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Brave New World: Genetics in the Modern World

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Introduction

The scientific and technological accomplishments of man during the twentieth century are astounding. With the development of specialized tools and perfected diagnostic procedures, research has surpassed what was thought possible a short time ago. The twenty-first century scientists will continue to make advances, especially in the field of biotechnology. This use of biological processes to manufacture new organisms and chemicals has transformed the area of science fiction into a reality.

Science education has metamorphosed from a strict content approach to one combining content and hands-on activity with the emphasis on hands on. Using the scientific method, students are taught to solve problems in an organized, methodical fashion. Viable research begins with observation/inquiry and proceeds to experimentation. It is through this process that scientists are able to address awaiting challenges in the areas of medicine and biology. This change will continue to motivate students and in turn begin the process of developing a scientifically literate population.

My unit, ”Brave New World,” will be used with seventh and eighth grade students as a supplement to the current curriculum. These two grades are divided into separate divisions of varying ability levels. The lessons developed can be modified to accommodate all students including the special education classes. This unit, consisting of a content/hands-on approach, will take about three to four weeks to complete and will be used along with the study of the cell and heredity.

“Brave New world” is divided into five sections. The first section, Genetics 101 begins with an introduction to cell structure and function, including detailed explanations of chromosomes, genes, inheritance and the work of Gregor Mendel. A student glossary will be included in this section.

Section two contains an introduction to an understanding of DNA. This begins with an explanation of the structure of DNA and the work of James Watson and Francis Crick.

After providing students with the basic concepts of genetics and an understanding of DNA structure, students will learn about the Human Genome project and the implications for future research. This section will prepare students for the portion of the unit, which deals with cloning.

The information presented next will include the history of cloning experimentation, how cloning is accomplished, why we clone and the future possibilities through its continued implementation.

Finally, student activities will examine the ethical implications of cloning and genetic engineering. Various case studies will be presented for analysis. This will tie the unit together and provide students with an opportunity to utilize decision-making and critical thinking skills through written activities.

Evolution Of The Cell

Anton Van Leeuwenhoek's invention of the microscope in 1675 provided scientists with an instrument, which opened up a whole new world for them. While examining pieces of cork under the newly developed microscope, Robert Hooke, an English scientist, observed very distinct empty spaces. He named these little box like structures "cells" and even though Hooke was observing a non-living structure, the term evolved to describe living things. Leeuwenhoek continued to observe everything he possibly could - blood, rainwater, and even scrapings form his teeth. "He called the living things 'animalcules'. Today they are known as bacteria"(1). The discovery of these single celled organisms fascinated Leeuwenhoek and eventually led to the development of more specialized microscopes.

Observations of microorganisms continued. In 1824 Dutrochet, a Frenchman, observed many different plants and animals and suggested, "various parts of organisms are composed of cells"(2). This work was followed by Robert Brown, a Scottish scientist who in 1831 announced the central part of the cell is called the nucleus and by Dujardin, another Frenchman, whose discovery in 1835 enlightened scientists to the fact that cells are not hollow but are in fact filled with a thick, jellylike fluid.

Research continued by Matthew Schleiden in 1838 and Theodor Schwann in 1839. After observing plant and animal cells they concluded all plants and animals are composed of cells which are alive and which contribute to the total operation of the organism of which it is a part of. Rudolph Virchow confirmed their findings and in 1858 "he stated that all cells come from other living cells. The works of these scientists led to the formation of the cell theory which states that all living things are made of cells; cells are the basic units of structure and function and living cells come from other living cells" (3). This persistence, curiosity and observations laid the groundwork for future cellular research.

Cell Structure And Function

Life in multicellular organisms begins as a single cell and develops into about 100 trillion cells. These cells are responsible for everything from weight to shape to movement. Information necessary for an organism to develop is contained in the single cell. A typical cell can be compared to a factory. Each worker in the factory has a specific job and like a factory, the cell performs many functions so it is organized so that each part carries out a different function. The specialized areas found throughout the cytoplasm of a cell are called organelles. " The organization of cell parts for specific jobs is known as division of labor- each part carries out its own functions. However it depends on other parts as well. The cell operates and survives only if all parts work together"(4)

