

Genetic Engineering

Goals

1. Review the structure of DNA and its properties, the central dogma, and the genetic code.
2. Get to know the topic of genetic engineering as an important scientific tool.
3. DNA extraction from an onion (see protocols online).

Keywords

First lesson: Introduction to genetic engineering

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|-----------------|-------------------|
| 1. DNA | 8. RNA |
| 2. Genes | 9. Replication |
| 3. Double helix | 10. Transcription |
| 4. DNA backbone | 11. Translation |
| 5. DNA bases | 12. Protein |
| 6. Nucleotide | 13. Amino Acid |
| 7. Genetic Code | 14. Codons |

Second Lesson: Genetic engineering

1. Genetic engineering
2. Hybridization
3. Enzyme

Lesson Summary

Review of the structure of the DNA, beyond simply the definition and characteristics, and through this topic, learning about RNA and protein coding. Next, we will speak about genetic engineering, genetic manipulations that have been done in the past, applications of genetic engineering, and, in short, what is needed to perform genetic manipulations.

Lesson Plan

Lesson 1- Introduction to genetic engineering

1. Introduction to cells- point out where the DNA is found. Explanation about the nucleus of eukaryotic cells and the difference between prokaryotic and eukaryotic cells. We are all built of cells: cell is a basic elementary unit which holds all the characteristics of life. Every cell contains DNA. Explain hereditary information- information that is passed on to descendants.
2. Speak about the structure of the DNA in two slides: the double helix the backbone, explain that at one time this was a theory and today we can see the helical structure with the help of electron microscopes. Elaborate about the bases and state that they make up the genetic code.

3. The genetic code is the same for all living creatures, so how is there so much diversity?
4. From DNA to traits- explain the replication, transcription and translation processes from DNA molecules in the cell to proteins.
5. RNA- how is it different than DNA?
6. The same RNA molecule is translated to protein. How? The DNA code codes amino acids (elaborate on this). Explain the structure of proteins- a basic structure of amino acids. From 20 amino acids coded in the RNA, we get an infinite number of different proteins.
7. How can we manipulate the knowledge we have about DNA and traits? With the help of genetic engineering which will be discussed in the next class.

Lesson 2- Genetic engineering

1. Remind the student that an organism's traits depend on their proteins and the genetic code which codes for those proteins. Ask the students what would happen if we could take a specific gene and transfer it from one organism to another. Afterwards, explain that this is possible through genetic engineering.
2. The manipulation of organisms' traits goes way back to the beginning of domestic agriculture. This could be done, for example, by hybridization. Explain hybridization.
3. Speak about the cons of hybridization- we get a mashup of a bunch of traits, rather than a product with all the exact desired traits. This makes the engineering process through hybridization very time-consuming and, at times, inefficient.
4. In contrast to hybridization, genetic engineering enables the transfer of desired traits from one organism to another.
5. What is genetic engineering? A process of changing, damaging, enhancing, or adding genes, leading to a change in the traits of an organism.
6. Genetic engineering has many potential applications: in medicine it can be used to create product with medicinal properties such as insulin (which can be used to help diabetic patients' blood sugar level balance out), vaccinations and antibodies, all using bacteria and yeast! Vaccinations, medicines, and antibodies can also be produced in animals, and genetic manipulations can be used to create model animals for research on problems such as heart disease, diabetes, and obesity. Additionally, there is a novel process of fixing genes- by inserting genetic fragments into cells, various diseases which stem from a damage or missing gene can be cured.

