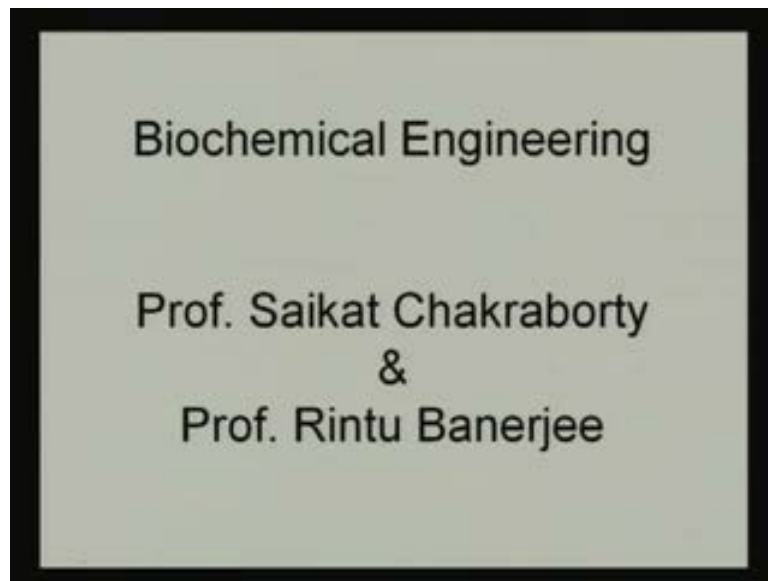


Biochemical Engineering
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Department of Agricultural & Food Engineering
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Department of Chemical Engineering
Indian Institute of Technology, Kharagpur

Module No. # 01
Lecture No. # 01
Fundamentals of Biology and Biotechnology

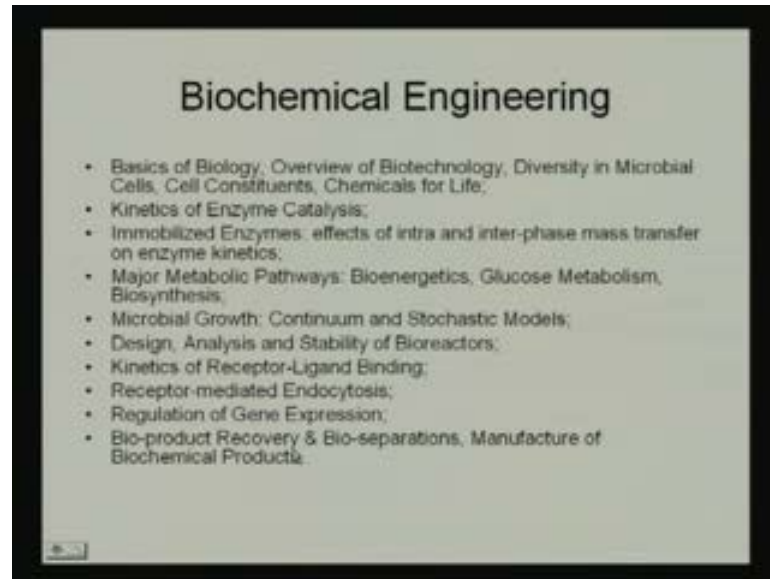
Good morning students. Today I will be starting a new course on biochemical engineering.

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The name itself indicates that it has got a bio and chemical engineering. Now, if we see the definition; it is a branch of chemical engineering or biological engineering that mainly deals with the design and construction of most processes that involves the biological organism. Now, this is the course which will be jointly taken by professor Saikat Chakraborty from chemical engineering department and me, professor Rintu Banerjee from agricultural and food engineering **engineering** department.

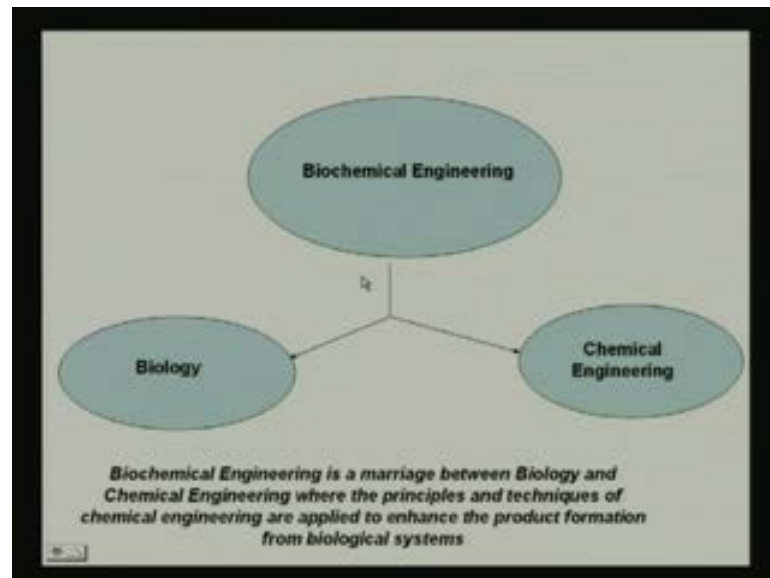
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At the outset let me tell you the course content of this particular subject. Now, if we see the subject biochemical engineering; we can find that this subject includes basics of biology, overview of biotechnology, diversity in microbial cells, cell constituents, chemicals for life. It also have that kinetics of enzyme catalysis, immobilized enzymes, major metabolic pathways that mainly includes the bioenergetics and different biosynthetic pathways, microbial growth kinetics, design analysis and stability of bioreactors, kinetics of receptor ligand binding, receptor mediated endocytosis, regulation of gene expression and different biological product synthesis in the living cell and the strategy for their separation.

So, we will also learn the recovery and bio separation of the biological products. So, this is the total course content of this particular course.

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Now, as I have already defined you this biochemical engineering; it has got distinctly two part that is, the biological portion and the chemical engineering. Now, if we see the total syllabus or if we define this particular subject as it is a fusion of biology and chemical engineering where the principles and techniques of chemical engineering are applied to enhance the product formation from the biological system or the living system.

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Fundamentals of Biology and Biotechnology

Glimpses of microbial world

Cell & its organelles

Macro molecules of living cell (Lecture I: Carbohydrates & Lipids; Lecture II: Proteins & Nuclie acids)

Enzymes

Bioenergetics & Metabolic pathways: Glycolysis, TCA cycle, oxidative phosphorylation, Glycogenesis, Glycogenolysis, Penlose phosphate pathway, Glucogeonesis, Uronic acid pathway

Manufacture of Biochemical products

Introduction to Bioseparations

Strategies of Bioseparations, techniques with examples

Reference:

1. Lehninger Principles of Biochemistry - Nelson and Cox
2. Biochemistry – L. Stryer
3. Microbiology – M. J. Pelczar
4. Cell Biology- Corn and Corn/ D. Roberts

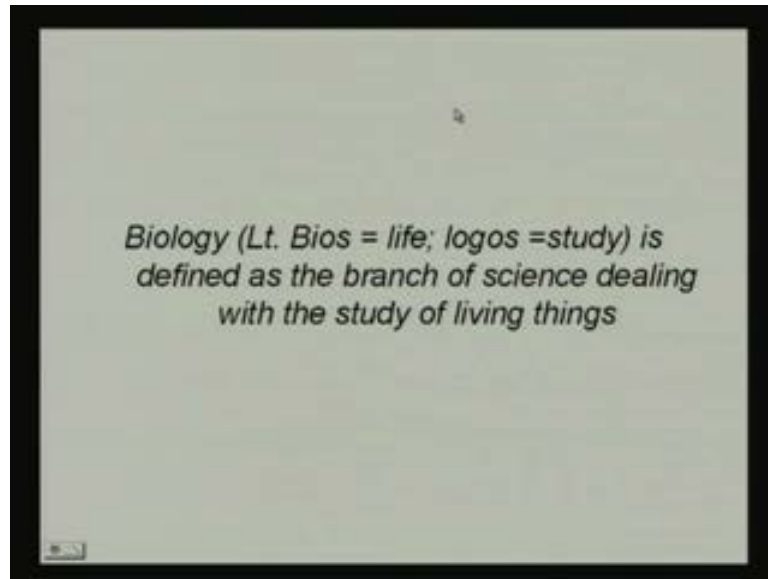
In this particular course I will be mainly concentrating towards the biology part.

Now, as biology, biochemical engineering the biology is the integral part I will be mainly covering the fundamentals of biology and biotechnology. Now, here this particular knowledge, this topic will include the fundamental knowledge of biology and then what is the difference between biology and biotechnology. I'll try to **emphasis** emphasize upon this particular thing. Then, we will gradually proceed to the microbial world. As you know, cells are the basic unit of life, from cells tissues are formed and from tissues different organs which perform different activities of the living system.

