

Genetic Variation & Human Health Contents

Overview	2
Activities Preview	3
California Science State Standards	5
National Science Education Standards	7
Teacher Notes	
Activity One: Genetics Preconceptions: Genetics or Not?.....	9
Activity Two: DNA Model.....	16
Activity Three: Differences Matter.....	20
Activity Four: Are Those My Chromosomes?.....	28
Activity Five: Sesame Street Genetics.....	35
Activity Six: Making Proteins and Mutations.....	41
Activity Seven: Mutation Challenge.....	46
Activity Eight: Genetic Applications and Ethical Issues.....	49
Student Notes	
Activity One: Genetics or Not?	52
Activity Two: DNA Model.....	53
Activity Three: Differences Matter.....	54
Activity Four: Are Those My Chromosomes?.....	56
Activity Five: Sesame Street Genetics.....	64
Activity Six: Making Proteins and Mutations.....	72
Activity Seven: Mutation Challenge.....	78
Activity Eight: Genetic Applications and Ethical Issues.....	79

Genetic Variation & Human Health Overview

The goal of this unit is to introduce the fundamentals of genetics to middle school students as well as provide them with the experiences necessary to appreciate and evaluate emerging genetic technology. Because genetics is an abstract science, it is also a goal to introduce genetic concepts in a tangible, active way through inquiry and a design challenge format. The **big picture** ideas that are being attempted here are the following:

- Biological systems copy themselves by virtue of a code within the molecule DNA. Some regions of DNA are known genes that code for proteins. Other regions of DNA are called non-coding because they do not appear to contain genes or they may have functions not yet understood.
- DNA is broken down into 23 pairs of chromosomes. There are mostly two copies of chromosomes (exceptions: XY in males, mitochondrial chromosomes) in all our cells, except gametes (eggs and sperm), which have one copy. Each chromosome contains genes. Genes regulate the expression of traits in an organism. Trait expression is more often regulated by multiple genes rather than one gene. The genes that regulate a trait do not necessarily exist on the same chromosome. Genes regulate traits through the production of proteins. For example, eye and hair color are produced by different levels of the pigment *melanin* being turned on or off by multiple genes.
- Traits are inherited from parents and varied through the processes of recombination and mutation.
- Genetic variation is important for the survival of a species. Through recombination and sexual reproduction, offspring will be more genetically diverse. In terms of long-term survival of a species, genetic diversity improves the chance a species population will withstand environmental changes that might otherwise lead to extinction of that species.
- Applied genetics is being used to improve human health in medicine, nutrition and agriculture. Along with its benefits there are ethical implications.

Genetic Variation & Human Health Activities Preview

Activity One: Genetics Preconceptions: Genetics or Not?

Introduce genetics through tabloid-related articles in order to flush out genetic preconceptions as they relate to heredity, DNA, proteins, mutations, disease.

Timeline: 1-2 fifty-minute periods

Activity Two: DNA Model

Students construct their idea of a DNA model using a variety of building materials. The goal is to design a molecule that can copy itself by use of a code. Additionally, students will switch DNA models, attempt to build that DNA model and make copies within a time constraint thus increasing the potential for mistakes/mutations. This activity will also introduce the process that scientists (namely Watson, Crick, Franklin) went through to determine the DNA molecular structure and function, information we often times take for granted. This activity culminates with students investigating the replication of DNA through web activities.

Timeline: 2 fifty-minute periods

Activity Three: Differences Matter

Students determine their own phenotypic traits to determine their possible genotypes for those traits. They use a *human genetic wheel* to compare their genetic number with their peers' numbers. The genetic wheel activity relates the genetic variation within the student class population and the advantages of having genetic variation within a population. A demonstration, *Does Sex Matter?* uses student participation and vegetables to convey the importance of sexual reproduction in maintaining diverse species populations.

Timeline: 1 fifty-minute period

Activity Four: Are Those My Chromosomes?

Students build pipe cleaner chromosomes in order to carry out genetic crosses for eye and hair color. The use of a Punnett square is introduced along with probabilities of genotypes and phenotypes of offspring from parent crosses. This activity will give students a better idea of the complexities of heredity by introducing the idea that multiple genes regulate eye and hair color.

