SUPPLEMENTAL DNA EDUCATION: FUNDAMENTAL PRINCIPLES AND ILLUSTRATIVE ACTIVITIES

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Overview

This unit incorporates supplementary enrichment for high school students enrolled in chemistry or biology. It consists of background information concerning DNA, applications of DNA technology in medical uses, and related safety and ethical issues.

While students have experienced a basic study of DNA, rarely do they have the opportunity to receive more in depth knowledge on the subject, it's current medical applications, as well as ethical issues. In addition to a theoretical study of DNA and genetics, students will have the opportunity to participate in demonstrations, experiments, individual and group research, oral presentation, and debate on these topics. Making connections between technological advances and students' everyday lives is basic to evaluating societal issues in the twenty-first century.

Rationale

This unit will be appropriate for secondary students, spanning grades nine to twelve. The skill base necessary will be a basic introduction to biology as well as chemistry, as may be accomplished through introductory courses in these subjects. This curriculum will fit into the existing curriculum as a supplementary curriculum unit, encompassing information learned in the existing curriculums for biology and chemistry as prescribed by the Pittsburgh Board of Education.

Advances over the past two decades have transformed biology from a descriptive science into a technical chemical methodology for manipulating the molecular mechanisms of life (Matta, Staley and Wilbraham, 747). One of the biological molecules that has taken center stage is the DNA molecule. DNA (deoxyribonucleic acid) is a major constituent in all living cells. DNA molecules have a molecular mass that is enormous, extending into the millions and even billions. The work of Watson and Crick laid the groundwork for identifying DNA's now famous double helical structure. According to Campbell, DNA is a double-stranded, helical nucleic acid molecule capable of replicating and determining the inherited structure of a cell's proteins (Campbell, G-8). The nucleic acid structure that characterizes DNA is a polynucleotide consisting of long chain pairs of alternating nitrogen bases, deoxyriboses, and phosphates. The sugar of one nucleotide is attached to the phosphate of the next consecutive nucleotide in the growing chain of nucleotides, with sugars and phosphates alternating in regular fashion. The bases project inward from their attachment points on the sugar molecules, joining to their complimentary bases by hydrogen bonds. These joined strands of nucleotides form into a spiral shaped ladder with the steps representing the pairs of nitrogen bases, and the phosphate-sugar backbone representing the supporting side rails of the ladder (Matta, Staley and Wilbraham, 748). The double helix formed has a diameter of 2-nm, this resulting from the consistent pairing of a purine and pyrimidine base pair, as witnessed in the DNA diffraction photos taken by various x-ray crystallographers.

Each sugar molecule of DNA can have either a purine or pyrimidine nitrogen-base attached to it (Campbell, 86). Purine and pyrimadine denote the actual structure of the nitrogen base-whether it is a double ring compound or a single ring compound. Purines are double ring compounds while pyrimadines are single ring compounds. Both are nitrogen bases known as residues (87). The sugar units in the nucleotides of the DNA are the five-carbon monosaccharide deoxyribose unit. There are four nitrogen base compounds, two of which are purine residues and two of which are pyrimadines in structure. The first two base compounds are adenine and guanine. These are each composed of a double ring, making them pyrimadine residues (86). The other base compounds are thymine and cytosine and are composed of a single ring. The abbreviations A, G, T, and C are used to denote adenine, guanine, thymine, and cytosine, respectively (86). The amount of adenine is always equal to the amount of thymine (A=T) because adenine binds with thymine in the double helix structure. The amount of guanine is also equal to the amount of cytosine (G=C) because guanine and cytosine bind together similarly in the formation of the double helix (Matta, Staley and Wilbraham, 748). Every double-ringed base, or purine, must be matched with a single-ringed base, or pyrimadine, on the opposing strand of the double helix (Campbell, 86). This matching of A with T and G with C occurs for a simple biochemical reason; pairing A with T and G with C allows the best fit, allowing the most hydrogen bonds to exist between opposite bases. It is for this reason that the double helical structure is molecularly favored, and why A binds with T and C binds with G**.**

The configuration of these opposing bases, G-C and A-T, permits the double helix structure to experience incredible biochemical stability (87). Furthermore, the configuration of nitrogen bases in any given organism's genetic makeup creates the basis for the variation of physical traits among species as well as within them. The order of these bases determines the genetic make-up of an organism by coding for specific proteins, which in turn create the basis of that organism's physiology. A particular portion of the DNA strand associated with a particular trait, or variant of character, is known as a gene (259). In this sense, the order of the DNA base pairs acts as a blueprint that allows an organism to have the structure that it does and the physiology that it exhibits. The diversity of living organisms is thus evidenced through the diversity of DNA configurations, as composed by an order of base pairs within the double helix structure.

