

Basics of Biology
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Module XI: Summary and Conclusions
Lecture 49
Summary (Part 1)

Hello everyone, this is Dr. Vishal Trivedi from Department of Biosciences and Bioengineering IIT, Guwahati and what we were discussing, we were discussing about the basics of the living organisms and in this course, which is almost about to end. So far what we have discussed, we have discussed about the different aspects of the living organisms.

So we started with a very basic understanding about the living organisms, where we discussed about the, what is the biology and how the biology is involved with to the different types of experimentations by the scientists and so on. So, in this particular module, what we are going to do is we are actually going to give you an overview of whatever we have discussed so far.

Since your exams are coming up very shortly, this kind of revision and this kind of recapitulation of whatever we have discussed so far, is actually going to help you to face the final exams or it will help you to prepare for the final exams. So, let us start our lecture today and what we are going to do today is, we are going to discuss about the very, superficially we are going to go through with the content what we have discussed so far in the last previous 11 modules.

And then we are going to deal some of the aspects which I feel that important for you to understand. And hopefully this is actually going to help you in terms of preparing for your exams. So, what we have started with, we started with the very basic understanding about the classifications, then we started about of the living different types of organisms and that could have helped you to understand how these organisms are complicated.

How they are actually been diversified from the other organisms and so on. And from where this diversity comes? This diversity comes because the every organism is trying to evolve over the course of time and that is how they are actually been evolved into the different types of species and different types of organisms.

With the basic understanding about the classification and the evolutions, we have then further moved on to tell you, give you the very detailed analysis or detailed description about the different types of cells, what are being found into the prokaryotic or the eukaryotic cell.

In the prokaryotic cell, we discuss about the cell wall we have discussed about the cell wall of the gram negative and gram positive we have also discussed very briefly about the gram staining and so on. And then we have also moved about the eukaryotic cell. So let us discuss some of these aspects in detail. And I hope it will help you to prepare for your exams.

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BIOLOGY

BIOS
↓
Living Organism

LOGOS
↓
Study

Definition: The field of science which study the living organism is known as **BIOLOGY**

Biologist – the person who studies Biology

So we will start with a very basic same questions what is biology? Biology is a field of science, where you are actually going to deal with the different aspects of the living organisms. So, as the name suggests biology is a submission of the two words one is called as the BIOS the other one is called as the logos and the BIOS means the living organisms whereas the logos means the study.



So, this means the biology is, the definition of the biology is that it is the field of science, which actually study the living organism and that is known as the biology. So, and the person who actually studied the field of biology are called as the biologist. Now, since we are talking about the biology and the biology is a field of science, which is study the living organism, it is important for us to even discuss about the what is living organism and how the living organism is different from the non living organisms?

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WHAT DEFINES LIVING OBJECT??

COMPARISON OF LIVING WITH NON-LIVING SYSTEM (DIESEL ENGINE).

Features	Living System	Non-living System (Diesel engine)
Energy Source	Food	Diesel
Machinery	Metabolic Reactions	Combustion
Mechanism to utilize energy	Anabolic Reactions	Torque
Dispose waste material	Present.	Exhaust in the form of smoke.

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So, what is living organisms? Living organism, we have discussed in detail about the different types of the properties of the living organisms and here I have given you a comparative differences or comparison of the living organism versus the non living organisms. So, they are different in terms of the intake of the food their mode of how they are actually generating the energy and how they are actually disposing of the waste material.

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WHAT DEFINES LIVING OBJECT??

Number of characteristics observed in a living organism can be define.


- Self Growth or Self Renewal
- Endogenous ability to produce energy
- Movement with an exception in the case of Plants as they don't Move
- Ability to self replicate.

Ⓞ

In addition, with the advancement in technology, the criteria for living organism is redefined. These re-defined criteria are as follows:

- Complex organization- Composed of different types of cells
- Metabolism- To produce energy and utilize preformed food material.
- Responsiveness- To respond to the extreme environmental conditions. Such as Temp, wind, starvation.
- Growth- Endogenous Growth
- Reproduction- ability to give off springs
- Evolution- To better suits to the changed environment or metabolism.

ROBOT



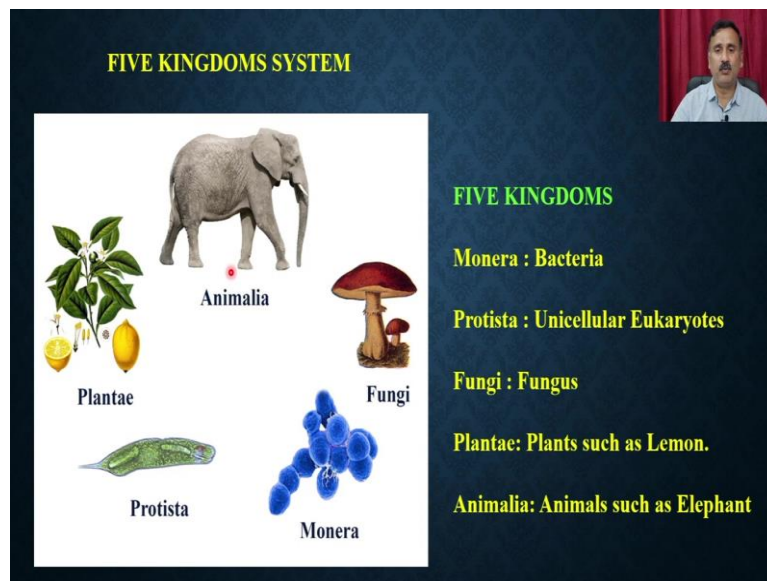
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Now, we have also further moved on and discussed in detail or defined what are the conditions which is actually going to define as a living organisms. So, one of the important feature of the living organism is that it is should be having a self growth or self renewal, which means that growth should be in indigenous rather than exogenous.

And it should have the indigenous ability to produce the energy right, and then should have a movement with an exception that plants they do not move, but the plants are also the living organisms, and then they also should have the ability to self replicate.