Timeline: 2-3 fifty-minute periods

Activity Five: Sesame Street Meiosis

Students use Sesame Street dolls in this activity. They determine the phenotype and genotype of a specific character. Using *Tinker Toys* to represent chromosomes, students carry out the process of meiosis (which includes the chance of recombination events) using the determined genotype of their Sesame Street character. After determining the gametes (eggs or sperm) that that individual produces, students choose another Sesame Street character with whom to have offspring.

Timeline: 2 fifty-minute periods

Activity Six: Making Proteins and Mutations: Students learn what proteins are and how they are made using colored blocks to model protein synthesis. Students introduce different mutation types (point, insertion, deletion) as they carry out protein synthesis in order to see how each mutation affects the protein being made. Additionally, students compare the beta globin gene of two individuals in order to estimate the percentage of genetic variation between any two individuals, also, taking a closer look at where the beta globin gene sequence differs and if the differences have an impact on one of the individuals. One of the individuals has a beta globin gene sequence that correlates with sickle cell anemia. Students investigate the cause, symptoms and heredity of sickle cell anemia along with its potential for malaria resistance.

Timeline: 2-3 fifty-minute periods

Activity Seven: Mutation Challenge: Student teams design and build models simulating how mutations occur. Their designs include random processes that produce mutations. Additionally, students consider the mutation type (point, insertion, deletion), its rate, whether it is beneficial, harmful or neutral and if there are selective pressures for or against it. If selective pressures affect their mutations, they describe the selective pressures and how they affect the organism and its population. An introductory activity called *When Milk Makes You Sick* can be used to review selective pressures by investigating how the mutation for lactose tolerance has been selected for historically.

Timeline: 2-3 fifty-minute periods

Activity Eight: Genetic Applications & Ethical Issues: Students apply their genetic knowledge by carrying out one of four laboratory exercises: *DNA Fingerprinting*, *pGlo Transformation*, *Alu PCR Amplification* or *GFP Purification*. After completing one of the above labs, students read current articles related to genetic applications from various sources. Article topics include gene chip technology, forensics, evolutionary history, disease and pathogens, and cloning. Through student-generated discussion, the ethical implications for the use of genetic applications are considered. In a culminating activity, students use creative means of expressing what the genetics for the future might be.

Timeline: 3 fifty-minute periods

Correlation to the California Science State Standards: Grade Seven

Genetics	
2. A typical cell of any organism contains genetic instructions that specify its traits. Those traits may be modified by environmental influences. As a basis for understanding this concept:	Correlation to Genetic Variation & Human Health
a. Students know the differences between the life cycles and reproduction methods of sexual and asexual organisms.	Activity 3
b. Students know sexual reproduction produces offspring that inherit half their genes from each parent	Activity 3, 4, 5
c. Students know an inherited trait can be determined by one or more genes.	Activity 3, 4, 5, 6, 8
d. Students know plant and animal cells contain many thousands of different genes and typically have two copies of every gene. The two copies (or alleles) of the gene may or may not be identical, and one may be dominant in determining the phenotype while the other is recessive.	Activity 3, 4, 5, 6, 8
e. Students know DNA (deoxyribonucleic acid) is the genetic material of living organisms and is located in the chromosomes of each cell.	Activity 2, 4, 5, 6, 7, 8
Evolution	
3. Biological evolution accounts for the diversity of species developed through gradual processes over many generations. As a basis for understanding this concept:	Correlation to Genetic Variation & Human Health
3.1 Students know both genetic variation and environmental factors are causes of evolution and diversity of organisms.	Activity 3, 4, 5, 6, 7, 8
3.5 Students know that extinction of a species occurs when the environment changes and the adaptive characteristics of a species are insufficient for its survival.	Activity 3, 6, 7, 8
Structure and Function in Living Systems	
5. The anatomy and physiology of plants and animals illustrate the complementary nature of structure and function. As a basis for understanding this concept:	Correlation to Genetic Variation & Human Health
d. Students know how the reproductive organs of the human female and male generate eggs and sperm and how sexual activity may lead to fertilization and pregnancy.	Activity 4, 5