As previously stated, the research of Watson and Crick, among other scientists, allowed for the lucidification of the DNA structure. Once the structure of the DNA molecule was known, the function of this nucleic acid could be understood. Over time, researchers deduced that discreet units along the DNA double helix ultimately encode the proteins that will be produced within the organism. These discreet units, or "codons," are each made up of three consecutive nitrogen bases. If DNA was viewed as a sort of instruction manual for creating proteins, which ultimately affect physiology, each codon would be considered a single word in the text (Campbell, 320). Because the nitrogen bases composing each codon reside on the interior of the double helix, the two strands making up the helix must be "unzipped" by enzymes known as RNA polymerases before each DNA codon can be copied, or "transcribed," into RNA, then to be "translated" into specific proteins (Campbell, 312).

The process of transcription describes how a codon of the original DNA strand can be coded into a complementary codon of messenger RNA (mRNA) (322). Because the complementary bases for C and G are G and C respectively, an mRNA G or C will denote any base in a DNA codon of C or G. The rule of nitrogen base complementarity essentially governs the transcription of each DNA base into an mRNA base (323). Along these lines, thymine (T) in the DNA code will be represented by an adenine (A) in the mRNA sequence. The only irregularity to the usual rule of nitrogen base complmentarity is the substitution of a uracil (U) base pair in mRNA for thymine. For this reason, U represents a DNA adenine when the DNA code is transcribed into mRNA.

Messenger RNA is called by the name "messenger" because it takes the code created by the nitrogen bases in the DNA, inside the cell nucleus, to a place outside the nucleus, to an organelle known as the ribosome (Campbell, 321). Many researchers consider the ribosome the protein production site of the cell. Inside the ribosome, the messenger RNA, a nucleic acid, is translated into a protein. Each codon of mRNA specifies a specific peptide, which can be linked together with other peptides to create a specific protein (325). Through the process of translation, mRNA codons specify the exact order of peptides to be linked together to create a given protein, which in its final form can take on one or several roles within the organism. Proteins can work within the cell to perform structural, storage, transport, hormonal, receptor, contractile, defensive, or enzymatic functions (Campbell, 76). Without the appropriate proteins, an organism could not exist. The diversity and the importance of the roles played by proteins within a cell and the organism itself illustrates the importance of the role of DNA, which acts as the template for each protein produced (76). In many ways, the function of DNA as an ultimate template for proteins is evident from its structure as a double helix composed largely of complementary nitrogen base pairs. Once researchers determined the structure of DNA, they were able to describe its primary function as a sort of instruction manual for every protein to be produced in an organism.

Because DNA is passed from parent to offspring and codes for the fundamental proteins necessary for an organism's creation and survival, DNA is known as the hereditary material of life (Ridley, 8). To understand how genetic inheritance works, the findings of Gregor Mendel, a nineteenth century monk and scientist, are of tremendous importance. Mendel worked with pea plants, and carefully tracked the inheritance of physical traits among pea plants through many generations (Campbell, 259). The scientist only followed the inheritance patterns of categorical variations in the pea plants, which had "either-or" physical traits. Some of these traits included flower color (purple or white), seed color (yellow or green), and seed shape (round or wrinkled) (261). Through his experiments, Mendel came up with a hypothesis that can be broken down into four main points. First, Mendel found that different versions of heritable factors account for variations in inherited characters (note: the "heritable factors" mentioned by Mendel are now known to be genes, thus I will substitute the word "gene" for where Mendel would have said "heritable factor," as he lived before it was known that genes were the medium of inheritance). In modern genetics, these alternative types of a single gene are known as "alleles." Secondly, Mendel found that for each trait an organism inherits two genes, one from each parent. Thirdly, Mendel determined that if two alleles differ from each other, then one, known as the dominant allele, is fully expressed in the organism's appearance; the other allele, known as the recessive allele, has no noticeable influence on the appearance of the organism (261). Finally, Mendel found that two genes for each trait segregate during gamete (ovum or sperm) production. Due to this segregation of genes, an ovum and sperm each receive only one of the genes present in two copies in the body cells of the organism. Mendel's experiments imply that if a plant had two different alleles for a given trait (making it heterozygous for that trait), 50% of its gametes would have the dominant allele and 50% would have the recessive allele due to the segregation of the two genes for each character during gamete production. In the case that the plant had two of the same alleles for a given trait (making it homozygous for that trait), 100% of its gametes would have either that dominant or recessive allele.