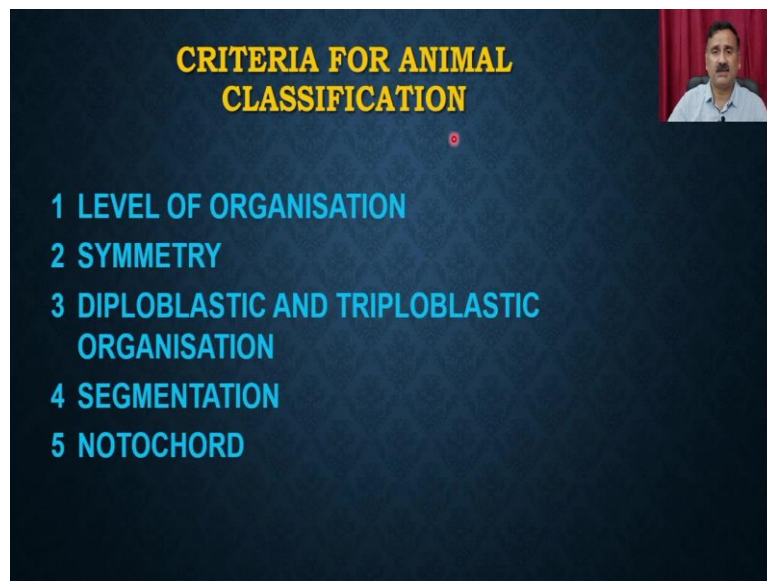
And once we understood the living organism, once we understood the biology and how the different biologists have studied the field of biology and their contribution into the biology before they are moved on to the ask the first question is how we can actually be able to classify the different types of organisms.

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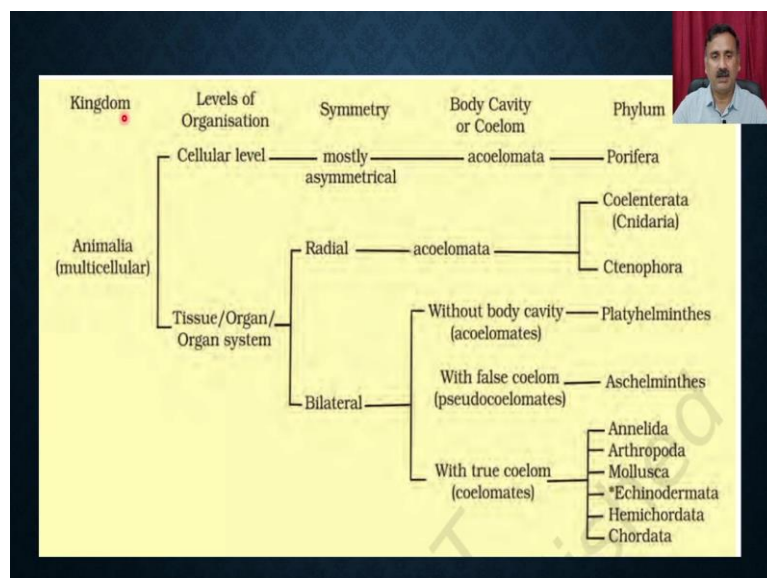
So, there was a proposal about the five kingdoms system, in a five kingdoms system, we have the five different kingdoms like Monera, Protista, Fungi, Plantae and Animalia and how these five kingdoms are being you know, how the animals are being classified into how the organisms are been classified into the five Kingdom is based on the differences or the similarity among the different types of organisms.

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So, then further, we move further moved on to discuss about the different types of criteria what people have used to classify the living organisms. So, we discuss about the five different criteria like the level of organizations, symmetry, different types of the membranes or present or diploblastic or diploblastic organizations, segmentations and notochord. And based on these kinds of criteria of the classifications, the whole animal kingdom is been classified into the multiple sub phylum and phylum.

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So, if you see it, how the Kingdom Animalia is been distributed. So, based on the level of organization, either you can have the cellular level organization or the tissue or the organ system of the organization, then within the symmetry you can have the asymmetrical, radial

symmetry or bilateral symmetry based on the body cavity, it could be acoelomate, coelomate or within the coelomate, you can have the pseudocoelomates or the coelomates.

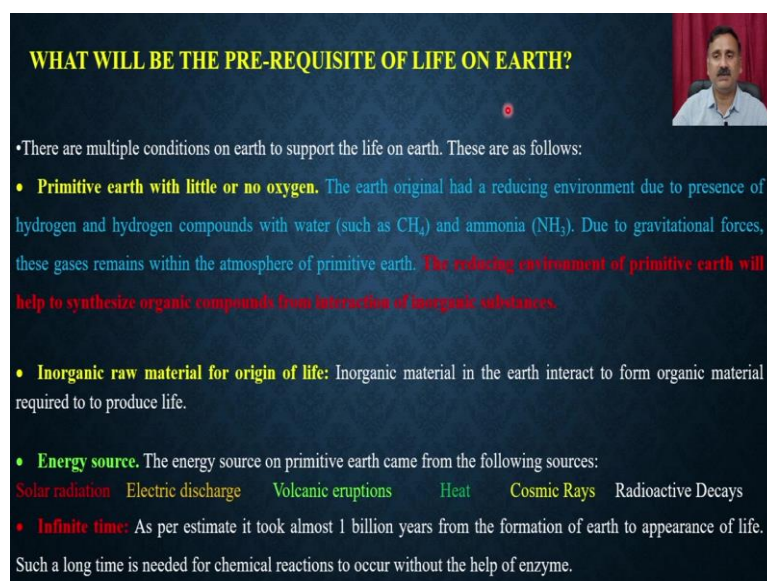
And then within the and based on this it has been divided into the different phylum for example, within the Porifera, so Porifera is a cellular level of organizations mostly asymmetrical, acoelomate, so that is why these kinds of organisms which you are following these kinds of organizations, it is been classified into the Porifera.

Similarly, when the organization is the tissue level or organ system, then it could be radial or bilateral. So, if the symmetry is radial and organism is acoelomate, then it can either be coelenterate or the ctenophora and then if it is symmetry is bilateral, then it can be acoelomate, pseudocoelomates or the coelomate.

If it is acoelomate then it can be a platyhelminthes or the flatworm then if it is a false coelom that is a pseudocoelomates then it can be Aschelminthes and if the true coelomate then it could be the Annelida, arthropoda, Mollusca, Echinodermata, Hemichordata and Chordate. Remember that this is a summary of what we have discussed in the previous module.

So, we are not going to discuss in detail about all of the properties of these firearms and so on. And if you see here if the chordata is at the bottom and the chordata is a well defined and well developed organisms. So, after this we have also discussed about how the organisms are being evolved or how the organisms are being originated on to the earth.

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WHAT WILL BE THE PRE-REQUISITE OF LIFE ON EARTH?

• There are multiple conditions on earth to support the life on earth. These are as follows:

- **Primitive earth with little or no oxygen.** The earth original had a reducing environment due to presence of hydrogen and hydrogen compounds with water (such as CH_4) and ammonia (NH_3). Due to gravitational forces, these gases remains within the atmosphere of primitive earth. **The reducing environment of primitive earth will help to synthesize organic compounds from interaction of inorganic substances.**
- **Inorganic raw material for origin of life:** Inorganic material in the earth interact to form organic material required to to produce life.
- **Energy source.** The energy source on primitive earth came from the following sources:
Solar radiation Electric discharge Volcanic eruptions Heat Cosmic Rays Radioactive Decays
- **Infinite time:** As per estimate it took almost 1 billion years from the formation of earth to appearance of life. Such a long time is needed for chemical reactions to occur without the help of enzyme.