Investigation and Experimentation	
<p>7. Scientific progress is made by asking meaningful questions and conducting careful investigations. As a basis for understanding this concept and addressing the content in the other three strands, students should develop their own questions and perform investigations. Students will:</p>	<p>Correlation to Genetic Variation & Human Health</p>
<p>a. Select and use appropriate tools and technology (including calculators, computers, balances, spring scales, microscopes, and binoculars) to perform tests, collect data, and display data.</p> <p>b. Use a variety of print and electronic resources (including the World Wide Web) to collect information and evidence as part of a research project.</p> <p>c. Communicate the logical connection among hypotheses, science concepts, tests conducted, data collected, and conclusions drawn from the scientific evidence.</p> <p>d. Construct scale models, maps, and appropriately labeled diagrams to communicate scientific knowledge (e.g., motion of Earth's plates and cell structure).</p> <p>e. Communicate the steps and results from an investigation in written reports and oral presentations.</p>	<p>Activity 2, 3, 4, 5, 7</p> <p>Activity 6, 7</p> <p>Activity 1, 4, 5, 7</p> <p>Activity 1, 2, 3, 4, 5, 7</p> <p>Activity 2, 4, 5, 7</p>

Correlation to the National Science Education Standards: Grades 5-8

<p>Content Standard A: As a result of activities in grades 5-8, all students should develop abilities necessary to do scientific inquiry and understandings about scientific inquiry.</p>	<p>Correlation to Genetic Variation & Human Health</p>
<ul style="list-style-type: none"> • Identify questions that can be answered through scientific investigations • Use appropriate tools and techniques to gather, analyze and interpret data • Develop descriptions, explanations, predictions, and models using evidence • Think critically and logically to make the relationships between evidence and explanations • Recognize and analyze alternative explanations and predictions • Communicate scientific procedures and explanations • Use mathematics in all aspects of scientific inquiry 	<p>Activity 7, 8</p> <p>Activity 2, 4, 5, 7, 8</p> <p>Activity 2, 4, 5, 7, 8</p> <p>Activity 1, 2, 3, 4, 5, 7, 8</p> <p>Activity 1, 2, 7, 8</p> <p>Activity 4, 5, 7, 8</p> <p>Activity 4, 5, 7</p>
<p>Concept Standard C: All students should develop understanding of reproduction and heredity and diversity and adaptations of organisms.</p>	<p>Correlation to Genetic Variation & Human Health</p>
<ul style="list-style-type: none"> • Reproduction is a characteristic of all living systems • In many species, including humans, females produce eggs and males produce sperm • Every organism requires a set of instructions for specifying its traits • Hereditary information is contained in genes, located in the chromosomes of each cell • The characteristics of an organism can be described in terms of a combination of traits • Biological evolution accounts for the diversity of species developed through gradual processes over many generations • Extinction of a species occurs when the environment changes and the adaptive characteristics of a species are insufficient to allow its survival 	<p>Activity 4, 5</p> <p>Activity 4, 5</p> <p>Activity 2, 4, 5, 8</p> <p>Activity 3, 4, 5, 6, 8</p> <p>Activity 3, 4, 5, 8</p> <p>Activity 3, 6, 7, 8</p> <p>Activity 3, 6, 7, 8</p>
<p>Content Standard E: All students should develop abilities of technological design and understandings about science and technology.</p>	<p>Correlation to Genetic Variation & Human Health</p>
<ul style="list-style-type: none"> • Identify appropriate problems for technological design • Design a solution or product • Implement a proposed design • Evaluate completed technological designs and products • Communicate the process of technological design • Scientific inquiry and technological design have similarities and differences • Science and technology are reciprocal • Perfectly designed solutions do not exist 	<p>Activity 7</p> <p>Activity 2, 7</p> <p>Activity 2, 7</p> <p>Activity 2, 7</p> <p>Activity 2, 7</p> <p>Activity 7</p> <p>Activity 7</p> <p>Activity 7</p>