Hereditary characteristics are determined by the transmission of coded sequences of base pairs along chromosomes and transmitted to offspring during the process of reproduction (Durham, 40). Because the genetic material of the maternal and paternal gametes is combined to create the complete genetic makeup (or genotype) of the offspring, understanding Mendel's laws of inheritance is key to understanding the manner in which genes, and the physical traits (or phenotype) these genes are associated with, pass from generation to generation. By understanding the relationship between the genotype, phenotype, environment and inheritance, researchers can chart the genetic progress of physical traits across populations of organisms. One manner in which this can be accomplished is through the test cross, commonly known as the "Punnett Square" (263). Basically, the Punnett Square is a useful tool for showing all possible combinations of alleles in offspring. A Punnett Square is designed to show the genotype of an organism that exhibits a dominant or recessive trait, which can be due to a genetic makeup that is either homozygous or heterozygous for the dominant allele, or homozygous for the recessive allele. By using a Punnett Square, scientists can determine the probability of an offspring to inherit a dominant or recessive trait based on the alleles each parent has for that trait (262). Punnett Squares can be used to track the probability of inheriting physical traits as diverse as albinism, determined by a recessive allele, to lethal diseases such as Huntington's disease, which is determined by a dominant allele (274).

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Having deduced the basic functional attributes of the DNA molecule from knowledge of its structural interactions, scientists have since been able to develop technology to help further elucidate the physiological significance of the DNA molecule. DNA technology has led the way for The Human Genome Project, an effort to map the entire human genome. These four approaches have led to success in that endeavor:

1. Genetic (linkage) mapping of the human genome.

2. Physical mapping of the human genome.

3. Sequencing the human genome.

4. Analyzing the genomes of other species.

The potential of genomic information is enormous. In health care, the mapping and identification of genes may lead to diagnosis, treatment, and prevention of genetic diseases. Mapping and identification of so-called "disease genes" may even lead to predicting a person's likelihood of acquiring a disease before they are born. By analyzing the genetic makeup of an individual's parents, medical scientists can determine the probability of that individual inheriting any given physiological trait. This maybe able to help a great deal in preventing the development of fully developed diseases/maladies because early treatment is key in many genetic disorders, and can dramatically reduce the severity of onset (Campbell, 405). In basic science, insight into the fundamental questions of genome organization, control of gene expression, cellular growth and differentiation will be aided by detailed information regarding the human genome as well as those of other species. Researchers from around the world continue to make advances in these areas.

Methods used to build the human genetic map include classical pedigree analysis of large families and a variety of molecular techniques. Using a technique known as chromosome walking, for example, a researcher isolates overlapping DNA segments, which have been obtained by cutting two samples of the original DNA with restriction enzymes. The overlaps between segments show the order in which segments occur in the original DNA and the rough order of any genes or other markers found on the segments. Advances in automation and utilization of the latest electronic technology, including computer software, have significantly increased advancement toward the continuing goals of the Human Genome Project.

Another modern genetic technique that has shown its value in the Human Genome Project is the use of PCR (polymerase chain reaction) amplification (Campbell, 405). PCR can amplify specific portions of DNA to create amounts of genetic material sufficient for study, and then analyze as large a sample as researchers need. Thus, as founded on the frequencies of crossovers between genes, scientists can perform human linkage mapping without needing to locate large families for pedigree analysis (405).