We will also learn that how cell functions and what are the different characteristics of the cell along with the different structure and function of the cell organelles. We will also concentrate on the macro molecules present in the living cell which includes carbohydrate, lipid, protein, nucleic acid and so on. Enzymes are the biocatalysts which are present in any living cell and they catalyze the different biological function. We will also learn something on the enzymes. We will also study the bioenergetics and different metabolic pathways which are playing a very important and significant role in any living system.

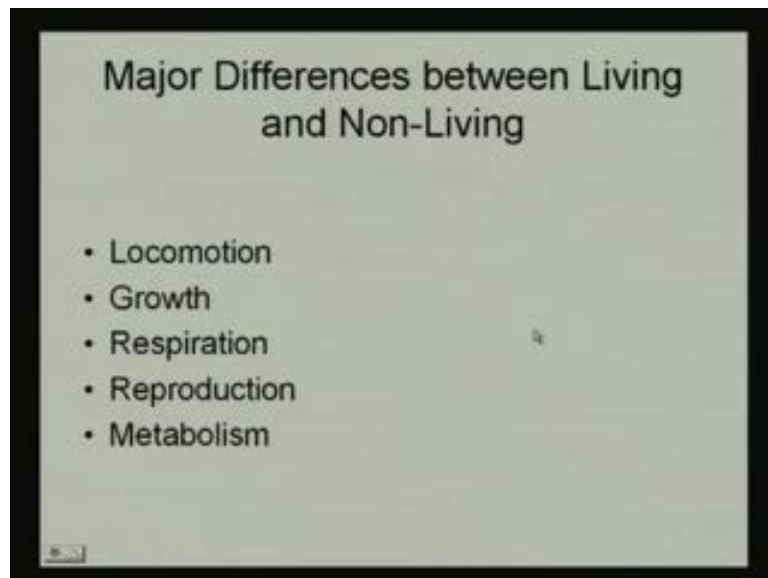
We'll also learn the synthesis of different biological product formation within the cell and what are the strategies which one can adopt for maximum recovery of the yield and we will also study some of those strategies along with few examples. Now, for this portion what I will be covering you can refer any standard book say, that Lehninger principle of biochemistry by Nelson and Cox, you can also study biochemistry by Stryer, microbiology by Pelczar, cell biology by Coen and Coen D Robertis. So, these are some of the books which you can refer. Any standard book can also be referred for these topics which I will be covering.

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Now, to start with I have told you that I will be giving you the fundamentals of biology and biotechnology. Some ideas to start with, let us start with biology. Biology is a Greek word which means bios is life and logos means study. So, biology can be defined as that branch of science which deals with the study of the living things.

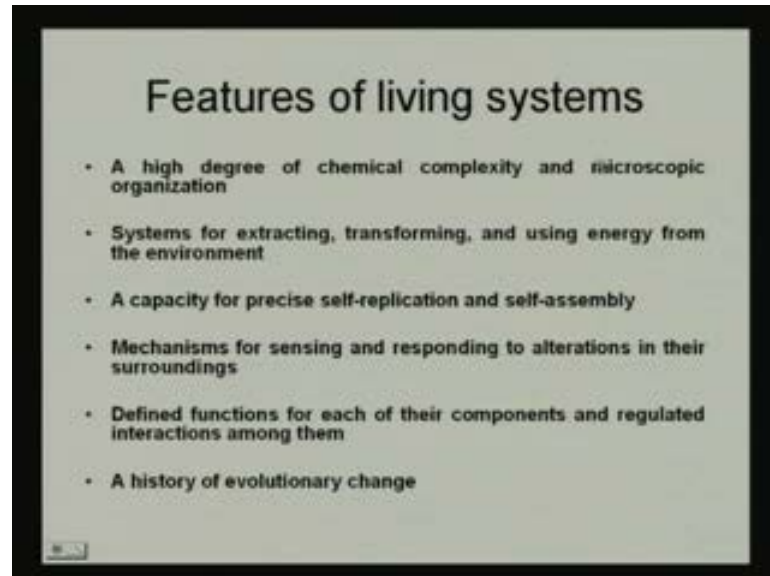
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So, if we see obviously that terminology which is coming to this picture is the living thing. So, how one can differentiate the living system from the non living system? There are certain characteristics which are present in the living system and are not present in

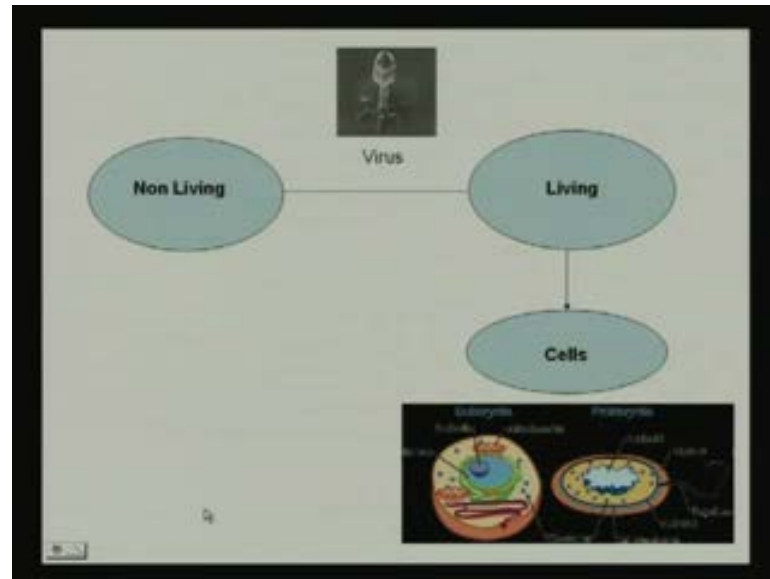
the non living such as locomotion, growth, respiration, reproduction, metabolism and so on. So these are the some activities which are performed by the living system or living cell.

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Now, the other features of the living system are; they have the high degree of chemical complexity and they are microscopic organization. A living system can extract transformed and can use energy from the environment. It has got the capacity for precise self replication and self assembly. Mechanism for sensing and responding to the alteration to their surroundings is also one of the characteristics of life. Defined functions for each of their component and regulated interactions among them are also the activities of living system. If we see the life system, evolution is one of such phenomena which is very common in the life system.

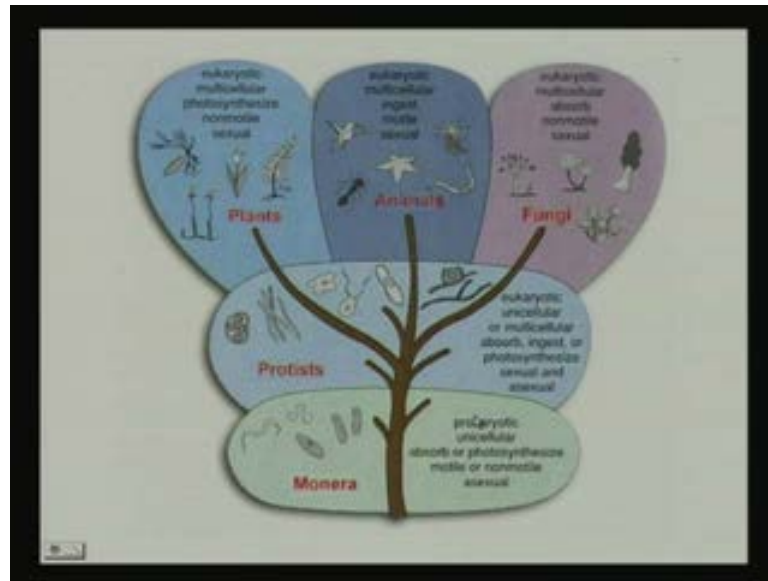
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Now, if we differentiate the living and non living as I have already mentioned by having some of the characteristics which I have already mentioned, we can easily differentiate the non living from the living system. Virus is one of such particle which is controversial in nature. Now, if we see the virus says we can find that, this virus behaves as a non living particle as long as it is outside of the living cell. As soon as, it comes in contact with the living host cell it performs certain activities through which the scientist they are compelled to think that yes, virus is a living organism. But, it is true that virus is an obligatory, obligate intra cellular parasite. For its normal behavior it needs host cell.

So if we see the living **living** cell, living system then cell is a basic unit of the living system. If we classify the cells it can be broadly classified into two major groups; one is called a prokaryotic cell, another is the eukaryotic cell. Prokaryotic cells are the primitive or it does not have the well defined nucleus which is covered by the nuclear membrane. That means pro means the primitive, karyon means nucleus. That means it has got the **the** nucleus which is very primitive in nature. Where as in case of eukaryotes, we can find that it is it has a well defined nucleus along with a nucleus membrane. And this is called the true nucleus eu means true, karyotes means nucleus. So this way we can differentiate prokaryotes and eukaryotes.

