Introduction to Biotechnology

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Part 1

CEV Multimedia presents Introduction to Biotechnology, a video active presentation. The goal is to offer an overview of some of the capabilities and potential of biotechnology. The objectives are to understand basic principles of molecular biology, to understand some of the applications of biotechnology in plants, to understand some of the applications of biotechnology in animals and medicine. Biotechnology is a rapidly expanding field. Scientists are continually learning about the fundamental unit of life, the cell, and the way it forms an interactive web with other cells.

What we're talking about is the use of the techniques of molecular biology to manipulate genes and gene products in medicine, and also, in the field of agriculture.

Depending upon the imagination of the people that are involved, there are so many things that could theoretically be done.

New technologies are advancing so quickly. In a very short period of time, we should be able to transfer a gene from one animal to another with relative ease to affect things, like human health, animal health, animal performance, survival in hostile environments, et cetera.

Part 2

The smallest unit of life capable of independent existence is called a cell. The genetic instructions needed to make an entire organism are located in chromosomes within the nucleus of a cell. Chromosomes are made of a molecule called DNA.

Each specific building instruction of an organism is recorded as a gene within the DNA. Genes control traits within the organism. Everything from eye, hair, and skin color to the inherited disabilities and diseases such as hemophilia, cystic fibrosis, or cancer.

So genes are responsible for the differences between individuals. The corn on the left is genetically different from the corn on the right. They're the same species, they're the same corn, they just differ in one or two genes, as much as people with different eye color, skin color can differ in just one or two genes, and this diversity is critical for plant breeding, because that's what provides the genetic basis for selecting plants with new traits.

In nature, there are two ways life reproduces and passes on genes, meiosis and mitosis. Fertilized eggs undergo mitosis to produce a completed organism. In mitosis,

Introduction to Biotechnology

body cells duplicate. This is how virtually everything in the human body develops and is maintained. In plant tissue culture, mitosis can be used to produce cells with the capability to generate identical clones from the cutting of a parent plant.

Meiosis results in cells having only half of the required set of genes. During fertilization, a male haploid cell or sperm fuses with a female haploid cell or egg to produce a cell that has a complete set of genes. This is called sexual reproduction, and it occurs in nearly all multicellular organisms. If a breeder wants two particular traits to appear in the same organism, the breeder would breed two organisms together, each parent's having one of the desired traits. For example.

If a breeder wanted to transfer some of the stress tolerance from this line of corn to this, then pollen from the tassels could be transferred to the cells on the ears at this point and then the offspring could be selected for increased stress tolerance.

Distantly related organisms cannot breed. Under natural conditions, crossing genes of an animal and a plant is impossible. The biotechnology in transgenics are offering new tools to scientists.

But they would be very interested in inserting into grapes the genes for called hardness of those could be found. There are fish that survive under extremely low cold temperatures and those genes have been taken out of fish and there is interest in putting those into various crops to see if they also can confer cold hardiness on those crops.

When an organism receives a new gene such as a great plant receiving the fish gene, that organism is said to be transformed or transgenic.

Transgenics can be simply explained as the transfer of a gene into another organism. Whether that be taking a gene from one bacteria and putting it into another bacteria or a gene from one mammal, such as a cow, into a different mammal like let's say a pig. When we add transgenic genes to bacteria or single cells, such as a muscle, we have no way of telling if that muscle cell or that bacteria is different from a normal bacteria because a transgenic cell will look just like a normal cell, so we incorporate what are called marker genes.

Marker genes are genes that are incorporated into the animal to identify-- visually identify-- a transgenic animal. They can be everything from coat color, fluorescence, and antibiotic resistance. When we talk about single cells or bacteria, that's usually a fluorescent marker. When the gene of interest in our marker gene or both incorporated into that cell, it'll show a fluorescent color, be it green or red, that is a protein that's been isolated from a jellyfish. So we've taken jellyfish gene and put it into a pig cell or bacteria cell and had that jellyfish green fluorescent expressed in a

Introduction to Biotechnology

non-jellyfish animal.