Major advances continue in the diagnosis of human genetic disorders and other diseases as the first applications of gene therapy make enormous contributions to the field of medicine through modern biotechnology. Gene therapy has especially proven its value in the treatment of single-enzyme deficiency diseases such as an immunodeficiency disease that results from a lack of the enzyme adenosine deaminase (ADA) in children (407). In this case, normal genes are introduced into a patient's own body cells; the patient receives intravenous injections of their own T lymphocytes, a type of white blood cell, that have been genetically engineered to carry a normal ADA allele. These applications of genetic technology via genetic engineering have met with success, and it is hoped that further progress will be made in the future of genetic research (407). Scientists further project the potential of genetic technology to influence vaccinations and pharmaceutical products in humans, not to mention agricultural uses of DNA technology including uses in animal husbandry (transgenic animals) and manipulating plant genes to influence desirable plant traits and crop yield, among other factors.

Despite the heady optimism felt by many in regards to the development of genetics to affect humans' everyday life, safety and ethical issues remain a concern. Many of the earliest concerns included the notion that genetic manipulations of microorganisms could create lethal new pathogens (412). More recent ethical concerns have involved the implications of having a complete map of the human genome, including whether it is ethical for a person to examine another individual's genes, whether a person's genome should be a factor in their suitability for a job, and whether insurance companies should have the right to examine an applicant's genetic makeup. Furthermore, insofar as the medical applications of genetic technology are concerned, there is great uncertainty as to the potential for harmful side-effects of genetic medical technology, both long-term and short-term (412). It is for this reason that the FDA requires extensive tests of any genetically engineered medical products in both laboratory animals and humans prior to its general marketing to the public. Another subject of ethical debate includes the selling of genetically engineered agricultural products due to the potential dangers of introducing new organisms into the environment. Currently, the FDA holds that if the result of genetic engineering is not markedly different from an agricultural product already on the market, further testing of the product is not required (412)

Objectives

During the course of a school year, this unit will be used to supplement curricular information on DNA, the chemistry of DNA, genetics, and scientific applications of this knowledge base to uses in society and associated ethical/safety choices. Pittsburgh Public School standards that will be addressed for secondary science students are many. For instance, students will need to explain how scientific principles of chemical and biological phenomena have developed and relate them to real-world situations. Students will also demonstrate knowledge of basic concepts and principles of chemical and biological sciences, and use and master materials, tools and processes of major technologies, which are applied in economic and civic life. Furthermore, students will explain the relationships among science, technology, and society, as well as construct and evaluate scientific and technological systems using models to explain and predict results. Students will also develop and apply skills of observation, data collection, analysis, pattern recognition, prediction, and scientific reasoning in designing and conducting experiments and solving technological problems. Finally, students will actively participate in evaluating the advantages, disadvantages and ethical implications associated with the impact of science and technology on past, current, and future life.

The above standards will be incorporated into this unit of study by providing students with the opportunity to construct a model of a segment of a DNA molecule, analyzing and discussing the chemistry involved. In the same activity, students will learn of the dynamic relationship between the structure and function of DNA. Students will also participate in several interactive website activities designed to encompass the most cutting-edge genetic discoveries and research, including understanding genes and gene testing and the questions involved in genetic disorders such as sickle cell anemia. Furthermore, students will investigate the nature of genetic inheritance by participating in an experiment that emphasizes the use of Punnett Squares and pedigree analysis to predict the heritability of a given trait. Finally, students will research an ethical/safety question posed during the unit using a variety of online scientific resources. Students will make an oral presentation of their issue, provide data to support their position, and entertain questions from classmates.

Strategies

The activities in this unit are designed to be taught either in sequence, as a supplement to your standard curriculum, or as individual activities that support the treatment of specific concepts in biology or chemistry. The activities are designed to offer students the opportunity to participate in active, collaborative, and inquiry-based learning. Students will be involved actively in the use of web-based learning. Ideally, one computer with Internet access for each student team will provide optimal access to the interactive displays, animations, and videos available.