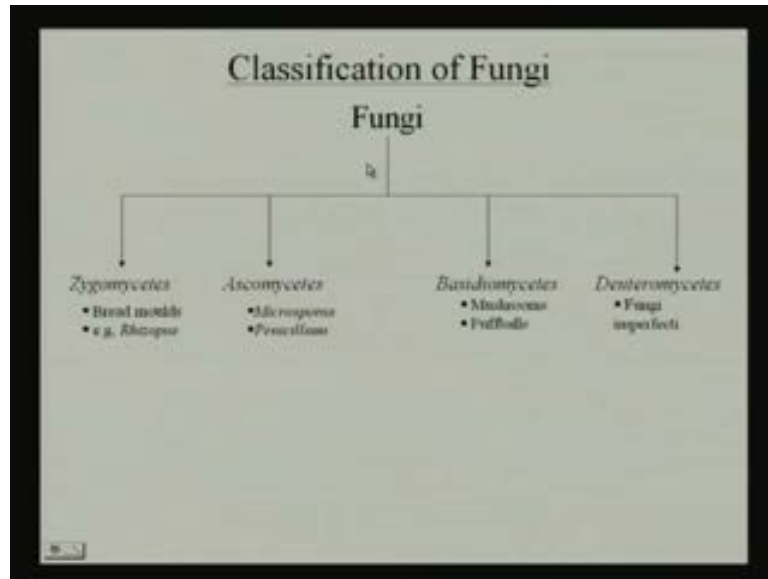
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Now, as I have already mentioned you that, the evolution is one of the indication of life system. So, when all the micro organisms were studied, it **it** has been classified into different kingdom. We take a five kingdom classification is one of the most popular classification of the living organism where it starts from monera which is the prokaryotic unicellular cells. Mainly it performs its normal activity nutrition and other activities through absorption or it can photosynthesize. It is either motile or non motile and mostly the reproduction is through asexual means. Little bit developed species are called protists. Protists are the eukaryotic unicellular or multicellular organism. It either take its food or nutrition through absorption or it can ingest or it can photosynthesize if any such pigmentation is there. Its main reproduction is either through sexual means or by asexual means. If we further classify this protest, depending upon its development, this protist can be once again classified into fungi plant and animal.

If we see the fungal classification, we can find that it is eukaryotic, multicellular organism. It can absorb, it is non motile and mostly it performs its activity through sexual means. In case of plants, it is also eukaryotic multicellular. But, in plant one particular organelle is present called chloroplast and for which it is it can perform, it can synthesize its own food through photosynthesis phenomena. It is mainly non motile and reproduction is sexual means. Then, coming to this animal world we can divide it is the eukaryotic multicellular organism. It mainly ingest the food and it is motile in nature and reproduction is through sexual means.

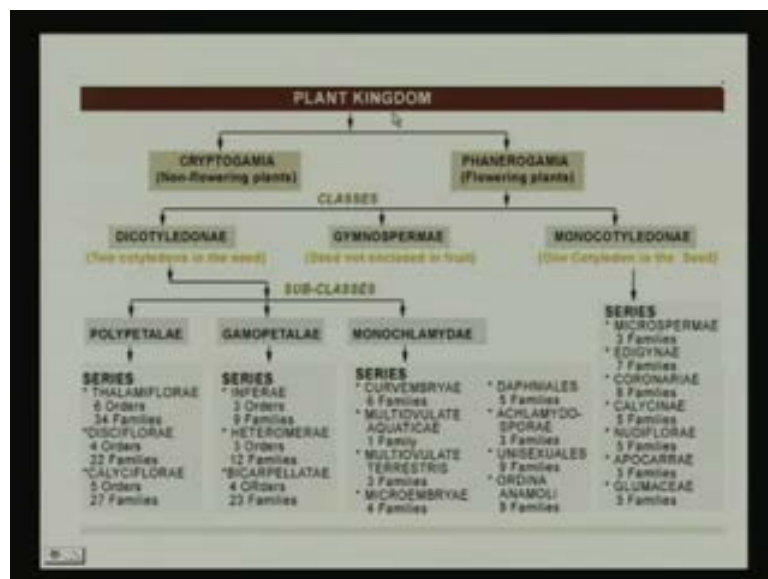
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Now, if we further go for this classification of three developed eukaryotic species; fungi, plant and animal, we can further classify this fungi into different groups like; ascomycetes, basidiomycetes and deuteromycetes.

So, depending upon its development this **this** fungi are further categorized into different groups.

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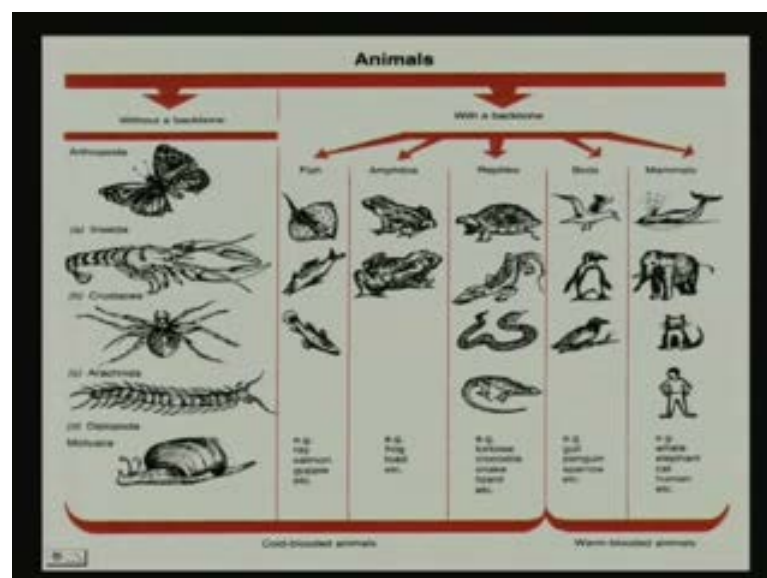
The next is the plant kingdom. Now, when we are coming to this plant kingdom these eukaryotic organisms can be divided into two groups based on the nature of the

flowering. Now one group is called cryptogamia or the non flowering plant, another group is called the phanerogamia which is the flowering plant. Now, depending upon the nature of the flowering pattern, it has been divided further into different classes. Now, in some, **this** in **in** case of this flowering plant it is divided into three major part; one is called monocotyledons, **monocotyledons** another is that dicotyledons and another is the gymnosperm. Monocotyledons are those groups of plant which during germination, it produce only the one cotyledons are coming from this embryo. And this is the parallel venation plant and any type of grass, grasses belonging to this particular, belongs to this particular group the parallel venation.

Whereas in case of dicotyledons, it is the two cotyledons are coming that means a pair of cotyledons are coming and depending upon its arrangement it is further divided into polypetalae, gamopetalae and monochlamydeae. Now, these are the sub classes of this particular flowering plant. The group of plants which do not contain any seed coat are coming under the group called gymnospermae. Now, in most of the cases it has been seen that that many of the students they do not understand the meaning of the terminologies and that is the reason they do not feel interest on this particular subject.

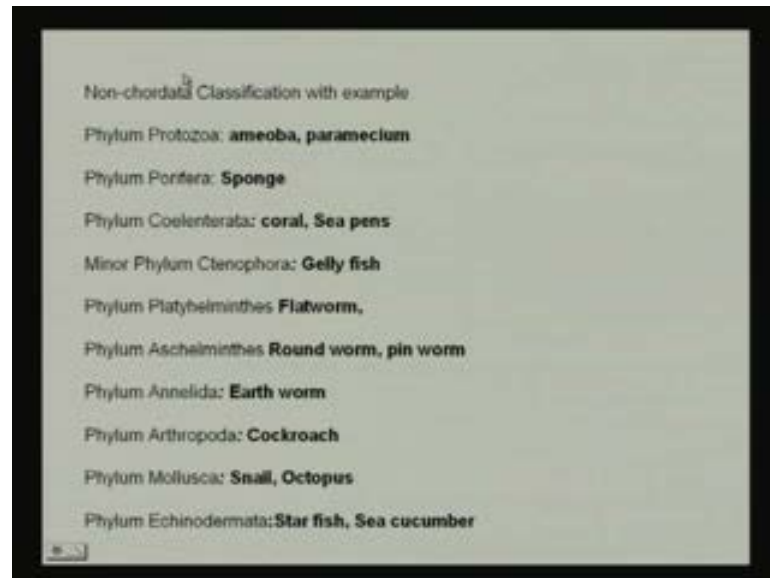
So, I am trying to give you the meaning of this groupism; how it has been classified so that you'll understand the basics and the evolution how these plants are evolved.