So, what is the pre-requisite of the life on the Earth? Because there is only one planet on which the life exist and that is the Earth right. So, there is a condition so primitive Earth with very little or no oxygen so that was the first criteria that why the Earth has been chosen as the planet for the origin of life right.

And then we have the lot of inorganic raw material for the origin of life for example, all these inorganic material is required to produce the organic material and then it also require an energy source. So, energy source could be the solar radiation, electric discharge, volcanic eruptions, heat, cosmic rays are the radioactive decays, and then there is a in finite time.

So, as per the estimate it took almost 1 billion year from the formation of Earth to the appear of the life and that is why such a long time is required for the origin of life and origin of life is a very, very complicated process and there are many hypotheses, what has been proposed for explaining the origin of life on the Earth.

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HOW LIFE ORIGINATED ON EARTH?

Six major theories are proposed to explain the origin of life on earth. These theories are as follows:

1. **Theory of Special Creations:** GOD is the creator of Earth and Organisms
2. **Theory of spontaneous generations:** Non-living matter give rise to organisms
3. **THEORY OF CATASTROPHISM:** Similar to theory of special creations.
4. **THEORY OF COSMOZOIC:** Life on earth comes from other planet.
5. **THEORY OF ETERNITY OF LIFE:** Life has no beginning or end
6. **MODERN THEORY:** Chemical molecules give rise to generation of organisms.

So, we have discussed about the six different types of theories, we have discussed about the theory of special creations, we have discussed about the theory of spontaneous generation theory of catastrophism, theory of cosmozoic, theory of eternity of life and then we have also discussed about modern chemical theory.

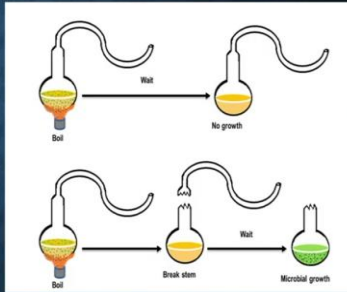
So, in the theory of special creation, God is the creator of Earth and the organisms and there are different steps in which the people have explained how the God has created the earth and as well as the different types of organisms, and there are all a lot of contradiction for most of these theories, including the modern theories.

So, as far as the experimental evidences is concerned, the theory of spontaneous generation and the theory of modern theory of chemical theory is actually been explained by the different types of experiments. Apart from that, there are so many experiments are being done to overrule the some of these, you know the proposals.

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Louis Pasteur's Experiment

In another conclusive experiment, Pasteur had designed experiment in a flask with "S" shaped curve tube. He took hay infusion in the flask and boiled for several minutes. After cooling, the steam condensed into the lower part of tube and act as barrier to stop the entry of microorganisms. No life appeared in the flask for several months. Analysis of condensed water indicates appearance of microorganism in the neck of the tube. Breaking of "S" tube allowed the growth of microorganisms in the flask.



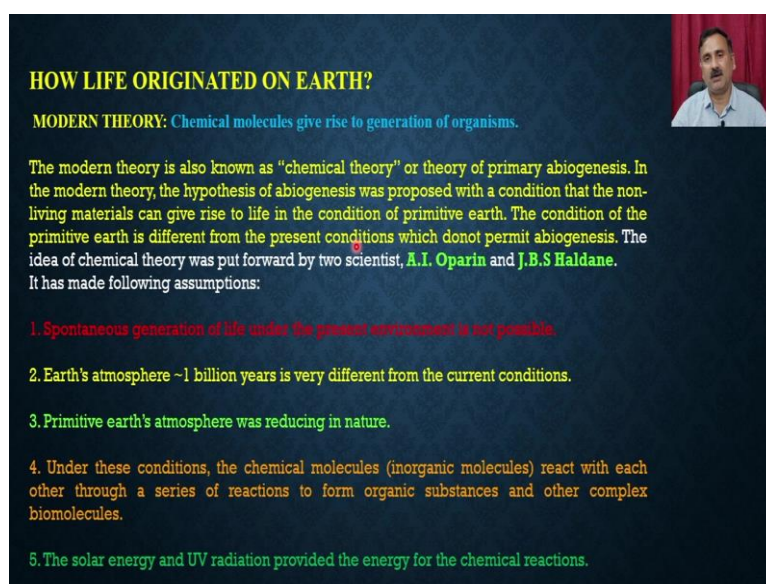
The diagram illustrates two experimental setups. The top setup shows a flask containing a yellow liquid being heated (labeled 'Boil'). The neck of the flask is curved into an 'S' shape. After the flask is cooled, the liquid in the neck has condensed, forming a barrier. The flask is then left to 'Wait', and the result is 'No growth'. The bottom setup shows a similar flask being heated ('Boil'). The neck is broken at the top, so the liquid in the neck does not condense. After 'Wait', the flask shows 'Microbial growth'.

So, one of the classical example, which is always been done by the Louis Pasteur is that, where the Pasteur has actually grown the broth into an S shaped curve. So, in a Pasteur whatever he has done is he has taken the S shaped curve Q, and he took the hay infusion in the flask and boiled it for the several minutes.

He boiled it so that the broth is going to be sterile. And after cooling down, the steam which comes out from the broth is actually been condensed into the this S color tube okay. And it actually act as a barrier to stop the entry of microorganisms. So, no life appeared in the flask was several month analysis of the condensed water indicates the appearance of the micro organism of the neck and the breaking of the S tube.

So, when if he wants to confirm that it is basically because of this kind of barrier, he broken the S tube and that is how he got the microbial growth. And that is actually been an experiment to disprove the some of the early early access or earlier proposed theories.

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HOW LIFE ORIGINATED ON EARTH?

MODERN THEORY: Chemical molecules give rise to generation of organisms.

The modern theory is also known as "chemical theory" or theory of primary abiogenesis. In the modern theory, the hypothesis of abiogenesis was proposed with a condition that the non-living materials can give rise to life in the condition of primitive earth. The condition of the primitive earth is different from the present conditions which do not permit abiogenesis. The idea of chemical theory was put forward by two scientists, **A.I. Oparin** and **J.B.S Haldane**. It has made following assumptions:

1. Spontaneous generation of life under the present environment is not possible.
2. Earth's atmosphere ~1 billion years is very different from the current conditions.
3. Primitive earth's atmosphere was reducing in nature.
4. Under these conditions, the chemical molecules (inorganic molecules) react with each other through a series of reactions to form organic substances and other complex biomolecules.
5. The solar energy and UV radiation provided the energy for the chemical reactions.