Most cells have similar characteristics. The outer covering of an animal cell is the cell membrane and the outer covering of a plant cell is the cell wall, inside which is the membrane. The membrane's job is to provide protection and support for the cell. It also contains tiny openings, which control the amount of materials, which enter and leave the cell. Everything the cell needs or needs to get rid of must enter or leave here. The nucleus (which will be discussed in greater detail) is a large structure found in the center of the cell. This structure controls all of the cell's activities. It also contains chemical substances that determine the inherited characteristics of the cell. The cytoplasm is the area of the cell between the cell membrane and the nucleus. Although jellylike and consisting of about 70% water it contains proteins, sugars, starches, fats, salts, vitamins and minerals which interact with each other. This is the site of metabolism and the site where organelles are stored. Within the cytoplasm lies the endoplasmic reticulum, which are tubular passageways serving as a transportation system for protein delivery. Ribosomes, which are found on the endoplasmic reticulum, are the protein making sites for RNA. Once the protein is made, it is then delivered to other cell parts via the endoplasmic reticulum. The golgi apparatus is where proteins made by ribosomes are delivered to needed areas. Other structures, which supply energy to the cell, are called mitochondria. These constructs break down sugars into water and carbon dioxide causing the release of energy. They are often called "the powerhouse of the cell" (5). Large fluid filled sacs also are floating in the cytoplasm. These storage bins for food and other materials are called vacuoles. Small structures called lysosomes contain enzymes, which help in the digestion of certain food molecules and the removal of undigested wastes.

The cell needs a number of different molecules to work efficiently. Nucleic acids DNA and RNA are the cell's blueprints carrying all information for inheritance. Proteins serve as enzymes that run chemical reactions in cells. They are built from smaller molecules called amino acids. Carbohydrates provide the fuel supply for the cell. They include glucose, sucrose, fructose, starch and cellulose. Lipids, which are found in fats and oils, help the cell store energy for future use and are a major component of membranes.

Growth is one of the basic characteristics of all living things and cells begin to grow by reproducing and dividing. The process of producing new cells occurs during cell division. During this process one cell divides into two cells, which are called daughter cells, identical to the other and to the parent cell. This happens in a series of 6 phases. Phase one is called interphase. During the beginning of this phase, the cell is performing all functions except the division. This stage is where chromosomes are copied. Phase two, called prophase, is where mitosis begins. The nucleus divides into two nuclei and the formation of two new daughter cells begins. Phase three, metaphase, is the phase where chromosomes attach to a meshlike spindle at the center of the cell. Phase four, the point at which the chromosomes begin to separate is called anaphase. Phase five is the telophase stage. Here two new nuclei form and mitosis is completed. However cell division goes through a sixth phase called cytokinesis, which is the division of the cytoplasm and the formation of two new daughter cells.

As stated earlier, the nucleus is the control center of the cell and the site of the structures, which determine chemical characteristics. These structures, called chromosomes, are visible during the cell's reproductive phase. Forty-six chromosomes are found in humans - 22 matched pairs and 2 sex chromosomes. Each chromosome is made up of either a single or double cord of DNA, deoxyribonucleic acid, the molecule containing the genetic instructions for making protein. Genes are located on the chromosomes. After cell division chromosomes are copied and passed on to offspring. The science, which studies how these traits are passed from parent to offspring, is called genetics.

The Double Helix

Gregor Mendel, an Austrian monk, is known as the father of genetics. His experiments laid down the foundation for future scientists' research genetics. Mendel's experiments with pea plants demonstrated that a certain strain of peas bred true- tall plants produced tall offspring and short plants produced short offspring. Mendel proceeded to produce a hybrid plant by mixing tall and short plants together. The offspring of these hybrids were tall, however, when Mendel continued cross breeding the offspring he found that 3/4 of their offspring were tall and 1/4 were short. It was concluded that adults possess two sets of genes - one contributed by each parent. The play between the genes determines the offspring's characteristics. Mendel continued and determined that genes can be dominant or recessive. When one trait is produced, the gene is said to be dominant. He also showed that genes could be recessive meaning they don't show up on all offspring and may in fact skip a generation. His experiments became known as the Law of Dominance and the Law of Segregation. His findings were published in 1865 but it wasn't until the early 1900s when biologists gave them credence, realizing the factors Mendel spoke of in his experiments were actually chromosomes.

Genetic material is composed of DNA and passed from one generation to the next. It is referred to as the "code of life" because it links generations together. After years of research scientists concluded that DNA " is a large molecule that is built from a large number of similar building blocks"(6). It looks like a ladder with two sides and a number of rungs. The sides are twisted around each other with 10 rungs for each twist or turn. It is described as a double helix and in 1953 two biologists, James Watson and Francis Crick published their visual explanation of its appearance. Their explanation of this structure explained how DNA copies or replicates itself through cell division. During replication the two strands of DNA separate and synthesize a new complementary strand with the existing bases, sugars and phosphates. This process produces two new strands of DNA. Sometimes a mistake occurs during the replication process. This mistake makes a permanent change in the structure of the DNA and as a result of this, a mutation develops. Some mutations only have a minor effect, however some may have a major effect depending upon the way in which the protein is changed. These finding have led geneticists to probe into human disease through research and more. Using Watson and Crick's explanation scientists were first able to begin unraveling the genetic code as a basis for future research.