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Now, coming to the animal world; the animal world has been divided into two major group depending upon the presence of back bone. That is the spinal cord. The group of organism animals which are having this backbone are called chordates. Those which **which** are without backbone are the non chordates.

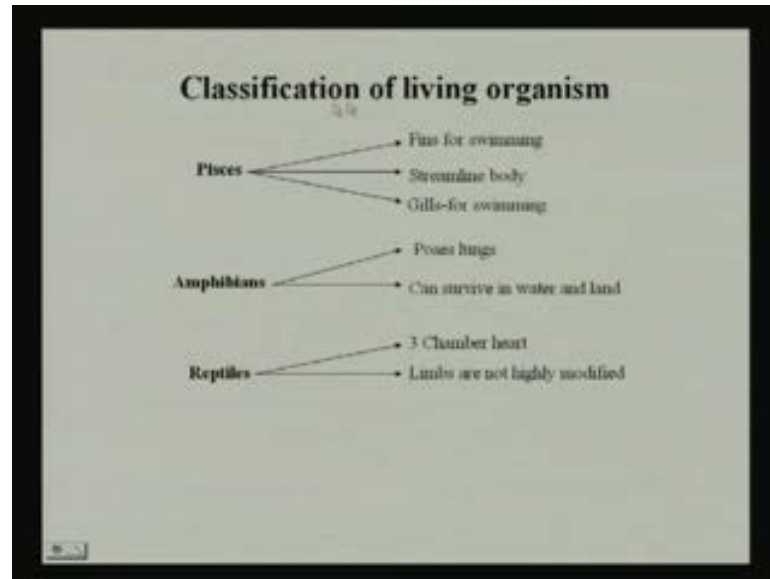
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So, if we further classify this animal world the non chordates can be further divided into several phylum like protozoa, porifera, coelenterate, ctenophore, platyhelminthes, aschelminthes, annelid, arthropoda, mollusca's and echinodermata.

So, some of the examples what in daily life we are coming across belonging to the without backbone animals are amoeba, paramecium, sponges, coral, sea pens, jelly fish, flatworm, round worm, pin worm, earth worm, cockroaches, snails, octopus, star fish, sea cucumber etc etc. Those group of creature which do not possess the backbone.

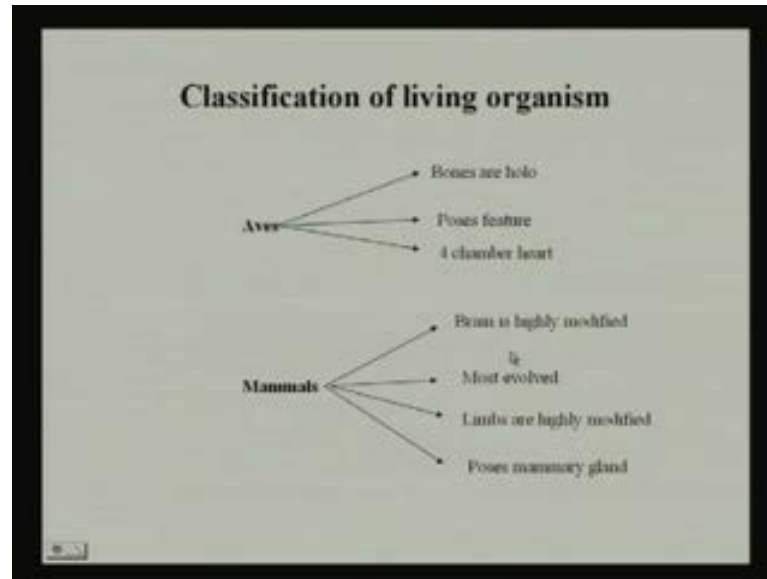
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If we further classify the chordates, the organism which are having the backbone, it can be further classified into different phylum; Pisces or the fish are one of such group which are having backbone and it has got the fins for swimming. It has got streamlined body and gills are present in this type of creature.

Now, if we see little developed animals which is called the amphibians. Amphibians can **can** be there it either it can survive in water or in land. And it possess the lungs and it has also got heart which is three chambered. Reptiles are those groups of creature which are also having three chambered hearts. Their limbs are not highly modified.

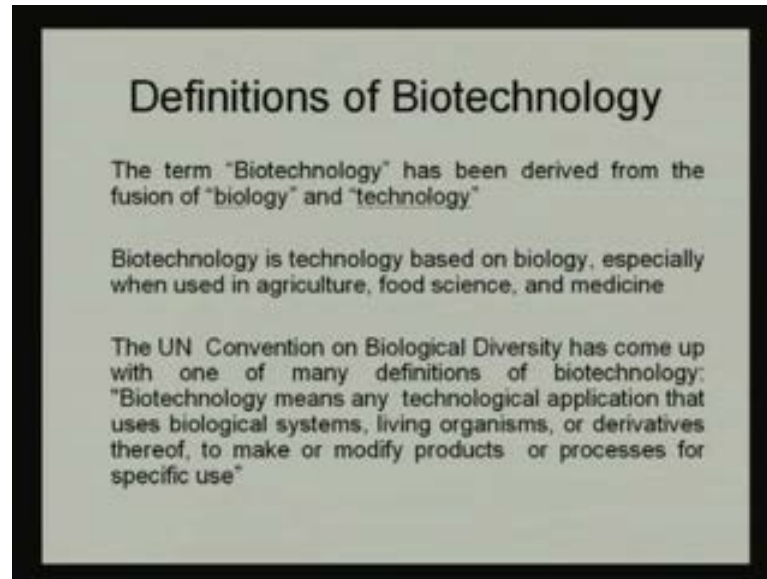
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And coming to the little more evolved species belongs to this phylum Aves. They have the, this Aves means it is birds. They have the bones which are hollow in nature. It possess feather, it can fly and they have the four chambered heart. Then the most developed species in this world are the mammals. The mammals are the most evolved, they have the mammary gland, their limbs are highly modified and they have the most developed brain and that is the reason why the mammals, the Homo sapiens are considered to be the most developed species in this world, in this universe.

Now, once again the enter animal kingdom can be divided into two major groups depending upon its nature, its certain character. Some group including the non chordates to up to this reptile are called cold blooded animal and Aves and mammals are considered as the warm blooded animals. Now, these are the certain classification what I wanted to give you to **to** make you understand that how the living cells are developed and **and** now I will be going for the transition phase of biology and biotechnology. How to define and how biological activities are different from that of the biotechnological activities.

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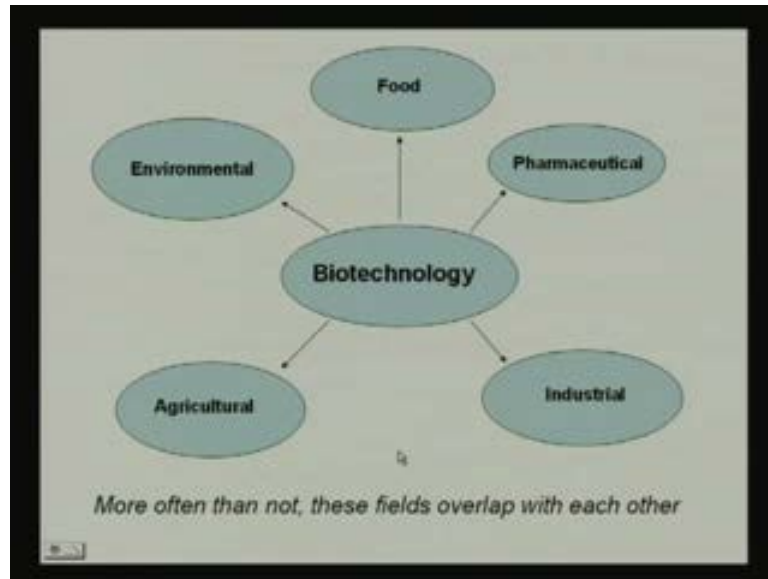


If we see, **I**, we have already learnt about the biology and we have learned that what is biology and how biological specimens are.

Now, what are the specimens which are coming under this living system? Now when we are defining this biotechnology, it is the fusion of two terminologies one is the biology, another is the technology. Now, biology is the, biotechnology is the technology based on biology especially when used in agriculture, food, medicine, pharmaceutical, environment and any other field. The united nation convention or biological diversity has come up with one of the most important definition of biotechnology as it is the means where the technological application that uses biological system that is the living organism or derivatives thereof to make or modify the products or processes for specific use.