7. In addition to creating models to research diseases, the function of various genes is being studied by inserting the genes into bacteria, yeast, or animals. One example of genetic manipulation in animals is the case of Dolly: Dolly was created in a scientific experiment in Rosalind Institute in Scotland, mainly by the research staff headed by Ian Wilmut. The original goal of the research was to make a clone of genetically modified animals in order to use them to create therapeutic proteins, such as insulin, in their milk. Dolly the sheep was created from the nucleus of an udder cell, using the cloning strategy of somatic cell nuclear transfer, in which an ovum is implanted with a donor nucleus.
8. In the industry, there is the protein production of enzymes, production of biofuels, cleaning ocean pollution, and identifying of dangerous materials.
9. In agriculture, the uses are very widespread- hybridization is brought up a level with genetic engineer, which results in plants with the desired traits alone. For example, protection of crops against environmental conditions, insects, viruses, and for improving agricultural yield. Examples:
 - a. The creation of potatoes containing a mix of starches idealized for use in industrial processes.
 - b. Cows can be engineered to produce milk with a higher percentage of proteins for cheese production.
 - c. Canola oil is extracted from rapeseed. Originally, the oil contained erucic acid, which may be harmful in high quantities. The rapeseed plant was genetically engineered to produce seed with significantly lower erucic acid.
 - d. Golden rice- rice enriched with vitamin A. In many areas of the developing world, rice provides a major form of sustenance. About half a million children suffer from blindness as a result of lacking vitamin A. Golden rice provides a solution- rice containing beta-carotene- the base molecule for vitamin A.
10. So how exactly is genetic engineering done? If we want to take a certain trait from an organism, to "copy" and "paste" it to a different organism, we need the ability to cut DNA, paste it, and, of course, replicate it. All these actions can be done using specific enzymes. Enzymes are proteins which catalyze processes. We take the desired gene, and copy it to the desired organism (which doesn't have the specific trait we want, naturally), so that the organism gets the new trait from its source in another organism. This is what we will be doing in the lab.

Supplementary Material for the Teacher

A good researcher is not afraid to question things that other scientists may take as law, or subjects which are not usually questioned. Though molecular biology and biotechnology are relatively new fields, biology is not. Scientific development began at a time when the world was ruled by religious figures and faith, a time when part of the required studies for medicine included astrology and horoscopes, and the explanation for many sicknesses was that it was fate.

One fact which was accepted unconditionally was that we are the descendants of our parents and similar to them. Furthermore, it was accepted that this similarity was part of the definition of the species: humans birth humans, frogs lay eggs that hatch to become frogs, and so forth. Most of history, many believed that this fact was the responsibility of an elite figure, a god, and that we must seek the source of this fact in spiritual sources. Nevertheless, some sought out a proof: if the source of this fact wasn't physical, they wanted to prove it.

With the invention of the microscope, researchers could notice that despite being seemingly uniform, creatures are not identical.

All living organisms are made up of similar basic building blocks called cells. Though there are many different types of cells, they also have a lot in common. All cells are surrounded by a lipid membrane. Additionally, they all contain proteins and other nitrogen-containing molecules. Alongside the similarities, researches noticed disparities: some cells have a nucleus, while others do not.

In the experiments of Gregor Mendel in 1865, it was shown that there are genetic units which are responsible for passing traits from generation to generation. In 1909, the researcher Wilhelm Johannsen called these units "genes."

At first, researchers hypothesized that since the diversity in traits from one creature to another is so great, certainly the hereditary material comes in many forms as well. It was only in 1944 that Avery, MacLeod, and McCarthy discovered that deoxyribonucleic acid, or DNA, is the material responsible for carrying hereditary information and for passing it on from generation to generation. DNA is the hereditary material found in all living cells.

Discovery of the Structure of DNA

In laboratories around the world there were researchers who focused entirely on finding the structure of DNA and the atoms which make it up. The way to analyze complex chemical structures, even today, is by creating repeating structures of the material and using x-ray crystallography. The process allows the identification of the atomic and molecular structure of crystalline structures by measuring angles and intensity of diffracted x-ray beams. Once the researchers discovered the structure of DNA, many rumors circulated. One such rumor was that the person who actually succeeded in imaging the structure was a woman, Rosalind Franklin, a woman who have thought to be a pioneer in a world ruled by men. Her best x-ray diffraction image was called "Photo 51." Watson and Crick, researchers at Cambridge University, received the photo before Rosalind Franklin was able to publish her results, with the help of Maurice Wilkins, a physicist and colleague of Franklin at King's College. With his help, they were able to decode the 3-dimensional structure of the DNA, and came to understand that it had a helical structure. They calculated the number of bases per turn, and built a 3-dimensional model of the DNA out of metal boards. The four scientists went on to publish their discoveries. In 1962, Wilkins, Crick, and Watson received the Nobel Prize for their discoveries (Franklin has passed away by that time).