Subsequent to that, the people have also proposed the modern theories and the modern theory is completely been a theory which is been dependent on the experiments. So, the modern theory or the chemical theory of the origin of life is been proposed by the AI Oparin and Haldane and it has the following assumptions.

The spontaneous generation of life under the present environment is not possible because the present environment is full of oxygen whereas in the primitive Earth it was the absence of oxygen, then the Earth's atmosphere approximately 1 billion years is a very different from the current conditions, then the primitive Earth atmosphere was reducing in nature currently, the Earth's atmosphere is oxidizing in nature.

Under these conditions, the chemical molecules react with each other through a series of reaction to form the organic substances and other complex biomolecule. And from where they are getting the energy, they are getting the energy from the solar energy and as well as the UV radiation.

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EXPERIMENT EVIDENCES

The hypothesis proposed by Haldane didn't find much support without scientific experimentation. To conclusively support the chemical theory, **Miller and Urey** conducted experiment in mimicking primitive earth environment.

The experimental setup consists of a glass flask, a condenser, and a liquid flask interconnected with tubes and a source of electric spark to provide energy.

He introduced a mixture of **methane (CH₄)**, **ammonia (NH₃)**, and **hydrogen (H₂)** in the ratio of 2:2:1 and **water (H₂O)** vapor at **800°C**.

he allowed to circulate the mixture into this closed glass apparatus for 18 days continuously.

He provided energy in the form of spark by supplying electricity of 75000 volts through two electrodes. The electric sparks mimicks lightning in the primitive earth atmosphere.

While passing the mixture, gases were passes through a liquid flask to simulate the volcano. The mixture was collected from the stop cock and analyzed using chromatographic and calorimetric techniques.

The analysis of mixture indicates the presence of amino acids such as glycine, alanine, aspartic acid, nitrogen base adenine and

https://en.wikipedia.org/wiki/File:Miller-Urey_experiment_-_Work_by_the_C3BC_consortium_licensed_under_CC-BY-3.0.webm#filelinks

To prove these hypotheses, the Stanley Miller has done very classical experiments and where he has actually taken gaseous mixture, water, methane, ammonia and hydrogen and into a flask and that is how he circulated that flask into apparatus which has been designed by the Stanley Miller and based on this analysis, what he found is that the mixture of the amino acids is being formed like the glycine, alanine, aspartic acid and all that.

And I have given you a link here in case you want to see the demo of the how or actually animated movie, you can actually be able to click this and it will actually going to give you the animations how the this experiment is being performed.

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ORIGIN OF LIFE (PROPOSED EVENTS)

Amino acids are building blocks for protein

Step 1 Formation of inorganic molecules

Carbohydrate: Glucose, Ribose

Glycerin

Step 3 Spontaneous formation of complex organic compounds:

COACERVATE FORMATION

Coacervate divides into multiple small ones.

Formation of first cells

Step 2 Spontaneous formation of monomeric organic compounds:

Step 4 Spontaneous formation of molecular aggregates:

So, based on the modern theory, there are different steps in which the origin of life is actually being done right. For example, in the step one there will be a formation of the inorganic molecules. So, inorganic molecules are being formed from the in from the condensation of the different types of so you have the inorganic molecules like the ammonia, acetic acid and so on and all these inorganic molecules are then subsequently being present into the primitive oceans and that will give rise to the formation of the monomeric organic compounds or the simple organic compounds.

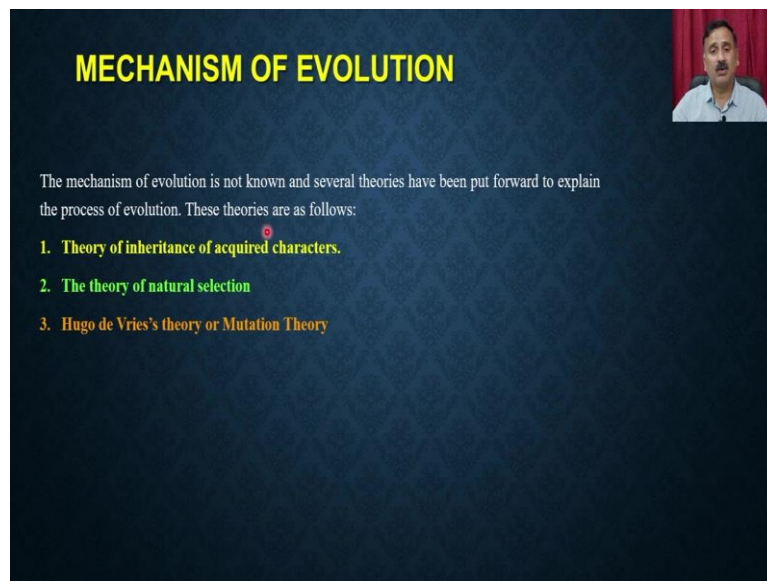
Then in the step 3 these simple organic compounds were reacting with each other to give you the complex organic compounds such as the glycerine, ribose, glucose and so on. And once these complex organic compounds were formed, they were reacting with each other to form the coacervate and these are the proteinaceous aggregates where the protein is present inside and whereas the lipid is present outside and the coacervate were dividing into the, into the multiple small ones. A

nd that is how the coacervate were eventually being developed into the primitive cell or the first cell. And that is how the people has proposed the different types of the different types, different steps in which the origin of life could have been happened on to the Earth. These all these events are being proposed based on the data what people have, you know, developed by the Stanley Miller experiments or some of the presumptions.

And now, it is true that the primitive cell is been formed into the primordial action, but how primitive cell which evolved into the much complex multicellular system and as well as the very very complicated organisms like humans. So, for that, the people have discovered or people have proposed the different types of the theories to explain the evolutions.

So, there are chemical evolution. So, chemical evolution is being supported by the many types of evidences like the morphological instructional evidences and based on the this the people have proposed the mechanism of revolutions.

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MECHANISM OF EVOLUTION

The mechanism of evolution is not known and several theories have been put forward to explain the process of evolution. These theories are as follows:

1. Theory of inheritance of acquired characters.
2. The theory of natural selection
3. Hugo de Vries's theory or Mutation Theory

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So, what we have discussed in this particular course, we have discussed about the 3 theories, we have discovered about the theory of inheritance of acquired character, and that is the theory which is given by the Lamarck. And then we also discuss about the theory of natural selection which has been done which has been proposed by the Charles Darwin.