The following interactive web-based site provides a motivational introduction to DNA, gene testing, the Human Genome Project, and related issues providing an excellent background of information and a thoughtful counter-balancing of ethical issues:http://rex.nci.nih.gov/patients/info_teacher/gene_testing.html. An accompanying worksheet for information synthesis is included in the Appendix.

Students will also experience an activity in which plastic pop-beads of rainbow colors are used to build the DNA double helix, with specific colors of beads signifying the sugar/phosphate backbone and the four nitrogen bases (A, C, T, G). This activity will work to familiarize students with the structure of DNA through interaction. The manner in which the structure of the DNA double helix influences its function will be further emphasized by having the students unzip the DNA double helix they created, and mimic the transcription process by using beads that represent mRNA. Similarly, the students will mimic the process of translation using the beads, ultimately to produce. This activity will help students fully understand the relevance of DNA's structure to its function as the hereditary material of life.

Students will also perform a Punnett Square activity to help familiarize them with the most basic and fundamental methods used to determine patterns of heredity and Mendelian inheritance for various traits. Using differently colored bingo chips to represent different alleles, students will have a highly visual manner in which to learn about the probabilities associated with genetic inheritance, as well model several single-gene traits.

Use of an interactive website for exploration of Human Genetic Variation culminates student learning providing a powerful tool for understanding a basic set of scientific principles related to human genetic variation, experiencing the process of inquiry and developing an understanding of the nature and methods of science, and recognizing the relationship between basic science, personal and public health, and the society. Classroom use of the following website as a supplement to the standard curriculum with one or more lessons, or as an integrated whole, will lead to a deeper understanding and integration of science in application to human variations, genetic variation at a molecular level and its practical value, genetic and environmental factors in multifactorial diseases, and making decisions in uncertain circumstances in view of biological research can be found at: http://science-education.nih.gov /scupplements/nih1/genetic /content/guide/module1.htm. This web-based series of activities includes worksheets, complete lesson plans, and extensive background information. It nicely culminates a supplementary study of genetics tying together basic scientific skills, information, and ethical issues as they relate to personal and public health within our society.

Classroom Activities

Lesson # 1

This is a web-based activity that necessitates access to an internet connected computer for use with student teams of two or more depending upon computer availability. If only one computer with internet access is available, you can use the web site by using a suitable display device to show the slide show to the entire class or by rotating teams through a computer station to access internet-based resources.

The objective for this activity is increasing the knowledge base of students relative to genes and gene testing. It includes graphics illustrating key concepts and relevant issues. Introduce students to the computer lab activity by issuing them a laptop computer from the class set (a computer lab with computers for each student can also be used). Write the web address onto the chalkboard so that the students can type it and go to the site. The address to be used is: http://rex.nci.nih.gov/PATIENTS/INFO_TEACHER/gene testing/Title.html. Provide students with background information regarding the National Institute of Health from their informational website: http://science-education.nih.gov/ supplements/nih1/genetic/

> "The National Institutes of Health (NIH), the world's top medical research center, is charged with addressing the health concerns of the nation. The NIH is the largest U.S. governmental sponsor of health studies conducted nationwide.
>
> Simply described, the NIH's goal is to acquire new knowledge to help prevent, detect, diagnose, and treat disease and disability, from the rarest genetic disorder to the common cold. The NIH works toward that goal by conducting research in its own laboratories in Bethesda, Maryland, and at several other locations throughout the United States; supporting the research of nonfederal scientists throughout the country and abroad; helping to train research investigators; and fostering communication of medical information to the public."

Students will then be given the activity worksheet to direct them in their search for the appropriate information as they proceed through the site (see Appendix A). Following completion of the web-based activity, lead the students in a discussion of each question, answers they've chosen, and future questions they would like to research regarding genes and gene testing. Create a large list of "Questions to be Considered" on a large sheet of poster board to remain posted in the classroom throughout the supplemental unit of activities. Plan to add new questions raised as the unit progresses and revisit these issues at the close of the unit, discussing new information relative to each question presented, additional questions to be investigated, and closing remarks.

Lesson # 2: The Structure and Function of DNA.