<ul style="list-style-type: none"> • Technological designs have constraints • Technological solutions have intended benefits and unintended consequences 	<p>Activity 7, 8 Activity 7, 8</p>
<p>Content Standard F: All students should develop understanding of personal health, populations, resources and environments, natural hazards, risks and benefits and science and technology in society.</p>	<p>Correlation to Genetic Variation & Human Health</p>
<ul style="list-style-type: none"> • Science influences society through its knowledge and world view • Societal challenges often inspire questions for scientific research and social priorities often influence research priorities through the availability of funding for research • Technology influences society through its products and processes • Science and technology have advanced through contributions of many different people, in different cultures, at different times in history • Scientists and engineers have ethical codes requiring that human subjects involved with research be fully informed about risks and benefits associated with the research before the individuals choose to participate • Science cannot answer all questions and technology cannot solve all human problems or meet all human needs 	<p>Activity 8 Activity 8 Activity 8 Activity 8 Activity 8</p>
<p>Content Standard G: All students should develop understanding of science as a human endeavor, the nature of science, and the history of science.</p>	<p>Correlation to Genetic Variation & Human Health</p>
<ul style="list-style-type: none"> • Scientists formulate and test their explanations of nature using observation, experiments, and theoretical and mathematical models • In areas where active research is being pursued and in which there is not a great deal of experimental or observational evidence and understanding, it is normal for scientists to differ with one another about the interpretation of the evidence or theory being considered • It is part of scientific inquiry to evaluate the results of scientific investigations, experiments, observations, theoretical models and the explanations proposed by other scientists • Many individuals have contributed to the traditions of science • Tracing the history of science can show how difficult it was for scientific innovators to break through the accepted ideas of their time to reach the conclusions that we currently take for granted 	<p>Activity 2, 4, 5, 8 Activity 2, 8 Activity 1, 2, 8 Activity 2, 8 Activity 2, 8</p>

Activity One: Genetics Preconceptions: Genetics or Not? Teacher Notes

Focus: Introduce genetics through tabloid, newspaper and magazine articles in order to find out what students already know about genetics and flush out genetic preconceptions as they relate to what DNA is and its function, what genes are and how they are inherited, what mutations are and what causes them, and how genetics can cause disease.

Objectives: After completing this activity, students will

- recognize what they already know about genetics or think they know
- recognize what preconceptions they may have about genetics
- be able to use a concept map to organize their ideas about genetics
- understand that some of their questions or preconceptions will be addressed in this unit
- review what science is and is not

Prerequisite Knowledge: Students should have a good foundation in the nature of science, namely as it applies to what science is and is not. See attached handout on what science is and is not from the *ENSI/SENSI* website <http://www.indiana.edu/~ensiweb/home.html> . This site is a good resource for lessons on the nature of science.

Additionally, students should have some experience using concept maps. Most likely they have used these in math or english. *The Graphic Organizer* website defines concept maps, suggests how they can be used and has examples of concept maps for different age levels. Go to <http://www.graphic.org>. Search the *Index*, *Concept Mapping References* and/or the *Concept Maps*.

Materials and Preparation: You will need to prepare the following materials before conducting this activity:

- Articles related to genetics or DNA from Weekly World News <http://www.weeklyworldnews.com> or National Enquirer <http://www.nationalenquirer.com> or any other tabloid publication. Many of the articles can be taken directly from the web. Go to *Story Archives* and do a search. Newspapers and magazines (i.e.: Glamour, Elle, Men's Fitness) may also have articles on health-related claims that are misleading. Make 3 copies of each article: 1 copy for each student in a group.
- Genetics or Not? Student Guidelines: make one copy per student
- Large Newsprint: One sheet per student group & one sheet for class final ideas to remain posted
- Post-it Notes: One pad per student group
- Bold Colored Pens

Procedure

1. Introduce the activity by telling students there have been some recent major breakthroughs in genetics. You want to know what they think about these new breakthroughs. Tell them you will be giving each one of them a science article on these genetic discoveries. It is up to each of them to explain to the class how each new discovery will affect humankind.
2. Give each student a copy of Genetics or Not? Student Guidelines. Ask individual students to read their assigned articles and record their thoughts on the following:
 - Explain how your article relates to what you know about DNA and genetics (why you have blue eyes, brown hair).
 - Does your article make sense to you as it relates to DNA and genetics? Why or why not?