And then we also discuss about the Hugo de Vries's theory or the mutations theory and all of these theories were having some of the positive aspects and some of the negative aspects and they were also heavily been criticized, because most of these theories were based on the non-scientific experiment, they were being done, they were be based on either the population studies or some of the mutational studies.

So, based on this discussion about these theories, it is been sure that the mechanism of evolution is still unclear, it could be a mixture of the Hugo de Vries's theory or mutations theory and as well as its theory of natural selections, but the Lamarck theory is also very much been used or very much relevant when the people have also taken up the modern molecular data or molecular components into that.

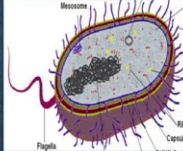
So, because when the Lamarck has proposed its theory of inheritance of acquired character there were so many information about the genetics, about the DNA and all those kinds of material is not or not known, right. So, that is why some of the all these theories were good to explain many things, but they were also lacking the full proof concept to explain the mechanism of evolutions. So, once we understood the mechanism of evolution, we have also discussed about the different types of cells.

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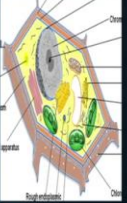

CELLS

Higher eukaryote has multiple organs to perform specific functions such as liver, kidney and heart. Organs have specific tissues and each tissue is composed of cells. **“Cell is the structural and functional unit of life”** and it contains all necessary infrastructures to perform all functions. Based on cellular structure, cells are classified as prokaryotic and eukaryotic cells. In most of the cases, prokaryotes are single cells where as eukaryotes are either single cells or part of multi-cellular tissues system.

Prokaryotic



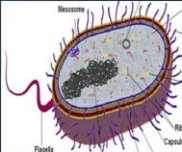
Eukaryotic Cells

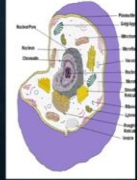
CELLS

TABLE DIFFERENCE BETWEEN PROKARYOTIC AND EUKARYOTIC CELLS		
Feature	Prokaryote	Eukaryote
Size	Small, in μm range	Variable size, upto $40\mu\text{m}$ in diameter.
Genetic material	Circular DNA present in cytosol as free material	DNA in the form of linear chromosome present in well defined double membrane nucleus, no direct connection with cytosol
Replication	Single origin of replication	Multiple origin of replication.
Genes	No Intron	Presence of Intron
Organelles	No membrane bound organelles	Membrane bound orgelles with well defined function.
Cell walls	Very complex cell wall	Except Fungi and plant, eukaryotic cells are devoid of a thick cell wall.
Ribosome	70S	80S
Transcription and translation	Occurs together	Transcription in nucleus and translation in cytosol

Prokaryotic



Eukaryotic Cells



So, when we talk about the different types of cells, we have the cell is the structural and functional unit of life and the cell is it would be a prokaryotic cell or it could be a eukaryotic cell. In the eukaryotic cell, you can have the plant cell or the animal cell. And in this particular module, when we were discussing about the different types of cells, we discuss about the differences between the prokaryotic and eukaryotic cell.

So that as far as the differences is concerned, the prokaryotic cell the major differences that the prokaryotic cell does not contain the nucleus, it only contains a circular DNA which is present in the cytosol as a free material, whereas in the eukaryotes, the DNA is formed in the presence of linear chromosome and it has been encircled within a well defined double membrane nucleus whereas and which does not have a direct connection with the cytosol.

As far as the replication is concerned, the prokaryotes have the single origin of replication whereas, eukaryotes have the multiple origin replications. As far as the genes is concerned the prokaryotic gene does not contain the introns whereas, the eukaryotic gene contains the intron as far as the ribosome, ribosome is 70S in the case of prokaryotes.

And it is 80S in the case of eukaryotes and transcription and translations, translation and translation, our courts work occurs together in the case of prokaryotes, whereas, the transcription in nucleus and the translation in cytosol is different. So, transcription occurs inside the nucleus, then the RNA is formed and then it transported outside and it will be used for the translations.

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STRUCTURE OF EUKARYOTIC CELL

Structure of Eukaryotic cell- The eukaryotic cells are much more complex and it contains many membrane bound organelles to perform specific functions. It contains a nucleus isolated from cytosol and enclosed in a well defined plasma membrane.

DIFFERENCE BETWEEN ANIMAL AND PLANT CELLS		
FEATURE	PLANT CELL	ANIMAL CELL
Cell wall	Present	Mostly absent
Size	Large	Comparatively small
Chlorophyll	Present	Absent
Vacuole	Large Central	Small and many in number
Mitochondria	Few	More
Lysosome	Almost absent	Present
Glyoxysomes	Present	Absent
Cytokinesis	By Plate method	By constriction

Then, we discuss about the structure of the eukaryotic cell and first thing that we have discussed we have discussed about the differences between the plant cell and the animal cell. So, this is the animal cell and this is a plant cell and there are so many differences, what we have discussed between the animal cell and the plant cell.

And then subsequent to that, we have also taken up the different types of organelles what are present in the either the plant cell or the animal cell. So, we have discussed about the mitochondria, plasma membrane, chloroplast, nucleus, we have discussed about the role of these organelles into the overall functioning of the cell and we also discuss about the organelles of the vesicular trafficking like endoplasmic reticulum, Golgi bodies and lysosomes. And, apart from that, we have also discussed about the differences between the plant cell and the animal cell.

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CELL NUTRITION AND GROWTH

Proteins **Carbohydrate** **Lipids** **DNA RNA**

Amino acids **Sugar** **Fatty acid** **Nucleotide**

Building Block **Energy** **Energy** **Genome**

CHONS **CHO** **CHOPS** **CHONP**

Minerals, Vitamins

MAMMALIAN CELL CULTURE MEDIUM

TABLE: RECIPE OF MAMMALIAN CELL CULTURE COMPLETE MEDIA.

Components	Composition
DMEM	13.4 gm/ltr
Sodium bicarbonate	3.7gm/ltr
Fetal bovine serum (FBS)	10%
100X Antibiotic (Pencillin Streptomycin)	- 1%

Preparation of cell culture medium : To explain the method of media preparation, we are taking the example of DMEM media. Add 13.4 gm dry powder medium to the water and mix to dissolve it completely. add 3.7g/L of sodium bicarbonate, mix completely and adjust the pH to 6.9 -7.1 using 1N NaOH or 1N HCl. Finally add cell culture grade water to the media to bring it to the final volume. Sterilize the solution using a sterilized membrane filter with a pore size of 0.22µm. Supplements, such as antibiotics and serum can be added to the sterilized solution using aseptic technique.