So under a microscope, we can immediately say, yes, this cell here has our transgene or this cell does not have a gene.

Part 3
Genes for specific beneficial traits can be isolated and inserted into a plant species, creating a transgenic organism by adding to its genetic code.

The most commonly used method is agrobacterium.

Ordinarily, this bacterium infects plant cells by injecting some of its genetic material into a cell, and using the cell to create its food.

We've replaced the bacterial genes with the genes we want to put in the cells.

When these bacteria infect cells, they transplant the gene of interest into the cell's chromosomes among the cell's original genes.

There are mechanisms which aren't understood that get the DNA from the bacterial cell into the plant cell, and once into the nucleus, into the chromosomes. I'd say the overall goal of plant biotechnology is to improve agriculture, whether that means through reducing the costs of allowing crops to grow under more marginal areas, increasing the quality of the crops.

Some agricultural qualities scientists would like to enhance in plants include resilience, herbicide resistance, harvestable quantity, flavor, nourishing quality, and spoilage resistance. There are many benefits to growing crops in places where it was previously not possible.

We're actually doing grape varieties that are tolerant to salt, which is a big issue for areas in which they grow a lot of grapes that have limited water, and the water that you do have may be very salty, and maybe very low-quality water, yet, you could still be able to grow the grapes that are very good and have high quality.

As agriculture gets pushed further and further, we're going to have to use more marginal areas, areas that maybe are traditionally too dry.

If genes could be found that defend a plant from insect, fungi, viruses, and bacteria, then losses could be greatly reduced.

Already existing in nature are thousands and thousands of compounds which, for as long as we have been growing plants, have conferred to those plants some selective advantage. What we would like to do is to design plants with those compounds to

Introduction to Biotechnology

meet our needs, for instance cotton plants, grapes, most vegetables, tomatoes, carrots, in this case, onions. All of those are susceptible to soil-borne pests, which, when they attack them, they can either kill the plant, or they can render it so that it's useless horticulturally, and then we can't eat that.

There is a corn called BT corn. There is also BT cotton. And "BT" stands for "Bacillus thuringiensis," a soil-borne bacterium. It was found when insects fed on this, they died.

Well, if you can incorporate, into the leaves themselves, this BT gene, then what happens is the insect ingests protoxin, and the larva dies. This means the growers don't have to spray their fields.

I read an article this morning about pesticide use in China on BT cotton, and they've been able to go from 15 pesticide applications to one pesticide application a season, which is incredible.

So it's cheaper in the long run, it's much better for the environment in the long run, and it is good for the consumer.

If we don't use BT, then the farmers are going to have to spray with conventional pesticides. In a few weeks, there'll be a bloom, an increase in aphids. Those conventional pesticide applications will kill the beneficial insects, the insects that eat the aphids, things like ladybugs.

Part 4

Some plants are engineered to be immune to herbicides. This enables the farmer to apply herbicides at more inopportune times, increasing production.

Farmers using herbicide-resistant crops can do much less cultivation. And instead of controlling the weeds with mechanical cultivation, they control them with extremely safe herbicides. Where before, farmers would plow a field, plant the crops, and then have to cultivate that field to get rid of the weeds. And maybe four or five times, they'd have to drive a tractor, burning diesel fuel, through the field, compacting the soil, leading to more soil erosion.

Reduced mechanical cultivation means reduced fuel usage, reduced soil erosion, and increased water efficiency. A key concern is meeting the agricultural needs of an increasing world population. If more can be harvested from the same amount of land and water, humanity will be better equipped to address this concern. Cotton is undergoing research in an effort to increase the amount of cotton fiber produced from each plant.

If you can engineer or you can somehow select plants that have higher rates of

Introduction to Biotechnology

photosynthesis, again, you can increase productivity on a given amount of land for a given amount of input of water and fertilizer input and pesticide input. And some of these lines, you can see, have a large number of flowers. Here's a large number of flowers and a large number of buds, which is good. Each flower has the potential to result in a bowl, and the bowl is where the cotton is formed. So more flowers can mean higher yield, more productivity.