DNA structure

The DNA structure is made of two strands of DNA backbone made of pentose carbohydrates, called deoxyribose, attached to phosphate residues. The sugar-phosphate repeats lead to the formation of a helical structure. Nitrogen bases are attached to the deoxyribose sugar residues. DNA is made up of four such bases: guanine (G), adenine (A), cytosine (C), and thymine (T). The overall molecule is called deoxyribonucleic acid, or DNA, because of the individual molecules which make it up. Every DNA molecule is paired to another with weak hydrogen bonds. Molecules with be A will bind to those with T, and those with G will bind to C. Thus, the result is two strands of DNA bound together in a helical structure, giving DNA its nickname of double helix.

What is DNA structure?

DNA is a nucleic acid built of two strands of nucleotide units. In eukaryotes, most of the DNA is in the nucleus, whereas in prokaryotes it is in the cytoplasm. Nucleotides are built from three basic parts: a nitrogen base, a pentose sugar, and phosphate, as previously stated. Adenine (A) and guanine (G) bases are purines, and thymine (T) and cytosine (C) are pyrimidines. The carbons in the sugar molecule are marked 1', 2', 3', 4', and 5'. The phosphate comes from the side chain of phosphatidic acid (H_3PO_4). The three building blocks of the nucleotide are connected with chemical bonds. The sugar is attached to the phosphate at the 5' carbon, and to the nitrogen base at the 1' carbon.

The DNA molecule

Thousands of nucleotides join to form a long chain. The nucleotide chain forms a strand of DNA. The nucleotides are attached to one another with covalent bonds. The bond is formed between the sugar of one nucleotide and the phosphate of the next nucleotide. The phosphate is attached to the 3' carbon of the neighboring sugar molecule. The resultant strand therefore has a 3' carbon that is free to attach another nucleotide. This is called the 3' end of the DNA. At the other end, a phosphate is attached to a 5' carbon, creating the 5' end. Each DNA molecule is built of two such strands which are found opposite to each other and "head to tail." The nitrogen bases stick out of each strand and link each other with hydrogen bonds between base pairs. However, there are only two four possible linkage pairs A-T, T-A, G-C, C-G as noted above, and therefore the sequence of one strand defines the sequence of the other strand. The two strands connected together are called "complementary strands." In addition to being connected, these strands curl around each other forming a "double helix."

A question for the students: What do you think scientists thought about this discovery?

The truth is that the world was disappointed. They had invested so many expectations in the structure and make up of DNA, and expected it to be some complex and diverse structure, included even various atoms and materials. The actual discovery seemed simple and boring in comparison. Nevertheless, every living organism: bacteria, plants, and even humans carry the same hereditary material- DNA. (At this point, ask for volunteers to come draw the DNA structure and explain it on the board)

What is the purpose of DNA?

DNA is essentially a code, upon which all the cellular proteins and living traits are based. We can imagine DNA as a sort of cookbook containing instructions for making and forming all the proteins of each cell. This cookbook would have chapters: insulin preparation, eye color, hair color, etc. An error in a sequence can cause problems in protein construction and sometimes even sickness.

Example:

Has anyone heard of diabetes?

Diabetes is a disease in which a person's insulin supply is stopped or lowered significantly. The disease can have a serious effect on patients. Pig insulin is very similar to human insulin, and until not long ago, pig insulin would be injected into diabetic patients. Today, insulin is synthesized using bacteria. How do you think they made bacteria synthesize insulin even though they don't contain the genetic data to do so?

Answer:

We know that the information needed for the creation of proteins is found in the DNA of the cells of all organisms. Scientists used this knowledge to insert a sequence coding for insulin production from man into bacteria, leading to bacterial ability to synthesize the protein. Today, DNA can be inserted from one organism to another in the laboratory.