3. After individual students have finished reading their articles, place students with the same article in a group. Student groups with the same article share their responses with each other.
4. Tell students they will be creating a concept map, using their article to generate ideas about genetics. Give each group a large piece of newsprint and a pad of post-it notes. Tell them to write the terms for their concept map on the post-it notes so that they can move them around as they discuss their connections to genetics. When they have made final decisions on where the terms will go, then they will write the terms with colored pens on the newsprint.

Depending on their prior experiences with concept maps, you may have to help them get started. Suggest they put the term *genetics* in the center or on top of the page. Use terms from the article or terms of which they are already familiar to connect to the term genetics. See the article ***Using Concept Maps in the Science Classroom*** from the NSTA website. Look at the middle school journal *Science Scope* archives or go to this link:

http://www.nsta.org/main/news/stories/science_scope.php?new_story_ID=50627

5. Ask student groups to record their responses to the questions on the back of their concept maps. Tell them they will be presenting their maps and genetic information to the class.

- Title of article
 - What was the article about?
 - How did the article relate to genetics and/or DNA?
 - Does it make sense scientifically?
 - On what ideas did your group members agree?
 - On what ideas did your group members disagree?
 - What was your group unsure or confused about?
 - What additional information did your group need as it relates to the article topic?
6. **Ask students what they learned from other group's concept maps. Did any of their ideas about genetics change?** Record their responses on a large piece of newsprint. This list should include all ideas regardless of whether they are accurate or inaccurate. Keep this displayed throughout this unit. Revisit it as the unit is covered, clarifying whether the conception is accurate or inaccurate. Cross off the misconceptions as you do the unit, with student involvement and agreement.

Extension Ideas: Use articles related to genetics from reliable sources that debunk pseudoscience claims. Examples include: ***Skeptical Inquirer*** <http://www.csicop.org/si> , ***The Skeptic*** <http://www.skeptic.org.uk>, and ***Bad Science*** <http://www.ems.psu.edu/~fraser/BadScience.html> .

These are ways of checking for understanding at the **end of this unit**:

- Have students write their own tabloid genetics articles at the end of the unit, then critique each other's articles for accuracy and creativity as they relate to genetics.
- Give students different genetics articles without their sources indicated, mixing in real published science and tabloid science. Students decide what is real science and what is pseudoscience.

Assessment: Students will be assessed on the completion of their concept maps and thoughtful responses to the questions as they relate to their concept maps.

References: for this activity include:

- Bad Science [Online]. Available <http://www.ems.psu.edu/~fraser/BadScience.html>
- Evolution and the Nature of Science Institutes [Online]. Available <http://www.indiana.edu/~ensiweb/home.html>
- National Enquirer [Online]. Available <http://www.nationalenquirer.com>
- Skeptical Inquirer [Online]. Available <http://www.csicop.org/si>
- The Graphic Organizer [Online]. Available <http://www.graphic.org>
- The Skeptic [Online]. Available <http://www.skeptic.org.uk>
- Vanides, J., Yin, Y., Tomita, M., Ruiz-Primo, M.A. 2005, July. Using Concept Maps in the Science Classroom. *Science Scope*: 27-31.
- Weekly World News [Online]. Available <http://www.weeklyworldnews.com>

What Science IS

So, what IS science? It has been defined many ways, and its meaning has changed with time. Like many words, "science" has more than one proper use, and the word can also be misused. In its most fundamental sense, modern science is a **process** by which we try to **understand how the natural world works** and how it came to be that way. It is NOT a process for merely collecting "facts" about, or just describing, the natural world, although such observations do provide the raw material for scientific understanding.

As a process, certain **rules** must be followed, but there is NO one "scientific method", contrary to its popular treatment in textbooks. The rules of science are intended to make the process as objective as is humanly possible, and thereby produce a degree of understanding that is as close to reality as possible. One constant theme is that there is **no certainty** in science, only degrees of probability (likelihood), and potential for change. Scientific understanding can always be challenged, and even changed, with new ways of observing, and with different interpretations. The same is true of scientific **facts**. New tools and techniques have resulted in new observations, sometimes forcing revision of what had been taken as fact in the past.