DNA is made of three substances: Phosphate (P), a sugar called deoxyribose (D), and a third substance, which is a base. The first two substances make up the sides of the ladder. There are four differently shaped bases, which make up the rungs of the ladder: Adenine (A), Cytosine (C), Guanine (G) and Thymine (T). A and G are "long" bases and T and C are "short" bases. A bases are always paired with T bases and C are always paired with G bases. The pairs of bases are held together by hydrogen bonds, but in order to stay bonded the base shapes have to fit together like puzzle pieces (6). The way in which the bases are sequenced makes up the DNA code. The cell uses this unique code to control protein synthesis, which determines our characteristics because many proteins are enzymes that control our biochemistry.

The Human Genome Project

Scientists used Watson and Crick's structure of the DNA molecule as a tool for future research. In the early 1980's scientists had an idea to begin mapping human DNA. Scientists at the Department of Energy's national weapon research centers in Los Alamos and Lawrence Livermore were interested in determining whether the DNA of the offspring of survivors of the Hiroshima bomb were mutated because of their exposure to radiation. Their only way of finding this out was to begin sequencing and studying the cells. In 1982 they attended a scientific conference in Colorado and introduced their proposal for finding out their answers. Their original proposal was modified after its introduction but it laid the foundation for the beginning stages of the Human Genome Project.

The project officially began in 1990 and became an international project when scientists from eighteen other countries got involved. They included Australia, Brazil, Canada, China, Denmark, European Union, France, Germany, Israel, Italy, Japan, Korea, Mexico, Netherlands, Russia, Sweden, United Kingdom and the United States. Their alliance formed the HUGO- Human Genome Organization. The United States Department of Energy led by Ari Patrios and the National Institute of Health led by Francis Collins along with scientists from various French agencies are at the helm of the research.

While reading the daily newspapers one can begin to understand the excitement generated by the project. Titles such as, "Scientists Plan: Map All DNA", "Who Owns the Human Genome", and "Genetic Questions are Sending Judges Back to the Classroom" are found on the front pages and beyond (7). The major goal of the project is to "produce a listing, base pair by base pair, of the entire human genetic code - all twenty-three chromosomes pairs with about three billion base pairs. The base by base survey is called sequencing and locating the genes along the DNA is called mapping" (8). This possible information uncovered through this process could help scientists understand and eventually cure genetic diseases.

"A genome is the sum total of genetic information in a living species" (9). The genetic information includes instructions for making proteins. Proteins are essential for all living things because they include instructions for how an organism looks, metabolize food and fight infections. "The code itself is a "series of codons" which is a sequence of three DNA bases" (10). The order of the bases is quite important. Sometimes there are abnormalities on DNA. These abnormalities are called mutations and are sometimes responsible for a number of diseases. Again, it is the hope of this project that scientists will be able to isolate disease-causing genes and suggest a therapy or treatment to correct them.

On April 6, 2000 an article in The New York Times reported that, "The Analysis of Human Genome is Said to be Completed." The report, made by Dr. J Craig Venter stated that within a few weeks his company, Celera, would be able to identify the whole human genome. To actually assemble the whole thing it will take until 2003. Venter, one of the pioneers of the Human Genome Project reported that the genome belongs to a man because it has one X chromosome and one Y chromosome as opposed to the genome of a woman, which has two X chromosomes. The DNA in the study includes men and women of differing age and race. After it is put together it will be annotated, identifying all of the genes and their capabilities. Worried about the information gained from this and its potential Dr Venter said, "it would take a century to understand what each human gene does and that an attempt to alter the human germ line should not be made until then if ever" (11). Celera will use technology to attempt to find a faster way to sequence the DNA and expand the knowledge of genetics. The gene samples are from a variety of subjects who donated samples of blood cells and sperm cells. "This sampling works well because everyone has a unique DNA sequence but variations for 2 different

genomes is said to be less than 1%" (12). The project has opened up enormous competition between the U.S Government and biotechnology companies.