Some plants can be genetically engineered to produce fruits and vegetables with more flavor and better color, increasing the enjoyment of a food. The reason that when you go to a grocery store and buy a tomato and cut it open and take a bite it tastes like sawdust is because to be harvested by machine, they need to be hard and firm, because the machines can't be gentle with the tomatoes. They have to be harvested green so they don't over-ripen by the time they get on the grocery store shelf.

By introducing these genes that slow down the softening, you can harvest the tomato later, after all the flavors have developed, but they'll remain firm and resistant to spoiling longer on the shelf.

This enables crops to be shipped further distances, stored for longer periods of time, and picked closer to ripeness, decreasing spoilage. Increased flavor is accompanied by increased nourishment.

Now, grapes are an example of a crop that is just packed with the antioxidants that we have heard a lot about lately.

In underdeveloped parts of the world where nutrition is lacking, a stable food can be engineered to supply missing proteins, vitamins, minerals, and other compounds, improving human health.

Rice traditionally is very, very low in vitamin A, and in fact, it's responsible for malnutrition leading to blindness and death in many poor countries where rice is the staple food. And golden rice is rice into which genes for the production of vitamin A have been introduced.

There is even work to make vaccines in plants, making immunization against diseases in underdeveloped countries more efficient and less expensive.

In the third-world countries, they don't have access to many of the medicines that we have here. And there is real need to provide for them vaccines.

If, on the other hand, you could ship a batch of bananas that carry the vaccine, that express the vaccine in the fruit, you can feed the kids the bananas, and they become vaccinated. This kind of technology certainly could save millions of lives in the third

Introduction to Biotechnology

world, where childhood diseases, diarrhea, bacterial diarrhea, and things like that kill literally millions of kids every year. If you could vaccinate them by just eating a piece of potato or a piece of carrot or a piece of banana, it would be incredible.

Advances in agriculture offer more solutions to commercial farming businesses. By enabling more possibilities, humanity is better equipped to address concerns of nutrition, hunger, health, and well-being for an increasing population.

Part 5
Gene transfer technology in animals depends on the type of animal. Some of the animals of greatest interest include pigs, cattle, sheep, and goats. Though it is very difficult and costly, an entire organism can be generated from a single cell taken from another animal.

Cloning of sheep is a very important issue in animal agriculture for one primary reason. If we can get an animal that makes a large amount of wool, is a very high quality muscled animal that would help solve our needs of feeding the hungry people in the world, one of the best ways would be to copy that same animal over and over and over again.

Pig cloning was originally started as a way to make animals that had very similar meat quality traits and performance traits so that the expense of managing the pig could be minimized. However, scientists quickly realized, because of the similarities of the pig to the human physiology, that there was a possibility to clone pigs for human organ transplant.

Pig tissues and organs are currently being used in human medicine. For example, they currently take pig skin tissue and actually place it onto severe burns in a human and repairs that skin. They actually currently transplant pig heart valves into humans.

There are some people that have pig arteries and blood veins in their legs and arms that have repaired damaged arteries and veins. Current research is looking at using pig livers and kidneys to repair liver damage and kidney damage in humans.

Cattle, sheep, and goats don't make good candidates for human transplant, organ and tissue transplant, for one primary reason. They're entirely different than us. Their organs are of a different size, located in a different place, and actually perform slightly different functions.

The cow has been heavily studied both in normal agriculture production and transgenics and cloning. We have a significant amount of data and can do cloning relatively easily in cattle compared to the other three species that we talked about.

I think in 10 to 15 years, cloning sheep, cattle or pigs will be extremely affordable, and

Introduction to Biotechnology

everybody will have the ability to do it, which will decrease the cost of producing animals, producing organs for transplant, producing transgenic compounds for administration to humans for disease. So I think that cloning has a huge potential to improve the overall quality of life of many people around the world.

By inserting genes, animals can be transformed into bioreactors, living factories of important chemicals.

Sheep and goats make an excellent bioreactor system because they have a very large and productive mammary system. It allows for us to add a human gene to their genome, allowing them to produce the protein from that human gene into their milk.