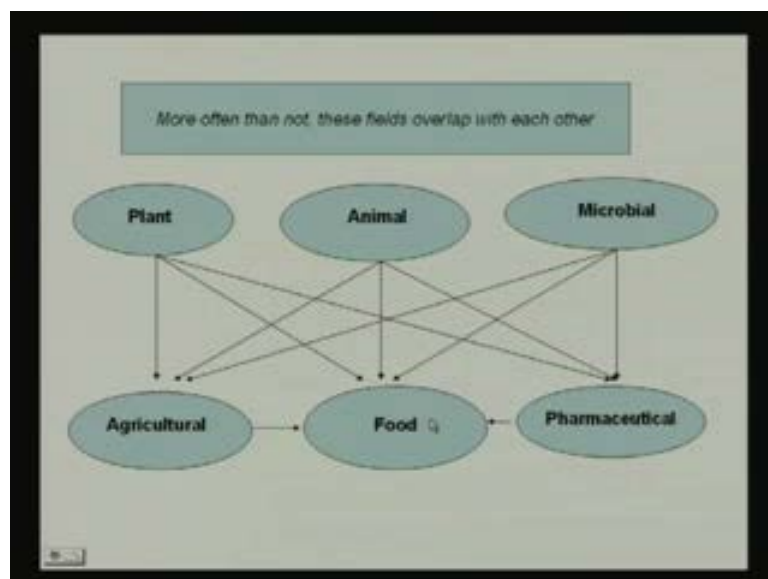
Biotechnology has been defined by many other ways; one of such definition is that it is the application of scientific and engineering principles to the processing of materials by biological agent to provide goods and services. It is the science of the future that will attract interest of many people and will bring about a big revolution in the lives of people and will show human how to live even comfortable life with lesser stress.

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So these are the definition of biotechnology. Now, if we see the biotechnological activities we can find that most often these fields are overlapping to each other. Now, any of the activities say for example, environment, food, pharmaceuticals, industrial or agricultural biotechnology if we see that, we will find that none of these disciplines are independent.

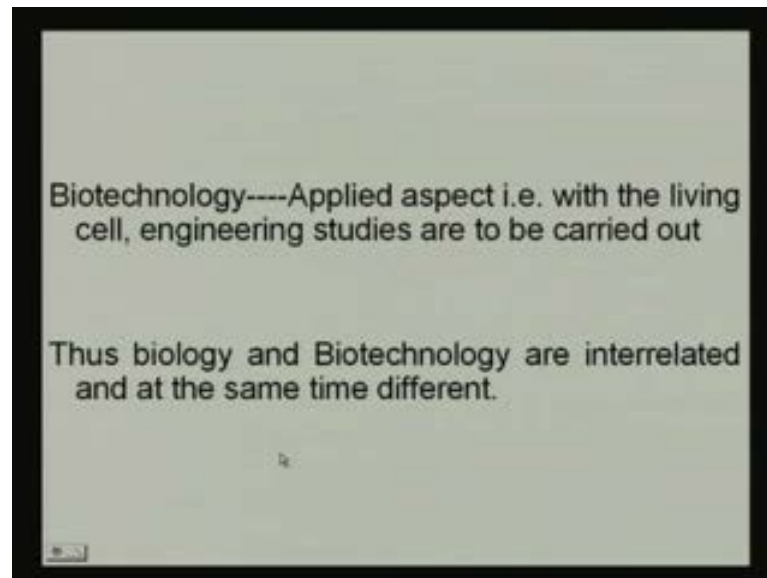
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They have certain connection with each other for which we can tell that these fields are highly interdisciplinary in nature. Say for example, plant biotechnology. This plant

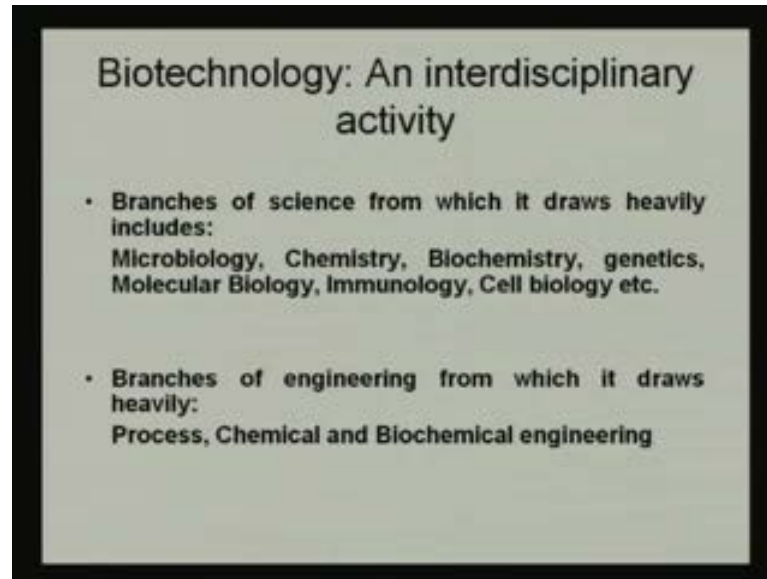
biotechnology has got direct connection with agriculture; it has got direct connection with food, pharmaceuticals. Similarly, animal biotechnology has got direct relation with agriculture. It has got direct relation with food, pharmaceutical, microbes, plant. Microbial biotechnology has got the connection with agricultural, food, pharmaceuticals and if we see, we can find that each of the disciplines are overlapping to each other.

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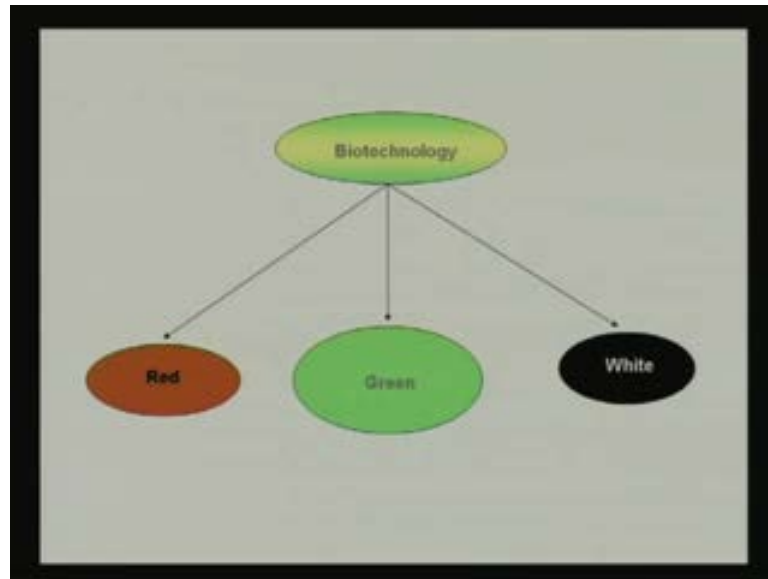
So, in other word what we can tell is that, biotechnology is an interdisciplinary science where we are mostly concerned with a applied aspect. That is with the living cell engineering studies are to be carried out. Thus biology and biotechnology are interrelated with each other. But, at the same time they are different. Now how they are different? Suppose, a person is working with some living system which has got immense application in future, in prolong after development it has got, it may have got immense application that particular work will not come under the activities of biotechnology. Rather, it will be a bioscience work. Similarly, when a product or process is in the **in the** transition phase from laboratory to pilot scale, pilot scale to commercial scale when any such engineering aspect or scaling of studies are carried out for any product formation or improvement of yield or improvement of productivity then only, we can consider that type of activities as biotechnological activities.

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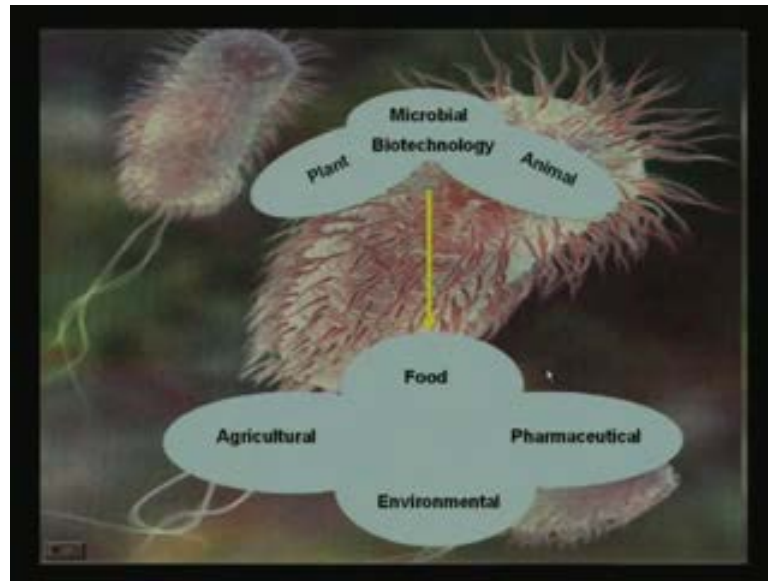
So, we cannot avoid the scientific development or bioscience activities from the biotechnological work. Different disciplines which can actively involve in such activities are microbiology, chemistry, biochemistry, genetics, molecular biology, immunology, cell biology and so on. Any basic biological science subjects can be considered as the basic subject of biotechnological activities. Similarly, the branches of engineering which can be **can** given their very important participation are the process engineer, chemical engineering and biochemical engineering disciplines. So, this is the branch of where the biologist and engineer should go together to make a process or product economically viable.