In this activity, students will be able to experience the relationship between the structure and function of the DNA molecule in a very hands-on way. Using plastic beads that pop together, students can build the double helical structure of the DNA molecule, including the phosphate and sugar backbone and the nitrogen bases. Different colors of dull beads will be used for each discreet type of molecule composing the helix; red for phosphate, blue for the deoxyribose sugar, and pink, green, purple and yellow for the nitrogen base pairs of the helix, respectively, adenine, guanine, cytosine and thymine. Prior to the students' participation in this exercise, the teacher should write the color key on the blackboard so that the students may easily remember which color represents which molecule within the DNA structure. The students will thereby be actively engaged in learning the structure of the DNA molecule, including the manner in which complementary base pairing occurs between A and T, and C and G. Students will be encouraged to use pre-arranged DNA base pair sequences that represent actual human codons on the template strand of the DNA, such as the sequence "TACCTACAATAGAG TAATATT." When the students have successfully created their double helix structure, they will be shown how to twist their ladder-shaped structures to resemble the helical shape of the true DNA polypeptide.

Having actively used their understanding of DNA structure to create a model of the DNA polypeptide, students will next be asked to "unwind and unzip" their strands as RNA polymerase would unzip the DNA prior to the transcription process. This will mainly involve unwinding the flexible beaded structure that the students had previously twisted into a double helix, and unpopping the nitrogen base pairs from their complements. At this point, the students should be given new beads, which differ in their appearance from the earlier nitrogen bases used in the sense that the new beads have a pearly appearance rather than dull. These beads will represent the mRNA nitrogen bases, which complementarily replicate the nitrogen base code on the coding strand of the DNA molecule. Again, pink, green, purple and yellow beads will be used to represent the bases, this time corresponding to adenine, guanine, cytosine and uracil, which is the mRNA substitute for thymine. Then, students will each be given two strings of yarn, and asked to encompass one around the unzipped DNA fragment, and to create of the other a circle on the other side of the desk. They should be informed that the yarn circle around the DNA fragment represents the cell nucleus that contains the DNA, and that the other yarn circle represents the ribosome, an organelle beyond the nucleus where protein production via translation takes place.

Students should next be encouraged to initiate the process of translation by moving their strand of mRNA from the nucleus and taking it to the circle of yarn representing the ribosome. In the ribosome, students should be reminded that the mRNA sequence is read in triplets, or codons, beginning with the start codon, or AUG mRNA sequence. On the blackboard, the teacher should write the peptides for which each mRNA codon encodes—AUG the start codon or coding for Met, GAU for Asp, GUU for Val, AUC for Ile, UCA for Ser, UUA for Leu and UAA as the stop codon. Students will then be given beads in different shapes to represent these different peptides, which would be linked together within the ribosome to form a finished protein, organized according to the original DNA sequence of nitrogen bases.

By simulating the structure of DNA and the activities involved in transcription and translation, this lesson aims to familiarize students in-depth with the basic structural and functional aspects of the DNA molecule.

Lesson # 3: The Punnett Square and Mendelian Inheritance.

In this lesson, students will be given square pieces of cardboard with a grid of sixteen boxes drawn on each piece. Also to be handed out will be the plastic chips used frequently in the playing of bingo—each student will receive twenty green chips, twenty blue chips, twenty red chips and twenty pink chips. Each chip represents a different allele involved in the inheritance of coat color that occurs when two mice mate.

The premise of the experiment, to be explained by the teacher, is that there are two parent mice, both of black coat color. The parent mice are heterozygous for two genes, the B gene and the C gene, which assort independently of each other. One gene determines whether the mouse's coat will be black (dominant, B) or brown (recessive, b). In terms of the plastic chips, the green chip represents the B allele while the blue chip represents the b allele. The second gene controls whether or not pigment of any color will be deposited in the hair, with the allele for the presence of color (C, dominant) and the allele for the absence of color (c), the cc genotype meaning that the coat is albino regardless of the genotype for the black/brown genetic locus. In terms of the plastic chips, a pink chip represents the C allele, whereas the red chip represents c.