Modern science is based upon several underlying assumptions:

1. The world is real. The physical universe exists, whether we can sense it or not. In other words, it is not just our imagination.
2. Humans can accurately perceive and understand the physical universe. In other words, such understanding is possible.
3. Natural processes are sufficient to explain the natural world; non-natural processes are unnecessary.
4. Nature operates the same way everywhere in the universe, and at all times, except where we have contrary evidence.

Modern science has its limitations:

1. Observations are confined to the biological limits of our senses, even with technological enhancement.
2. The mental processing of our sensory information is unconsciously influenced by previous experiences, which may result in inaccurate or biased perceptions of the world.
3. It is impossible to know if we have observed every possible aspect of a phenomenon, have thought of every possible alternative explanation, or controlled for every possible variable.
4. Scientific knowledge is necessarily **contingent knowledge** rather than absolute knowledge:
 - a. Scientific knowledge is based only on the available evidence which must be assessed and (and is therefore subject to more than one possible interpretation), not on indisputable "proof".
 - b. The history of science is filled with numerous examples of scientific knowledge changing over time.
5. Science must follow **certain rules**, such as:
 - a. Scientific explanations must be based on careful observations and the testing of hypotheses.
 - b. It must be possible to disprove a hypothesis.
 - c. Scientific solutions cannot be based merely upon personal opinion, belief, or judgment.
 - d. Scientific explanations cannot include supernatural forces (these can never be disproved).

--e. The "best" hypothesis, out of the choices, must be one which best fits several explicit criteria.

6. Science, as for any human endeavor, can be done poorly.

7. Science can be misused.

So, if there are so many limitations and uncertainties to science, **why is science so useful?** It turns out that the limitations are the strengths of science. From the actual use and application of the knowledge of science to real world problems, we have found that scientific knowledge is the most reliable knowledge we have about the natural world. In other words, most of the time, **it works!** This has enabled much of our work in space exploration, modern medicine, agriculture and technology to be as successful as it has been, at an ever-increasing rate.

Taken from ENSI/SENSI

What Science is NOT

1. Science is **not** a process which can solve all kinds of problems and questions.

The realm of science is limited strictly to solving problems about the **natural world**. Science is not properly equipped to handle the supernatural realm (as such), nor the realm of values and ethics.

2. It's **not** a process which can ignore rules.

Science must follow certain **rules**; otherwise, it's not science (just as soccer is not soccer if its rules are not followed).

3. It's **not** a process which seeks the truth or facts.

The goal of science is to come as close as we can to understanding the cause-effect **realities** of the natural world. It's never "truth" or "facts". "Truth" and "facts" can mean different things to different people.

4. It's **not** a process which attempts to prove things.

The process of science, when properly applied, actually attempts to **disprove** ideas (tentative explanations)... a process called "testing", or "challenging". If the idea survives testing, then it is stronger, and more likely an accurate explanation.

5. It's **not** a process which can produce any kind of explanation.

Scientific explanations must be potentially **disprovable**. Therefore, supernatural explanations cannot be used, since they can never be disproved (supernatural forces, by definition, do not predictably follow the laws of nature). Whatever results occur in any test can be attributed to those nebulous forces, effectively ending any further efforts to explain.

6. It's **not** a process which produces certainties, or absolute facts.

Science is a process which can only produce "**possible**" to "**highly probable**" explanations for natural phenomena; these are **never certainties**. With new information, tools, or approaches, earlier findings (theories, or even facts) can be replaced by new findings.

7. It's **not** a process which can always be relied upon due to its total objectivity and internal self-correction.

Science can be done **poorly**, just like any other human endeavor. We are all fallible, some of us make fewer mistakes than others, some observe better than others, but we are still subjective in the end. Internal self-correction mechanisms in science merely increase the reliability of its product.

8. It's **not** a process which is always properly used.

Unfortunately, science is all too frequently misused. Because it works so well, there are those who apply the name of science to their efforts to "prove" their favorite cause, even if the rules of science were not followed. Such causes are properly labeled **pseudosciences**. Also, some scientists have been known to do fraudulent work, in order to support their pet ideas. Such work is usually exposed sooner or later, due to the peer review system, and the work of other scientists.