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Now, if we classify this biotechnology; now a day's many of you have come across the terminologies like red biotechnology, green biotechnology, white biotechnology and so on. So, what are those biotechnologies? Red biotechnologies are the pharmaceuticals biotechnology or you can consider this **this** branch as the, which has got direct connection with the health care activities. Green biotechnology is otherwise known as plant biotechnology or agricultural biotechnology. Food biotechnology is also a part of this type of biotechnological activities. White biotechnology is the industrial biotechnology. Whatever may be the branches; whether it is white, green or red any scientist and engineers they have the direct role on the product and process improvement and optimization.

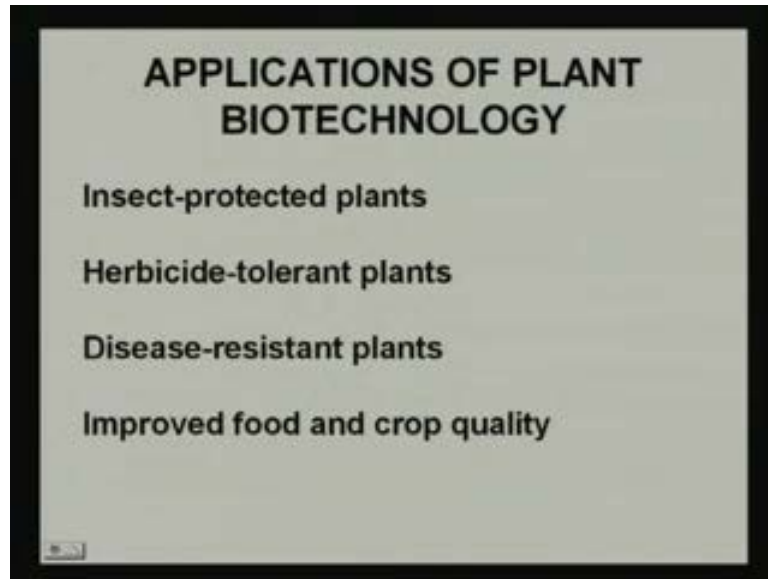
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Thus, in a nutshell we can tell that whatever may be the living system irrespective of the sources, whether it is the animal source, whether it is a microbial source, that microbial sources may be also the bacterial source or the fungal source it can be the plant source. Whatever may be the product formation, if we are going for the biotechnological activities may be depending upon the nature of the living system; we have we will have to study the product formation in a different way and it can have direct application in a food sector, pharmaceutical environment and agriculture. So, whatever may be the sources has got the direct applications to all those disciplines which has got direct link with the mankind.

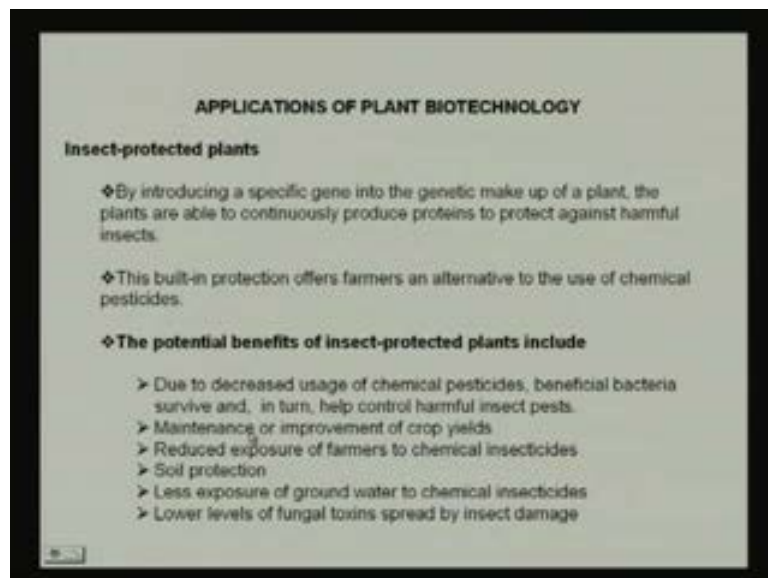
Now, let us come one by one and I will give you some example to make you understand that what is biotechnology, how a scientist can contribute and what is the role of any engineer like you to take part in this process product formation.

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Now, the examples, this plant biotechnology are the insect protected plants, herbicide tolerant plant, disease resistant plant, improved **improved** food and crop quality.

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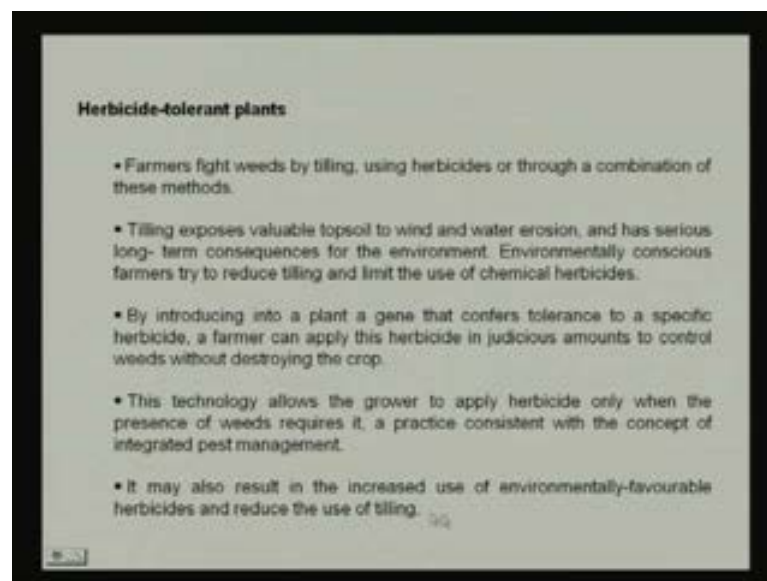


Let me come one by one to each of these. Now, when you're talking about this insect protected plant what we are doing? We are introducing a specific gene into the genetic makeup of a plant and that plants are able to continuously produce the protein to protect them from the harmful insect bite. Say for example, b t toxin.

Now, Bt toxin is one of the toxins which is produced by the bacillus thuringiensis. It is a bacterial toxin protein. If we put that gene into any plant system, that plant will be continuously producing that particular protein and when any insect will come and attack that plant because of the presence of that toxin inside the plant that pest will die. So, this inbuilt protection offers the farmer an alternative to the use of chemical pesticide. That means in built the toxins are there which when it comes in contact with the pest, pests are taking care of automatically.

So obviously the farmer need not have to spray that chemical pesticide. What is actually happening if chemical pesticide application is getting reduced? Due to the decreased uses of the chemical pesticide, beneficial bacteria which are present can survive. In turn it helps the harmful insect plant. It maintains or improves the crop yield. It reduces the exposure of farmer to the chemical pesticide, soil can be protected, less exposure of good ground water, **water** and chemical insecticide is also there and lower level of fungal toxin sprayed by the insect damage.

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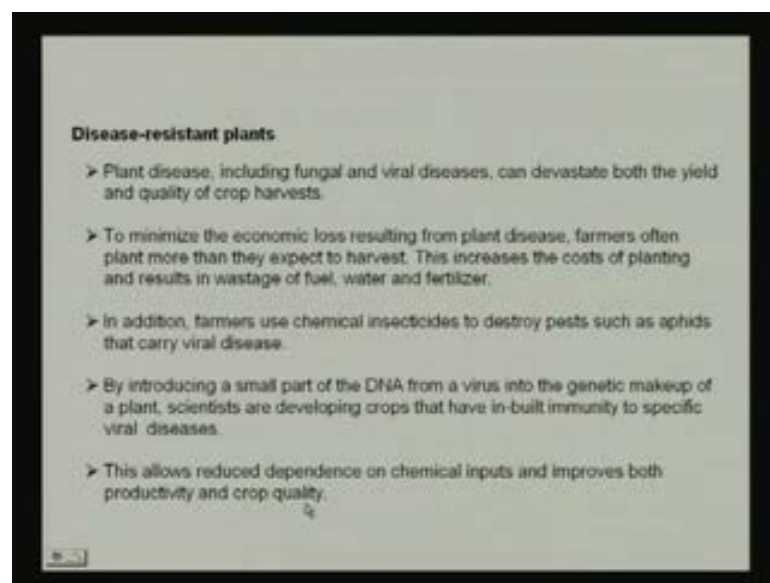


So, these are this is one of such example. If we see **the** another example that is the herbicide tolerant plant.