Because the parent mice are both heterozygous for the B and C genes, they will have genotypes of BbCc, represented each by green, blue, pink and red chip. Having been taught a supplemental lesson on the principles and significance of Punnett Squares in determining Mendelian inheritance patterns, students will be asked to predict, using their plastic chips as representations of the alleles on their Punnett Squares, the ratios of the total offspring that can be expected to have albino, brown, and black coat colors. By first determining the possible allelic combinations in each mouse parent's gametes (one ova, one sperm), students will be able to perform a test cross to determine the probability of the mice having offspring of each coat color. Ultimately, students will be able to determine that there is a 25% likelihood that offspring will be albino, 56% probability that the offspring will have a black coat, and a 19% likelihood that the offspring will have a brown coat phenotype.

By participating in this classroom activity, students will have a very visual, interactive understanding of the test cross technique for determining inheritance, broadening their comprehension of classic Mendelian methods of genetic analysis.

Lessons #4 through #8

Hands on activities involving available laptop computers are interactive in nature and highly motivational to students. Reinforcing the concepts of DNA, gene mutations, disease, and other concepts can be assessed through the Carolina webpage for classroom activities in genetics (http://www.carolina.com/how_do_I/classroom_activities.asp) and the National Institute of Health website for science educators (http://science-education.nih.gov/ customers.nsf/ highschool.htm).

Through the curriculum supplement designed specifically for grades nine through twelve, use of the unit, "Human Genetic Variation" will provide a "study of the basics of human genetics, its potential to improve human health, and its application towards understanding and describing human evolution."

In the classroom, allow students to join into groups of two or more as needed to access available computers. Instruct students to locate the website listed above. Beginning with Lesson 4, *Alike, But Not the Same*, connections between past and present learning experiences are linked with anticipation of upcoming activities. Students are given a worksheet downloadable from the website for engaging in the topic of human genetic variation. Students are instructed to stand with one volunteer following along a set of human traits such as detached earlobes, middigital hair, and hitchhiker's thumb (each trait specifically defined). As the volunteer gives his/her response to each question, only those students sharing the same trait may remain standing. By the end of the list, the student volunteer is expected to be the only one standing, demonstrating the differences between individuals along such traits. Students may work in pairs to complete their worksheets, or additional group volunteers may proceed in like manner. Following the Teacher's Guide presented online for this activity, proceed through lesson extensions if desired and time permitting.

On each subsequent day, proceed through:

Activity 5: *The Meaning of Genetic Variation*, where students investigate variation in the beta globin gene as it relates to sickle cell anemia.

Activity 6: Molecular Medicine Comes of Age, allowing students to assume the role of two fictional pharmaceutical companies to discover medical benefits of understanding variation at a molecular level.

Activity 7: *Are You Susceptible?* Students explore the relationship between genetic variation and environmental factors in the onset of heart disease.

Activity 8: *Making Decisions in the Face of Uncertainty*. Students analyze a family's decisions about testing for variants of genes that increase susceptibility to breast cancer and consider personal and social implications of genetic testing.

Lesson #9: Reflections on Genetics

Return to the student-generated questions posted throughout the duration of the unit on topics covered. Read each question, discuss subsequent learning, opinions, and results of investigations. Upon completion of the process for student-generated questions, ask students if any additional or new inquiries come to mind for future investigation. List each of these issues on a fresh sheet of poster board titled, "Future Topics of Interest." Encourage students to visit more advanced genetics websites, such as "Chime Resources" (Martz, 2002), "Your Genes, Your Choices" (http://ehrweb.aaas.org/her/books/content.html), and Carolina's "Protein Explorer" (wysiwyg://65/http://www.umass.edu/microbio/chime/explorer/index.html).

Allow students to post dated news articles, websites, and printed information from a variety of resources on, or around, the "Topics of Interest: Genes" title. Revisit the topic, and area, as appropriate throughout the school year.

Works Cited

Campbell, Neil A. Biology. 3rd ed. California: The Benjamin/Cummings Publishing

Company, Inc., 1993.

This is an introductory textbook to a plethora of biological subjects, including many fundamental genetic concepts including DNA structure and function, Mendelian genetics, and modern genetic techniques.

"Classroom Resources." Carolina World-Class support for Science & Math. Website.

May 20 2002 <wysiwyg://74/http://www.Carolina.com/biotech/Default.as. html>

As the website for Carolina Scientific, this page offers a plethora of links under the heading of "Classroom Resources," which allow teachers and students to explore many aspects of biotechnology as it relates to genetic material.