DEMO

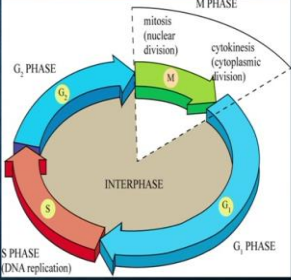
Subsequently, that we have very briefly discussed about what is the requirement of different types of cells for their replication or that for their growth. So, for every cell it requires a protein carbohydrate, lipids and DNA and RNA protein is being supplied in the form of amino acids, carbohydrate in the form of sugar, fatty acid and nucleotides and all these are required, because you want to synthesize the different types of biomolecules.

And we also discussed very briefly about how you can be able to grow the cells under the in vitro conditions by preparing the mammalian cell culture media and how at and we have also shown you a very small demo how you can be able to prepare the cell culture media.

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CELL CYCLE

The eukaryotic cell undergoes precise cell cycle and division to produce two daughter cells. Cell-cycle is the series of tightly regulated events leading to the division and duplication. It is a vital process used to single celled fertilized egg is developed into full organism. Cell division is the crucial event underlying the regeneration and repair in tissue, liver and heart. In prokaryotic cells, parent cell is divided simply by division into two halves through the process of binary fission. In eukaryotic cells, cell cycle has three phases; Interphase (synthesis of genomic DNA and cytoplasm), mitotic phase (division of DNA into two halves) and cytokinesis (division of cell).



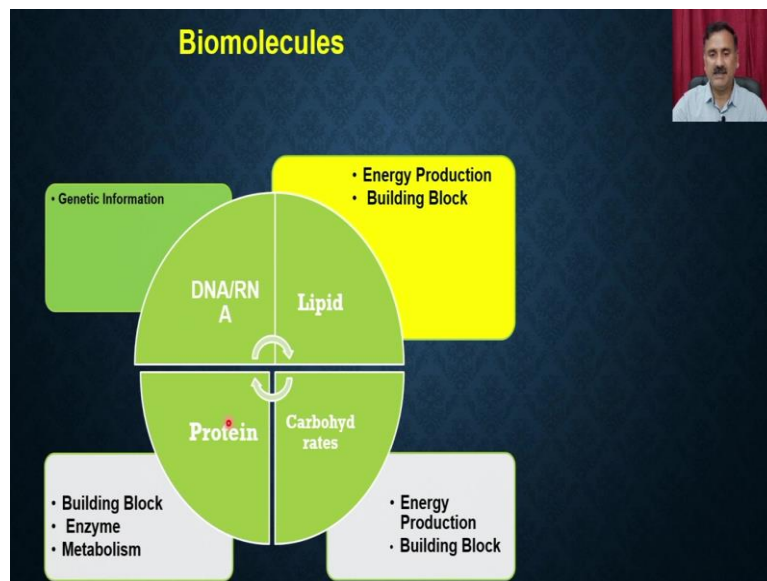
The diagram illustrates the cell cycle as a continuous loop. It starts with the G₁ phase (blue), followed by the S phase (red) where DNA replication occurs. This is followed by the G₂ phase (blue). The cycle then enters the M phase (green), which includes mitosis (nuclear division) and cytokinesis (cytoplasmic division). The cycle then returns to the G₁ phase. The text on the slide explains that the eukaryotic cell undergoes a precise cell cycle and division to produce two daughter cells. It is a vital process used to develop a single-celled fertilized egg into a full organism. Cell division is the crucial event underlying the regeneration and repair in tissue, liver, and heart. In prokaryotic cells, the parent cell is divided simply by binary fission. In eukaryotic cells, the cell cycle has three phases: Interphase (synthesis of genomic DNA and cytoplasm), mitotic phase (division of DNA into two halves), and cytokinesis (division of cell).

Apart from that, we also discuss about the cell cycle and cell cycles are actually been you know been discussed, so that you understand that when one single cell is dividing and giving rise to 2 cell it does not happen in the all of sudden, it actually cell undergoes the different phases where you have the G₁ phase, S phase G₂ phase and M phase.

So, within the G₁ phase, it actually prepared the cells for the DNA replication. And in the S phase, there will be a DNA replication or the synthesis of DNA and then in the G₂ phase it actually prepare the cell for the division and in within the M cell it is actually going to go for the division. So, after the M phase, it is actually going to divide and give you the 2 cells, one mother cell and the other one is a daughter cell.

Now, after discussing the cells, the cell cycles and so on and while we were discussing about the cell cycle, we have also shown you a couple of demos how you can be able to study these events under the invitro conditions utilizing the flow cytometer. We said that what are the molecules are responsible for you know, governing these processes and there are 4 molecules which are present in the cell.

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These are DNA or RNA, lipids, protein and carbohydrates. So, we also discuss about the different types of biomolecules. So, DNA and RNA is required for maintaining the genetic information, lipid is required for producing the energy and as well as it is a building block because the lipid is a part of plasma membrane.

And then we also discuss about the carbohydrate. So, carbohydrate is a energy production and as well as the building blocks, some of the carbohydrates are being used for modifying the protein as well as the lipids. And the protein is a building block, it is worked as an enzyme and it also works as a metabolism.

So, in this particular module, when we were talking about the biomolecules, we discussed, each of these biomolecules in detail, their structure, their functions and their role in the governance of the different types of cellular processes.

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NUCLEIC ACID

- Most of the organism (prokaryotic/eukaryotic) has DNA as the genetic whereas a minor fraction (virus etc) has RNA as genetic material.
- DNA or RNA is the biopolymer and is acidic in nature.
- In eukaryotic cells (animal or plant), nucleic acid is present within the nucleus whereas in prokaryotic cells, it is present as free form in the cytosol.
- The first nucleic acid was isolated by Friedrich Miescher in 1868.

So we started with nucleic acids and most of the organisms actually has a DNA as a genetic material whereas, the minor fraction such as the viruses has RNA as a genetic material. So, DNA or RNA is the biopolymer and it is acidic in nature and that is why it is called as a nucleic acid. In eukaryotic cell, the nucleic acid is present within the nucleus, whereas in the prokaryotic cell, it is present as the free form into the cytosol. The first nucleic acid was isolated by the Friedrich Miescher in the year of 1868.

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Nucleic acid as Genetic Engineering

The diagram illustrates Griffith's experiment with four scenarios:

- (1) live S:** Mice injected with the virulent strain S die.
- (2) heat killed S:** Virulent strain S is heat killed. Mice injected with it do not die.
- (3) live R:** Mice injected with the non-virulent strain R do not become infected.
- (4) mixture of live R and heat killed S:** Mice injected with a mixture of live R and heat-killed S die. The heat-killed virulent strain S is recovered from these mice.