Through the identification of genes and map-making capabilities of the human genome. "Recombinant DNA Technology allows researchers to snip out pieces of DNA and splice them into bacteria, where they can be grown, or cloned in large quantities"(13). Scientists use a variety of methods to copy genetic materials. " A clone is a group of identical molecules, cells or organisms that are descended from a common ancestor through asexual reproduction" (14). In asexual reproduction, the offspring come from only one parent; so all cells contain the same genetic material. The members of a clone may be regarded as extensions of a single individual. Although cloning is not a new subject it has received a lot of negative publicity because of its comparison to science fiction. Scientific cloning has provided scientists with enormous capabilities for studying cancer, aging, genetic disorders and agriculture.

Cloning

As stated earlier, the cloning process has been around for many years. Twins, produced by sexual reproduction, have identical nuclear DNA and identical mitochondrial DNA. In a laboratory setting, the embryo is mechanically divided allowing the cells to grow and develop separately. "Twinning is also referred to as embryo cloning" (15).

"Gene splicing is a method of cloning in which pieces of genes or whole genes are inserted into bacteria. The bacteria multiply and make large amounts of the protein called for by the newly inherited gene"(16). Dr. David Jackson pioneered gene splicing. His research with viral and bacterial cells provided scientists with tremendous capabilities in terms of genetically engineering specific host cells especially in his explanation of breaking DNA molecules into much smaller pieces. This contributed to a wide interest in how genetic materials of viruses can be turned on and off, making huge numbers of offspring. "The Recombinant DNA Technology allows researchers to simply snip out pieces of DNA, splice them into bacteria and clone them in huge quantities"(17). The fusion of the DNA samples is aided by plasmids. "Plasmids "are ring-shaped pieces of DNA and are the vehicles by which some bacteria inject some of their DNA directly into other bacteria when they mate in a process called conjugation" (18).

Plants also go through a cloning process. This type of cloning is done either naturally through stem cutting or by using laboratory methods. Using the lab methods scientists isolate single cells and provide appropriate conditions necessary for them to divide and form numerous cells that make up young plants. The method known as "tissue culture" uses hormones and certain growing conditions to produce clones (19).

Another method of cloning is through a process known as nuclear transfer. The nucleus of an egg cell is removed from a host animal and replaced with a cell nucleus from a different adult animal. Next the egg cell with the transferred nucleus is placed into the host animal's reproductive system. This cell now has all of the capabilities needed to develop into an exact genetic replica. An experiment performed by John Gurdon in the early 1950's used this process to clone the cells of tadpoles. Although the embryos never developed beyond the tadpole stage, this experiment illustrated that technology and perseverance would enable scientists to move forward in their research. In the 1970's this technique was used to clone mice. Unsuccessful attempts at cloning followed until the research of Steen Willardon, an employee at the Granada Genetics, Inc. used the nuclear transfer method to produce calves from embryos. The embryos progressed to the 64 and 128-cell

stage and confirmed the possibility of successful nuclear transfers in mammals (20).

Finally in 1995, Ian Wilmut, a Scottish scientist and his colleagues produced Megan and Morag, two live lambs whose embryos had been cultured for months in the laboratory. This set the stage a couple of years later when the world was introduced to Dolly, the first successfully cloned mammal. Dolly was cloned from a cell belonging to an adult animal. Cells were taken from the udder of a 6-year-old Finn Dorset ewe. These cells were cultured in a lab and then fused with unfertilized eggs from which the genetic material was removed. Two hundred and seventy-seven “reconstructed eggs” were cultured in temporary recipients. Twenty-nine eggs, which appeared to have developed normally, were implanted into thirteen surrogate Scottish Blackface ewes. One hundred and forty-eight days later, Dolly was born and later introduced to the world.

Conclusion

The birth of Dolly and other technological advances provided the media with daily headline stories. Cloning took on a new meaning, not only for scientists but also for business and the movie industry. The headlines also opened up a Pandora’s Box in terms of ethical issues. The successful “mapping” of the Human Genome will eventually provide us with a detailed guidebook of the human body. What we do with this powerful information raises all kinds of questions. Do we use this information to cure diseases? Do we use this information to “design” our future children? Should this information be made public? Who owns our chromosomes? Will companies hire based on genetic information? These are some of the questions that will attempt to be answered in the near future and will most certainly be discussed in most classrooms in the 21st century.