Durham, William H. Coevolution: Genes, Culture, and Human Diversity. California:

Stanford University Press, 1991.

A more advanced book regarding the relationships between genes, the diverse phenotypes they produce, and theories regarding how human culture is affected by the complexity of phenotypes.

"FrontDoor to Protein Explorer 1.901 Beta." ProteinExplorer.org, National Science Foundation. Database. May 20 2002 <wysiwyg://65/http://www.umass.edu/ microbio/chime/explorer/index.html>

This website, sponsored by the National Science Foundation, is a good resource for educators and students who wish to explore the complex relationship between DNA and proteins. Among other things, this website provides a tutorial regarding how to use it effectively and lesson plans.

Martz, Eric. "Chime Resources." Chime Resources at Umass. May 20 2002 <http://www.umass.edu/microbio/chime.html>

This webpage provides a long list of links that allows the user to explore multiple aspects of chime, as well as offering tutorials to help beginners understand the fundamentals of chime.

Matta, Michael S., Staley, Dennis D., and Wilbraham, Antony C. Chemistry. United States of America: Addison-Wesley Publishing Company, Inc., 1997.

This is a basic introductory chemistry textbook, containing a section on the chemistry of nucleic acids and specifically, DNA structure.

Ridley, Matt. Genome: The Autobiography of a Species in 23 Chapters. New York: Perennial, 2000.

This is a detailed discussion regarding the most interesting genes located on each of the human chromosomes, thus spanning the complete human genome.

Science Education, National Institutes of Health. April 25 2002. <http://science-

______ education.nih.gov/customers.nsf/highschool.htm.>.

This database was incredibly helpful in understanding the basic principles behind human genetic variation, as well as in brainstorming activities that students might be able to use in class to help them more fully understand genetic concepts.

"Understanding Gene Testing." Online Database. National Institutes of Health. April 25 2002 <http://rex.nci.nih.gov/PATIENTS/INFO_TEACHER/Gene_testing/Title.html>

This online database provides an interactive program for teachers and students to improve their understanding of gene testing.

"Your Genes, Your Choices." Online Database, Table of Contents. May 20 2002 <http://ehrweb.aaas.org/ehr/books/contents.html>

This site lists different topics relating to how findings in genetics can affect modern, everyday life. By using realistic narrative stories, this webpage raises important questions in an interesting way regarding the ethics of applying DNA technology.

Reading List for Students

Ridley, Matt. Genome: The Autobiography of a Species in 23 Chapters. New York: Perennial, 2000.

This national bestseller provides a detailed discussion regarding the most interesting genes located on each of the human chromosomes, thus spanning the complete human genome. It reads like a natural history of the human genome and provides many insights into the different chromosomes and the state of human genetics.

“Understanding Gene Testing.” Online Database. National Institutes of Health. April 25 2002 <http://rex.nci.nih.gov/PATIENTS/INFO_TEACHER/Gene_testing/Title.html

This online database provides an interactive program for teachers and students to improve their understanding of gene testing.

“Understanding Human Genetic Variation: Teacher’s Guide.” Online Database. Science Education, National Institutes of Health. April 25 2002. http://science-education.nih.gov/customers.nsf/highschool.htm.

This database was incredibly helpful in understanding the basic principles behind human genetic variation, as well as in brainstorming activities that students might be able to use in class to help them more fully understand genetic concepts.

Appendix-Content Standards

The Pittsburgh Public School standards that will be addressed for secondary science students include:

(1) Students explain how scientific principles of chemical and biological phenomena have developed and relate them to real-world situations

(2) Students demonstrate knowledge of basic concepts and principles of chemical and biological sciences

(3) Students use and master materials, tools and processes of major technologies, which are applied in economic and civic life

(4) Students explain the relationships among science, technology, and society

(5) Students construct and evaluate scientific and technological systems using models to explain and predict results

(6) Students develop and apply skills of observation, data collection, analysis, pattern recognition, prediction, and scientific reasoning in designing and conducting experiments and solving technological problems

(7) Students evaluate advantages, disadvantages and ethical implications associated with the impact of science and technology on current and future life.