9. It's **not** a process which is free from values, opinions or bias.

Scientists are people, and although they follow certain rules and try to be as objective as possible, both in their observations and their interpretations, their **biases** are still there. Unconscious racial bias, gender bias, social status, source of funding, or political leanings can and do influence one's perceptions and interpretations.

10. It's **not** a process in which the product (understanding) is based on faith or belief.

The product of science (probable explanations for natural phenomena) are **always based on** observations carefully analyzed and tested. The high confidence we have in science comes from the many successful applications to real-life problems (e.g. in medicine, space exploration, chemistry and technology).

11. It's **not** a process in which one solution is as good as another, or is simply a matter of opinion.

In science, there is a rigorous analysis and fair-test comparison of alternative explanations, using discriminate criteria, e.g., confirmation by multiple independent lines of evidence, leading to one **"best" solution**.

12. Scientific Theories are **not** "tentative ideas" or "hunches".

The word **"theory"** is often used this way in everyday conversation, but a theory in science refers to a highly probable, well-tested comprehensive explanation, usually for a large collection of observations.

Taken from ENSI/SENSI

Activity Two: DNA model Teacher Notes

Focus: Students design and build models that represent what DNA can do, namely replicate and interpret code. They will exchange models with another student group, attempting to interpret the code and replicate that group's model within a time constraint. The time constraint will introduce errors or mutations in the process of replicating. The processes students experienced designing their models will link to a historical perspective on the work of discovering DNA, structure and function.

Objectives: After completing this activity, students will

- appreciate the complexity of biological systems as it relates to their ability to interpret a code in order to replicate themselves
- gain a historical perspective on the research of Watson, Crick and Franklin, that lead to what we understand about DNA today
- appreciate the scientific endeavors in the past as they relate to understanding genetics that we take for granted as common knowledge
- understand how mutations can occur in the replicating of DNA
- appreciate that models and simulations enhance scientific understanding

Prerequisite Knowledge: Students should understand that all living organisms contain DNA and that DNA is ultimately what allows organisms to make more cells, proteins and more of themselves. Additionally, students should have been introduced to the importance of detailed directions/notes in scientific investigations (i.e.: write directions for making a peanut butter and jelly sandwich, then have someone try to make the sandwich with the directions).

Materials and Preparation: You will need to prepare the following materials before conducting this activity:

- Model building materials can include: straws, paper clips, different colored beads, string, twist ties, pipe cleaners, candy sucker sticks, candy, toothpicks, colored blocks, etc. Students will make their own decisions as to what to use for their designs.
- *DNA Model Activity* student handout: 1 copy for each student
- Stopwatch: 1 per group
- Scratch Paper: for preliminary design ideas
- DNA structure diagram: the *Biology Coloring Book* will have a DNA diagram: 1 copy for each student
- Computers with internet access: 1 per student group or whatever is available

Procedure

1. Introduce this activity by asking students: **What are examples of things that can make copies? How do those things make the copies? How do organisms copy themselves? What does the copying? How often does it happen? Are there different ways of copying? Do all organisms copy the same way?** Use these questions to encourage students to begin thinking about what it means for something to copy itself and the processes that are carried out to do so. Examples of ways things are copied could include photographs copied with negatives or digitized, paper copiers, scanners, reproduction in organisms.

2. Place students in groups of 3. Give each student a copy of *DNA Model Activity* handout. Explain that the design challenge in this activity is to build a model that can copy itself with a code using only the materials provided, constraints given on their **student notes** and their own knowledge. They must show with their model what code it uses to copy itself and how it copies itself. They can use any of the materials provided.