Now, when we when we are talking about this herbicide tolerant plant; the farmers they fight against weeds by tilling using herbicide or through a combination of these methods. Tilling exposes the valuable topsoil to wind and water erosion and has serious long term

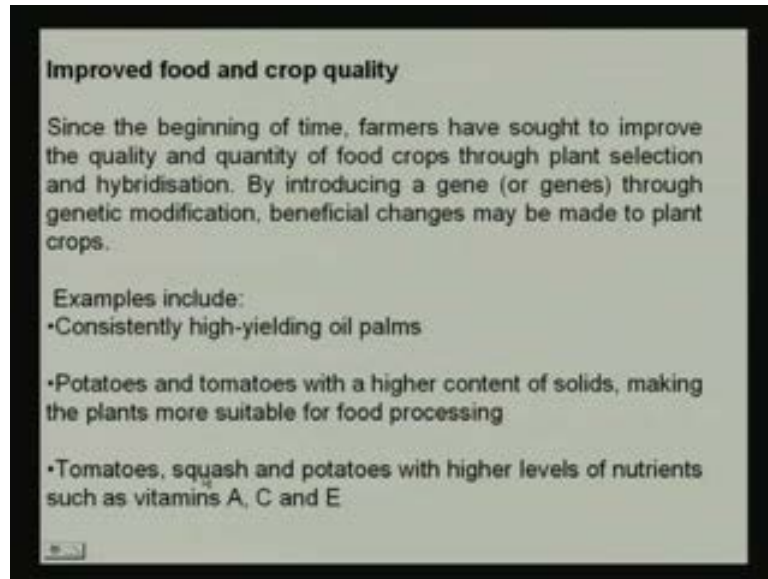
consequences for the environment. Environmentally conscious farmer try to reduce the tilling and limit the use of chemical herbicides. What can be done if the **the** introduction of gene to the plant that confer the tolerance to a specific herbicide can be done? A farmer can apply this herbicide in judicious amount to control the weeds without destroying the crop. This technology allows the grower to apply herbicide only when the presence of weeds is required. A practice which is generally there is called the integrated pest management. It may also result in the increased use of environmentally favorable herbicide and reduce the use of tilling.

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Another approach is the disease resistant plants. Plant diseases like which include the fungal and viral diseases can devastate both the yield as well as the crop quality. To minimize the economic loss resulting from the plant diseases, farmer often plant more than what they are expected to harvest. This increases in both the ways; the cost, the fuel cost, water, fertilizer and everything is getting increased. In addition, farmers use chemical insecticide to destroy pest such as aphids which carry the viral diseases. Now, by introducing a small part of DNA from the virus into the genetic makeup of the plant, the scientists are developing the crop that have in built immunity to such type of viral diseases. This allows reduced dependence on chemical input and improves both the productivity and crop quality.

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Improved food and crop quality

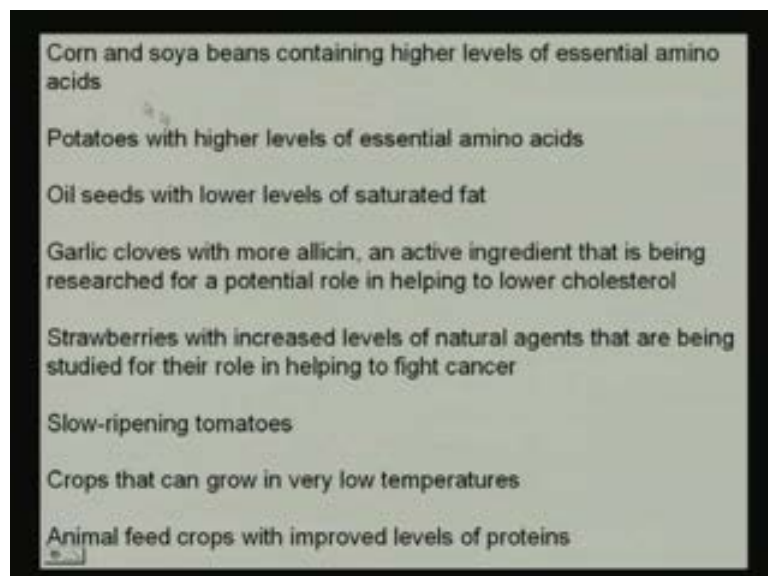
Since the beginning of time, farmers have sought to improve the quality and quantity of food crops through plant selection and hybridisation. By introducing a gene (or genes) through genetic modification, beneficial changes may be made to plant crops.

Examples include:

- Consistently high-yielding oil palms
- Potatoes and tomatoes with a higher content of solids, making the plants more suitable for food processing
- Tomatoes, squash and potatoes with higher levels of nutrients such as vitamins A, C and E

So, these are some of the techniques. Now, what are the input food which is already available with us. By introducing a gene through the genetic modification, beneficial changes has already been made in some of the crops which include consistently high yielding oil palm, potatoes and tomatoes with a higher content of solid making the plant more suitable for food processing. Tomatoes or squash and potatoes with high level of nutrients such as vitamin A C and E are already available.

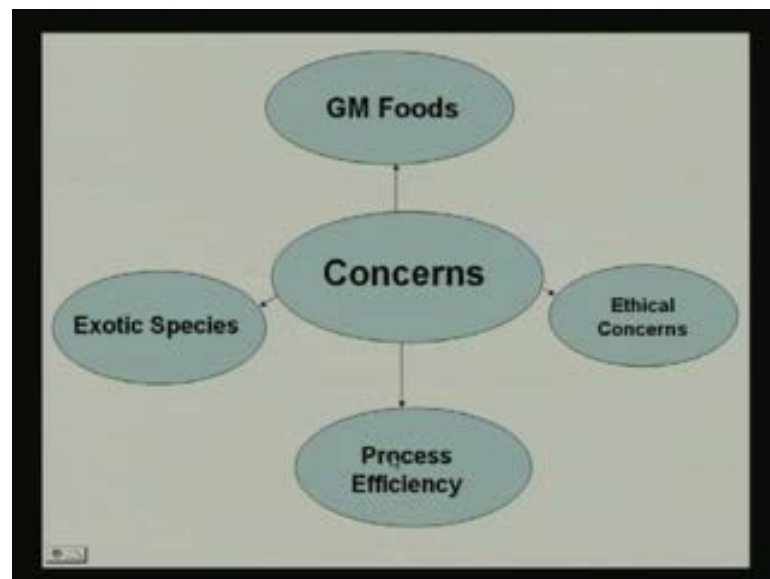
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- Corn and soya beans containing higher levels of essential amino acids
- Potatoes with higher levels of essential amino acids
- Oil seeds with lower levels of saturated fat
- Garlic cloves with more allicin, an active ingredient that is being researched for a potential role in helping to lower cholesterol
- Strawberries with increased levels of natural agents that are being studied for their role in helping to fight cancer
- Slow-ripening tomatoes
- Crops that can grow in very low temperatures
- Animal feed crops with improved levels of proteins

Corn and soya beans containing high level of essential amino acids, potatoes with higher level of essential amino acids, oil seed with lower level of saturated fat, garlic cloves with more allicin which help in lowering the cholesterol level. Strawberries with increased level of natural agents which are being studied and it has got some positive effect which help in fighting against cancer. Slow ripening of tomatoes, crop that can grow in very cold temperature and animal feed crops with improved level of protein content are already been there in the market. Some work is already being done.