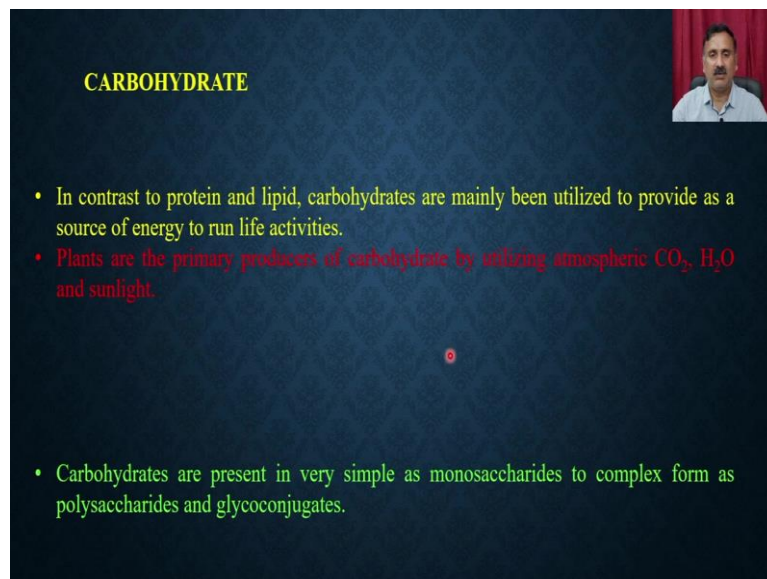
Two different *Streptococcus pneumoniae* strains, virulent (S, causes disease and death of mice) and avirulent (R, incapable of causing disease or death of mice).

And then we discuss about how we people have identified as the nucleic acid is the genetic material. So, this is a classical experiment of the Frederick Griffith in the year of 1928, where he has taken the 2 different strains of the bacteria and one is virulent strain the other one is

nonvirulent stain and then he has injected the mice with these virulent strains in the 4 different conditions either taken the life strain live or you know, non virulent stains or heat killed virulent stains or the mixture of that.

And based on this, he has concluded that the DNA is been genetic material, because, the when he has used a mixture of the live attenuated strain versus plus heat killed virulent strain, the DNA from the virulent stain is being transferred into the R strain and that is how it is actually going to also be responsible for killing of the mice.

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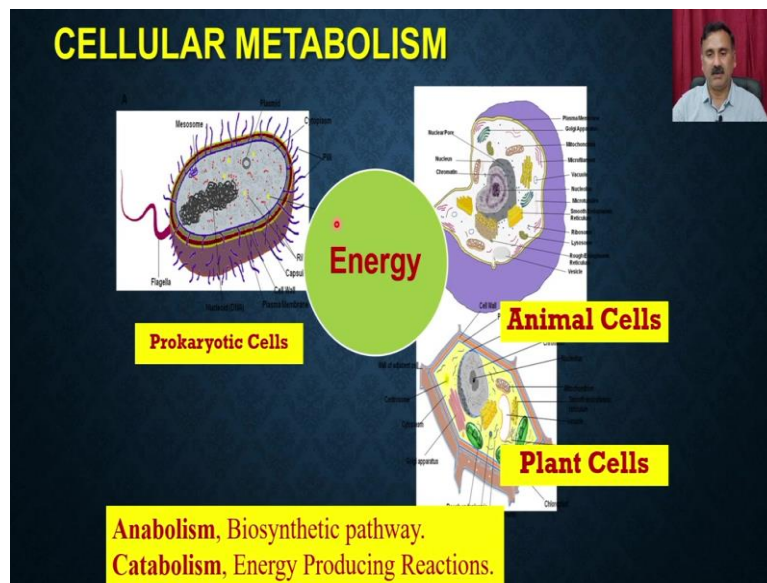
CARBOHYDRATE

- In contrast to protein and lipid, carbohydrates are mainly been utilized to provide as a source of energy to run life activities.
- Plants are the primary producers of carbohydrate by utilizing atmospheric CO_2 , H_2O and sunlight.
- Carbohydrates are present in very simple as monosaccharides to complex form as polysaccharides and glycoconjugates.

And then we will discuss about the carbohydrates. So, carbohydrates are the mixture of the, are the biomolecules which are formed by the carbon, hydrogen, oxygens, and they are the primary producer of carbohydrates. So, plants are the primary producer of carbohydrate by utilizing the carbon dioxide water and sunlight.

And we have also discussed about the different steps of the photosynthesis and carbohydrates are present in a very simple as like monosaccharides to complex forms such as polysaccharides and glycoconjugates. And what is the role of the carbohydrates? The carbohydrates are participating in the different types of metabolic reactions and that is how they are actually being used very extensively for generating the energy.

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So, this is you know the role of the carbohydrates, it is actually been used for energy production. So, energy whether it is for the prokaryotic cell, animal cell or the plant cell. So, we have the 2 different types of cellular metabolisms, which could be anabolism or the catabolism. Anabolism is the biosynthetic pathway, where you are actually going to have the synthesis of the different types of biomolecules.

So, it is actually a pathway where the energy is going to be consumed whereas, the catabolism the catabolism is the energy producing reactions and where actually the carbohydrate is actually participating into the cellular metabolism. So, when we were talking about the cellular metabolism, we discuss about the glycolysis, we discuss about the Krebs cycle, and we also discuss about the ATP you know the ATP balance sheets for the glycolysis and as well as the Krebs cycle.

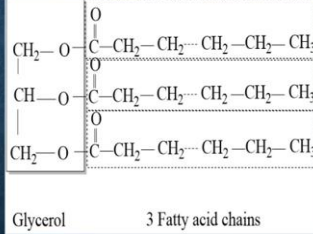
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WHAT IS LIPID ?

The lipids are a heterogeneous group of naturally occurring compounds; including fats, oils, steroids, waxes, and related compounds, that are related more by their physical than by their chemical properties.

They have the common property of being

- (1)relatively **insoluble in water** and
- (2)**soluble in nonpolar solvents** such as ether and chloroform.



Glycerol 3 Fatty acid chains

The diagram shows a glycerol backbone (CH₂-O, CH-O, CH₂-O) esterified to three fatty acid chains. Each fatty acid chain is represented as -C(=O)-CH₂-CH₂-CH₂-CH₂-CH₃.