Cattle are also used as bioreactors. Again, the primary advantage to cattle is they have a very large mammary system and can produce thousands and thousands of gallons of milk per year that you can isolate a humanized protein out of. But a problem with cattle, as with the goats, is that it's hard to get human genes into these animals to produce human proteins.

The reason pigs have become a candidate for bioreactors for human compounds is because of how closely and similar their organ tissue and physiological systems are to those of humans. Pig proteins look a lot or are very similar to human proteins. And so while researchers have used larger milking machines like cattle and goats, they've come back to the pig because the proteins that they produce very closely resemble the proteins that a human produces.

So when we isolate a protein from their milk and inject it into a human, there's a far less chance of an immune reaction to that than there would be from cattle or goats or sheep because the pig has the similar reproductive, digestive, and overall physiological systems that humans do.

Perhaps a gene transferred into cattle will enable them to produce enough human blood clotting factor to treat patients with hemophilia or perhaps transplanted organs will be able to produce insulin and cure diabetics. But what about small animals, such as pets?

Every year, the United States spends something like $5 or $6 billion treating diseases in pets, in dogs and cats mainly. If we had accurate information on all the genes in cats and dogs, it would be possible to breathe out these genetic defects that cost so much money and cause pet owners so much grief.

There's a large number of people in the United States who are deathly allergic to cats, and this is mainly because of a particular gene in the cat that makes a protein present in the saliva of the cats when they groom themselves, and this is mainly responsible

Introduction to Biotechnology

for the very violent reaction that a lot of people have against cats.

Now, it's perfectly reasonable that we could find this gene and remove it from the cat genome. We could breed strains of cats that were not allergenic. And once again, you could look at a tremendous saving of money and grief. Lots of people want to have cats, but they can't have cats because they're so allergic to them.

Colonies of specific types of cells can be produced that ordinarily couldn't be produced so quickly. In the human body, lymphocytes produce antibodies which neutralize bacteria, viruses, and even cancers. These antibodies are key in the body's defense against disease. Cell cultures can produce large amounts of antibodies, which can be tested, studied, and manipulated to treat diseases such as cancers or infections.

There's a lot of effort going on in terms of trying to understand disease processes on the molecular level-- cancer, heart disease, genetic inherited disorders. The DNA of the human genetic constitution has been read. That is, all the letters in the genetic alphabet are being translated.

And it should help us in the long run to understand a lot of genetic diseases. If you understood them, you could probably design drugs and therapies that would act against a debilitated genetic constitution and would predict people who were at risk for heart disease, for strokes, heart attacks, and so forth. And autoimmune diseases are a huge problem in the United States.

Rheumatoid arthritis, of course, is a big blockbuster disease-- diabetes, lupus erythematosus, Crohn's disease, Hashimoto's thyroiditis. So there's many, many different diseases. Autoimmune diseases are going to be one of the big frontiers of research in the coming years. They affect many, many people, and they're not well understood at all.

Part 6

These are just a few of the possibilities associated with biotechnology. Continued research offers a host of possibilities, however this new technology is not without its risks. As with all new technologies, there are controversies. Since biotechnology has such a broad scope, it has an equally broad range of concerns. What if herbicide-resistant genes accidentally make their way into weeds and they grow out of control? Could some of the genes cause the organism to produce toxins that aren't detected? What if new agricultural products kill important insects or other animals in the food chain? Could a hostile terrorist organization use this technology to unleash a worldwide epidemic?

Fortunately, since the technology is still being developed, some of the controversy is

Introduction to Biotechnology

more science fiction than it is science. So it'll probably be a long time before anyone has to worry about humans being cloned or genetic warfare. Nevertheless, concerns are being addressed by ethicists, politicians, sociologists, and others. It's the other questions that keep the research going. What if we could feed all of the Earth's population? What if there was a way to cure all cancer? Is it possible to eliminate certain diseases in developing countries?

Who knows? With time, dedication, and cooperation, we may be able to find the answers.