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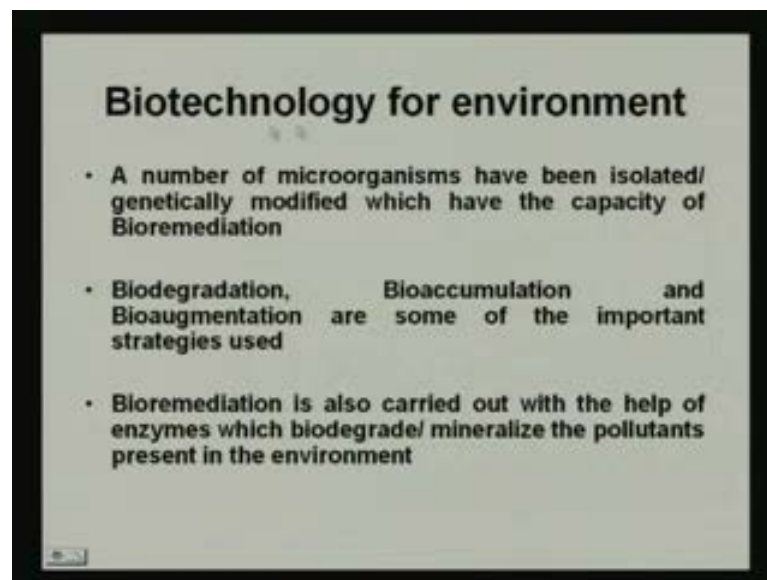


I will be talking to you now about another area of biotechnology which is called food biotechnology. And genetically modified food is one of such example of food biotechnology.

Now, if we see the genetically modified food, it is of course, a controversial topic as far as today's world is concerned. It has got ethical concern and if we see the genetically modified food, we can find that the exotic species can also be **explode** explored. Now, suppose if, this type of attempt can be taken, suppose mango is available in summer. Instead of getting it only in summer season, if we can get, if we can develop some species of mango which can produce such mangoes throughout the year and if such type of attempt can be done then how nice it will be. Those who are liking mangoes I am just telling for example, it may be applicable for any type of any variety of vegetable or fruits which are seasonal in nature.

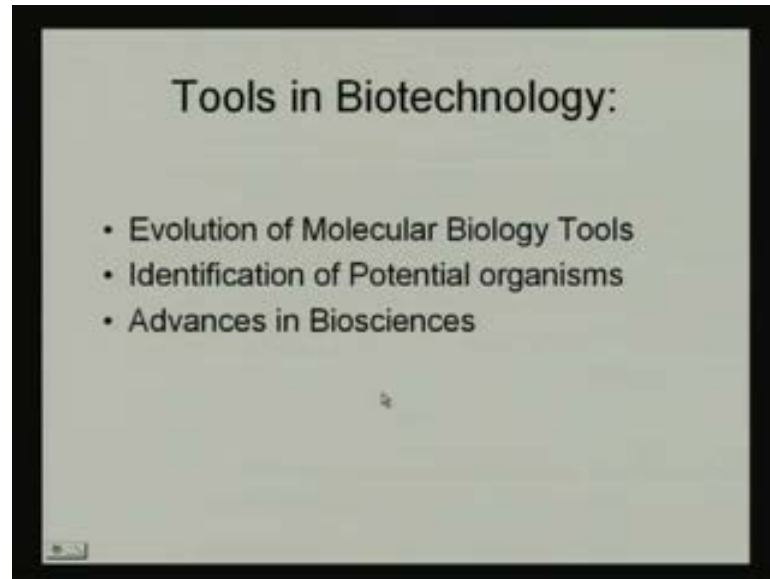
Now, it may be also applicable for the exotic species to, now this is one aspect of genetically modified food. Now, very recently that genetically engineer **bringer** brinjal has come to the market. Now, I am not telling that yes whether it is good or bad. But, what I am telling, this is one type of modifications which are there. Now, the scientist or the biochemical engineer can also participate actively in the area of processing. Now, when the normal cereals and pulses are getting processed; irrespective of its sources whether it is genetically modified or not but, through biotechnological activities one can go for the better polishing technology which may retain the more and more amount of nutrients. That means, nutrient quantity retaining of the nutrient quantity in that cereals and pulses can be improved with the modern processes, modern processing technology, biotechnological applications.

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Another area is the environment. Biotechnology can also be applied equally to the environment. A number of microorganisms that have been isolated, genetically isolated and genetically modified which have the capacity of bioremediation of solid as well as liquid waste. Biodegradation, bioaccumulation, bioaugmentations are some of the important strategical issues which are generally used for taking care of such type of pollutants. Bioremediation is also carried out with the help of enzymes which biodegrade and mineralize the pollutants of environment.

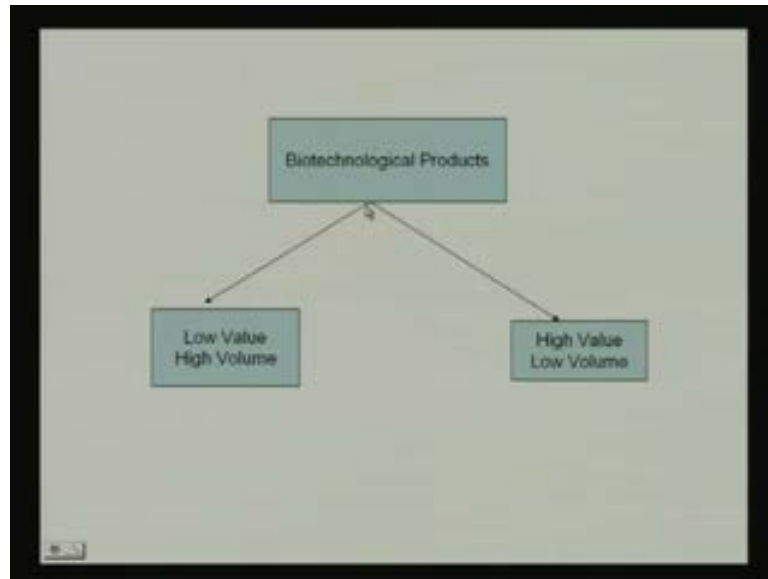
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Now these types of technologies are also applied to the animal system too. Now when we're talking about the tools in biotechnology, then we can find that genetic engineering is one of such important tool which is playing an active role as far as today's biotechnology is concerned. Now, this particular tool can be applied to any branches of the living cell; may be plant, may be animal or microbes. Through this technique we can go for the better improvement of yield. This is one way of modification. As I have already mention you in my earlier few slides, that when starting this lecture I have already mentioned you that evolution is one of the indication of life.

Now, in any living system the improvement on evolution is naturally taking place. Now, when such type of changes is taking place, sometimes the microbes which are present in this universe are automatically getting mutated. And sometimes we are identifying some of those important microorganisms which are present in our surroundings for better yield and those microorganisms are called the hyperactive microorganism. By isolating that type of microorganism, we can also go for the product process development. And whatever may be the activities which what I am talking about are coming under the umbrella of biosciences. Now, when such type of developments are going on in the laboratory these are coming under the banner of bioscience.

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Now, if we see the different biological or technological products, it can be divided, it can be distinctly classified into two major group; one is called the low value high volume product, another is the high value low volume product. Now, here the low value high volume means, here the volume of this particular product what we are manufacturing is in huge quantity. Let us take one example that ethanol from lignocellulosics. It is the second generation biofuel. It has got huge demand as far as today's world is concerned.

Now, what we will be doing with this ethanol? We will be using this ethanol as the petroleum substitute. And when we are talking about this ethanol then, we are handling the raw material which are lignocellulosics in nature and these lignocellulosics what we are getting is a huge amount of lignocellulosics. And from here, the ethanol which we are getting it is also high volume. Huge quantity of ethanol we are producing but, its value is not that high, if we see another system which is the high value and low volume. Now, in this system what we have seen that, it is the very costly product and its volume is in a very, very small quantity. That means, this product is produced in the living cell in a minute quantity but, its value is very high. Say for example, taxol. Taxol is a secondary metabolite which is produced in a very, very low quantity. And it is in the tune of microgram level and it is present in the plant cell and if we want to go for the production of such type of product obviously our attempt will be of what type? Then, what we are going handling we are adopting the process for handling a huge quantity of biomass.

So, this is the reason why these types of information are very, very essential for all of you. For those who are studying engineering, for them this information's, why this biological information the information of cell and its constituent is so much important. If you know, the behavior of the cell characteristics of the cell it will be very easy for you to design a reactor. Now, say for example, if we are taking a plant cell, if we are taking any microbial cell, if we are taking any animal cell obviously the reactor design will not be same as plant cell has got cell wall, microbial cell also has cell wall but, animal cell they do not have any cell wall. They have the cell membrane. Obviously the reactor what we will be using for microbial culture will not be the same for the plant cell culture; will not be the same for animal cell.

So, this type of information, then another information which is very, very important is that what type of product we are producing? Is it intra cellular or extra cellular? So, such type of information are very, very important and through this particular this information the biological information what I will be giving I think you will you can enrich yourself to understand the living system the living cell and its behavior.

So, with this I am concluding my today's lecture in the next class I will be talking to you about a tiny particle which cannot be seen without microscope, in our naked eye. So, that type of organisms coming to a particular group, **of a it is** it is a part of the prokaryotic organism and I will be talking to you about that type of micro creature in my next class.

Thank you very much.