STUDENT GLOSSARY

Amino Acids - Building blocks of proteins. Bioethics – The study of ethical problems in genetics, medicine and agriculture raised by advances in biological research. Cell- The basic unit of structure in a living thing. Chromosome- Structure composed mostly of DNA located in the nucleus. Clone- To make an exact copy of an organism. DNA- Material inside cells those carries the genetic information. Scientific name: Deoxyribonucleic acid. Dominant trait- Genetic trait which dominates or prevents the expression of the recessive trait. Embryo- animal in the early stage of development before birth. Genes- a segment of a chromosome that carries the genetic information for a single protein or trait. Genetics- The study of genes and traits. Genome- Complete set of instructions for making an organism. Genotype- All the genes one carries; some are not always expressed. Mitosis- Process in which the nucleus of a cell divides into two nuclei. Mutation- A random change in the genetic material of an organism. Nucleotides- Linear arrangement of a base attached to a sugar and a phosphate. Phenotype- Physical expression of a gene. Plasmid- A small piece of DNA from a prokaryotic cell that can be used to carry genes from one cell to another. Prokaryotic- Cell which lacks a nuclear membrane such as bacteria. Protein- Large molecule composed of amino acids. Replication- Process by which any entity, such as DNA strands, are duplicated.

LESSON PLANS:

DNA MOLECULES

OBJECTIVE:

Students will design a three dimensional model of DNA to learn how nucleotides are formed.

MATERIALS:

Plastic straws, two different colors

Lucky Charms cereal (4 different colors)

Toothpicks

Yarn or string

PROCEDURE:

Pass out a set of materials to each student.

Using cereal to represent bases, assign each base a certain color - yellow/thymine, green/adenine, pink/cytosine and blue/guanine.

Pair and connect bases using toothpicks.

Cut straws into one-inch pieces and arrange by alternating color.

Connect the pieces of straw using the yarn or string.

Finally connect the cereal bases to the straw strands.

QUESTIONS:

Which bases pair together?

What is a code?

What do the pieces of cereal represent?

What do the pieces of straws represent?

What makes up the rungs of the ladder?

What makes up the sides of the ladder?

EXTENSION:

Using your individual model demonstrate the replication process.

DO YOU SEE WHAT I SEE?

OBJECTIVE:

Students will understand how to extract DNA from a given cell source.

MATERIALS:

Several plant tissues- broccoli, spinach, and onion

Blender

Warm water

Plastic container

Clear glass

Strainer or filter paper

Rubbing alcohol

Meat tenderizer, any variety

Liquid detergent

PROCEDURE:

Cut up small amount of plant tissue.

Put into blender.

Add warm water and blend until consistency is similar to thick soup.

After obtaining desired consistency, pour mixture through a strainer into a small plastic container.

Add 1/4-cup liquid detergent and 1-tablespoon meat tenderizer. Stir for about 5 minutes.

Empty 1/2 the mixture into a clear glass container.

Hold the container at a slightly tilted angle and slowly pour the alcohol down the side of the glass so that it forms a layer on top of the soap mixture.

Let it stand for about 5 minutes and you will observe white stringy stuff that rises to the top of the container.

Gather some DNA, slowly rotating it on a glass rod and observe it.

QUESTIONS:

What does the blender do?

Why is liquid detergent used in the experiment?

What does the meat tenderizer represent?

How come alcohol is used rather than water to extract the DNA?

Which part of the cell is the DNA located in?

DECISIONS, DECISIONS!!!

OBJECTIVE:

Students will analyze a bioethical scenario and prepare a written presentation that explains their position.

MATERIALS:

Bioethical studies 1 and 2

PROCEDURE:

Assign one of the scenarios.

Students will read and analyze the scenario and will prepare a written presentation demonstrating their knowledge of basic genetics and bioethics.

SCENARIOS:

Research has confirmed that an inherited gene causes Sickle Cell Anemia. Recently Alice found out that her mother carried the gene. Alice's oldest daughter Jane just got married and is considering starting a family. She needs to know if she is a carrier of the gene and thus needs some medical testing. Unfortunately her husband is unemployed and they lack insurance. Where does Jane go from here?

After the birth of their second child, Frank and Tina were very excited. While Tina was busy one morning the baby fell and broke his arm. After being rushed to the hospital and treated, life seemed to go on normally for the next couple of weeks. During the baby's routine arm check-up, x-rays revealed that the bones were completely healed. Doctors were so confused by this amazing recovery that they began to perform a series of tests on the child.

After extensive testing the doctors discovered that the baby had a rare gene that gives him the power to heal broken bones at a rate confusing to man. Immediately the doctors get so excited. They approach Frank and Tina with this amazing news and ask their permission to extract some of the baby's DNA so that the gene can be cloned. News like this travels very fast and reporters and several biotechnology companies bombard Frank and Tina. The companies are offering 5 million dollars for DNA samples. What should Frank and Tina do?

QUESTIONS:

What is the dilemma?

What are the facts?

What are your views on the issue?

What are arguments for and against?

Who will be affected by the decisions reached?

What ethical problems does the decision seem to raise?

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