagens (e.g. nitrous acid, colchicine, nitrogen mustard etc.).

(v) Genetic drift:

It is the elimination of the genes of some original characteristics of a species by extreme reduction in a population due to epidemics or migration or Sewell Wright effect.

The chances of variations are also increased by non-random mating.

2. Natural Selection:

Natural selection of Neo- Darwinism differs from that of Darwinism that it does not operate through "survival of the fittest" but operates through differential reproduction and comparative reproductive success.

Differential reproduction states that those members, which are best adapted to the environment, reproduce at a higher rate and produce more offsprings than those which are less adapted. So

these contribute proportionately greater percentage of genes to the gene pool of next generation while less adapted individuals produce fewer offsprings.

If the differential reproduction continues for a number of generations, then the genes of those individuals which produce more offsprings will become predominant in the gene pool of the population. Due to sexual communication, there is free flow of genes so that the genetic variability which appears in certain individuals, gradually spreads from one deme to another deme, from deme to population and then on neighbouring sister populations and finally on most of the members of a species. So natural selection causes progressive changes in gene frequencies, 'i.e. the frequency of some genes increases while the frequency of some other genes decreases.

more offsprings?

(i) Mostly those individuals which are best adapted to the environment.

(ii) Whose sum of the positive selection pressure due to useful genetic variability is more than the sum of negative selection pressure due to harmful genetic variability? (iii) Which have better chances of sexual selection due to development of some bright coloured spots on their body e.g. in many male birds and fish.

(iv) Those who are able to overcome the physical and biological environmental factors to successfully reach the sexual maturity. So natural selection of Neo-Darwinism acts as a creative force and operates through comparative reproductive success. Accumulation of a number of such variations leads to the origin of a new species.

3. Reproductive isolation:

Any factor which reduces the chances of interbreeding between the related groups of living organisms is called an isolating mechanism. Reproductive isolation is must so as to allow the accumulation of variations leading to speciation by preventing hybridization.

In the absence of reproductive isolation, these variants freely interbreed which lead to intermixing of their genotypes, dilution of their peculiarities and disappearance of differences between them. So, reproductive isolation helps in evolutionary divergence.

EVIDENCES TO SHOW ORGANIC EVOLUTION

1. CYTOLOGY

The establishment of the cell theory was more directly related to the origin of cells biology and most fundamentally biological generalizations. It states in its present form that all living beings (animals, plants and protozoans) are composed of cell products. The cell theory hence had wide range of events in all the fields of biological research. Loevrenhoek established that every cell is formed by the division of another cell. Much later with the progress of biochemistry . it was shown that there are fundamental similarities in the chemical composition and metabolic activity of all cells. The function of the organism as a whole was also recognized to be a result of the sum total of the activities and interactions of the cell unit. The cell theory soon applied to pathology by Virchow (1858).

2. GEOLOGY (FOSSILS) AND EVOLUTION

Life appeared on this planet perhaps three to six hundred million years ago. For about a thousand million years the earth revolved around the sun as a fiery, lifeless mass. Gradually it cooled and rocks solidified from the motten lava born of the flames. As a result these rocks are called igneous rocks. As cooling went on, further layers, or strata were laid down. Soon the wind, rain and frost wore off bits of these hard rocks. The small particles so formed flowed down in streams and rivers until, when the flow became sluggish, they fell to the bottom where they formed thick layers of mud. In time pressure from above hardened this mud into further rock, so that on top of the original igneous rocks lay the sedimentary or stratified rocks in layers. As igneous rocks and sedimentary rocks underwent great earth movements, metamorphic rocks were formed. The remains organisms which existed many years ago could be found in the sedimentary rocks.

3. ANATOMY AND EVOLUTION

There are evidences of evolution in certain anatomical features of vertebrates. There is a progressive evolutionary change in the anatomy of the heart in the various classes of vertebrates. Fishes have a simple heart with one auricle and are ventricle. Amphibians have two auricles and one ventricle, reptiles have two auricles and a partially division ventricle, and birds and mammals have two auricles and two ventricles. In the course of these changes the circulation of the blood also changed from a s "single" to a perfected double circulation.

Other evolutionary changes in anatomy can be traced in the progressive development of that the brain, sense organs like ears, and the limbs. The limbs of various vertebrates have been modified for a number of functions. Thus, the pentadactly fore limbs is modified into: wings for flying in birds and bats; flippers for swimming in whales; legs for walking and running in horses and arms for grasping and holding in human beings and other bipeds.

4. EMBRYOLOGY AND EVOLUTION

A study of comparative embryology provides further evidence for phylogenic evolution. A young human embryo looks very similar to the young embryos of other mammals, birds and reptiles. At certain stages in their development of all these embryos have fish-like appearance and a vascular system with a single circulation. From these and other characteristics, it is possible to infer that land vertebrates probably had aquatic ancestors.