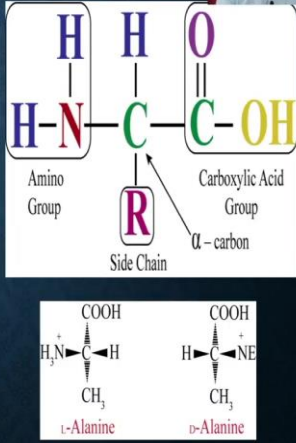
Subsequent to that we discuss about the lipids and lipids are the heterogeneous group of the naturally occurring compounds including the fat and all that. They have the common property of being a relatively insoluble in water and they are soluble in nonpolar solvents such as the ether and chloroform. And lipid is made up of the two different types of groups it has the backbone, which is made up of the glycerol and it also has the fatty acid so it can have the 3 fatty acid chains, and that is how this is called as the lipids.

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PROTEIN

Amino acids share common structure: All 20 amino acids are α -amino acids with a common structure. Each amino acid has a carboxyl group and amine group attached to the primary carbon (the α -carbon). They differ from each other in terms of side chain or R group. The side chain varies in structure, chemical nature and that has influence on the over all property of amino acid.

Each carbon is attached to the four different groups; making it a chiral center to give stereoisomers. There are two common forms of stereoisomers called as **enantiomers** found in the amino acids. These are non-superimposable mirror images to each other.



The diagram illustrates the general structure of an α -amino acid: $\text{H}-\text{N}(\text{H})-\text{C}(\text{H})-\text{C}(\text{O})\text{OH}$, where the central carbon is the α -carbon. The side chain (R group) is attached to the α -carbon. Below, the enantiomers L-Alanine and D-Alanine are shown as mirror images. L-Alanine has the amino group (H₃N⁺) on a wedge and the methyl group (CH₃) on a dash. D-Alanine has the amino group (H₃N⁺) on a dash and the methyl group (CH₃) on a wedge.

PROTEIN STRUCTURE

The ordered folding of polypeptide chain give rise to the 3-D conformation known as secondary structure of the protein such as helices, sheet and loops.

Arrangement of the secondary structure gives rise to the tertiary structure. α -helix and β -sheet are connected via unstructured loops to arrange themselves in the protein structure and it allows the secondary structure to change their direction. Tertiary structure defines the function of a protein, enzymatic activity or a nature of structural protein.

Different polypeptide chains are arranged to give quaternary structure.

Primary Structure

Secondary Structure

Tertiary Structure

Quaternary Structure

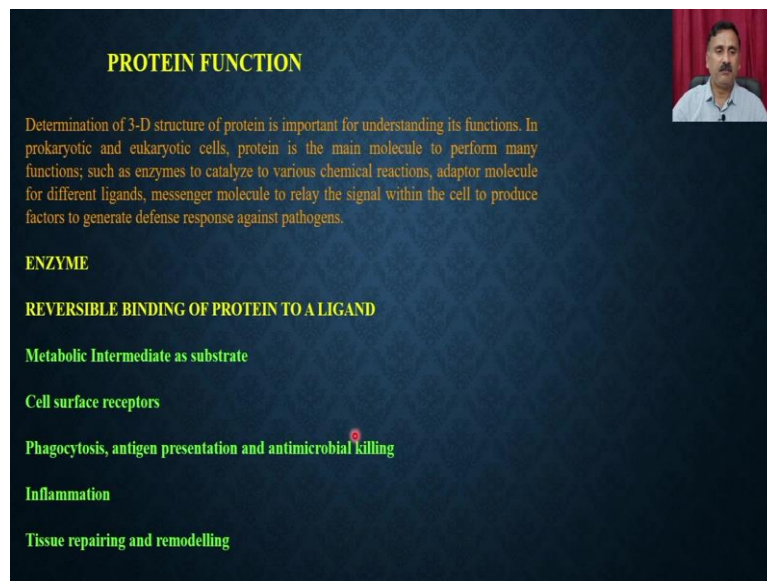
The diagram illustrates the four levels of protein structure. At the top is the primary structure, shown as a linear sequence of amino acids. This folds into secondary structures, specifically an α -helix, a β -sheet, and a turn. These further fold into a tertiary structure. Finally, multiple tertiary structures assemble into a quaternary structure, shown as a complex of four subunits (Subunit 1, 2, 3, 4).

Then we discuss about very extensively about the proteins. So, proteins are made up of the amino acids, and where the amino acid is actually having the 4 groups attached to a single carbon. So, you in one side, you can have the amino groups other side is carboxyl group, the 3rd is the side chains and the hydrogen and based on the R chain, amino acid could be of different types.

So we have 20 different types of amino acids which are present in the proteins and the protein is actually adopting the four different types of structures, it could be a primary structure, secondary structures, tertiary structure and a quaternary structure. So what you see here is this is the primary structures where the amino acids are attached to each other by the peptide bonds.

And then that gives rise to because when you have the amino acids attached to each other, they forced to each other and that is how they are going to form the secondary structure. So secondary structure could be alpha helix, beta sheets and turns and once the cells, the secondary structure folds to each other, it actually gives the tertiary structures and the quaternary structures.

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PROTEIN FUNCTION

Determination of 3-D structure of protein is important for understanding its functions. In prokaryotic and eukaryotic cells, protein is the main molecule to perform many functions; such as enzymes to catalyze various chemical reactions, adaptor molecule for different ligands, messenger molecule to relay the signal within the cell to produce factors to generate defense response against pathogens.

ENZYME

REVERSIBLE BINDING OF PROTEIN TO A LIGAND

- Metabolic Intermediate as substrate
- Cell surface receptors
- Phagocytosis, antigen presentation and antimicrobial killing
- Inflammation
- Tissue repairing and remodelling

Proteins are also playing a very crucial role in terms of the different types of functions. So, proteins could be working as an enzyme they could be having a receptor for the ligands they could be metabolic intermediate as a substrate, they could be cell surface receptors, they could be having a role in the different types of cellular processes like phagocytosis, antigen presentations, anti microbial killing, and the proteins could have the role in the inflammation and tissue repair and remodeling and all these functions, we have discussed in details and how the proteins are participating into any of the some of these reactions.

So, with this, we have completed our summary of this course up to the biomolecules. So, what we have discussed? We had discussed about the classifications, evolutions, understanding the different types of cells, whether it is prokaryotic or eukaryotic cell and the organelles, their structure their role, and then we ultimately also discuss about the biomolecules.

And subsequent to that, we are also going to discuss or summarize what we have discussed into the cellular processes and as well as the physiological processes in our subsequent lectures. So, with this, I would like to conclude my lecture here in our subsequent lecture, we are also going to summarize what we have discussed into the cellular processes and human physiology. So, with this I would like to conclude my lecture here. Thank you.