3. Explain that each member of the group is responsible for completing the DNA Model Activity handout, however, they are working together to design their model. Provide scratch paper for preliminary design ideas. Remind students of the importance of good directions—see *prerequisite knowledge*.
4. Once student groups are satisfied with their model, they will draw it on their activity handout and how it works to copy itself. The drawing must have a key indicating what each part represents. Additionally, a brief narrative explaining their reasoning used in designing their DNA model which includes how it replicates and uses a code, will accompany their diagram.
5. Student groups will exchange DNA models and directions with one other group. Student groups will follow the directions for copying the exchanged DNA. Give students a time constraint while copying the DNA (i.e.: 30 seconds), which should cause mistakes (mutations). Have student groups record how many mistakes they made in the 30 seconds.
6. Have each group present their model design, how it works and their design reasoning to the class.
7. As a class, student groups will share what problems they encountered.
8. Introduce the history of DNA. The website <http://www.dnai.org> put out by the Howard Hughes Medical Institute has a DNA timeline that includes all scientists involved in the discovery of DNA, its structure and function. This timeline has brief biographies of Rosalind Franklin, James Watson, Francis Crick. The **Code** section gives students the opportunity to look at the puzzle pieces contributed by various scientists that led to understanding the structure of DNA. Ask students: **What puzzle pieces contributed to understanding DNA as we know it today? Who were the scientists behind these discoveries?**
9. Show the DNA model we presently use today. Have students attach it to their activity handout. Discuss with students what differences/similarities they see between their model and today's model. Use the website: <http://www.thetech.org/genetics> Go to Zooming into DNA for a look at a hand from macroscopic to microscopic. Show how DNA replicates itself by using interactive activity from <http://www.pbs.org> Go to *A Science Odyssey, You Try It: DNA Workshop Activity: Replication*. From the Genetic Science Learning Center <http://gslc.genetics.utah.edu/units/basics> Go to *The Basics and Beyond*. Students can build a DNA model or investigate other topics as they relate to DNA.

Extension Ideas: Students can extract DNA from various sources. This is a lesson for extracting cheek cells. <http://biology.arizona.edu/sciconn/lessons2/Vuturo/vuturo/dna.htm> A centrifuge is required for this activity. This lesson from the *Genetic Science Learning Center* uses different organisms to extract DNA at home and does not require a centrifuge. <http://www.gslc.genetics.utah.edu/units/activities/extraction> The Tech Museum website also has an activity for removing the DNA from strawberries at home. Go to <http://www.thetech.org/genetics/medicine.php>.

Assessment: Assess individual student work on the DNA Model Activity handouts using the rubric attached. The point system can be converted to your own where a 4 is 100%, 3 is 85%, 2 is 70% and 1 is 50%.

References: for this activity include:

- DNA Interactive [Online]. Available <http://www.dnai.org>.
- Genetic Science Learning Center [Online]. Available <http://gslc.genetics.utah.edu/units/basics> and <http://gslc.genetics.utah.edu/units/activities/extraction>.
- Griffin, R. 1986. *The Biology Coloring Book* (1st ed.). Harper Collins.
- Public Broadcasting Service [Online]. Available <http://www.pbs.org>.
- Rubistar [Online]. Available <http://rubistar.4teachers.org/index.php>

- The Tech Museum of Innovation [Online]. Available <http://www.thetech.org/genetics>.
- Public Broadcasting Service [Online]. Available <http://www.pbs.org>.
- The University of Arizona: General Biology Program for Teachers [Online]. *DNA Extraction From Cheek Cells*. Available <http://biology.arizona.edu/sciconn/lessons2/vuturo/vuturo/dna.htm>.

DNA Model Activity: Rubric

Teacher Name:

Student Name:

CATEGORY	4	3	2	1
Function	DNA model clearly demonstrates how DNA could copy itself using a code. It is easy to interpret what code is being used for copying.	DNA model somewhat demonstrates how DNA could copy itself using a code. The code is clear, but it is a bit confusing as to how it works.	DNA model barely demonstrates how DNA could copy itself using a code. The code is vague and not consistently used.	DNA model does not demonstrate how DNA could copy itself using a code. The code is inconsistent.
Construction -Materials	Appropriate materials were selected and creatively modified in ways that made them even better.	Appropriate materials were selected and there was an attempt at creative modification to make them even better.	Appropriate materials were selected.	Inappropriate materials were selected and contributed to a product that performed poorly.
Journal/Log - Content	Journal provides a complete record of the DNA model, materials used in construction, reasons for materials and model plan, and some reflection about the strategies used and the results.	Journal provides a complete record of the DNA model, materials used in construction, reasons for materials and model plan with little reflection about the strategies used and the results.	Journal provides adequate details about the DNA model, materials used in construction, reasons for materials and model plan with little reflection about the strategies used and the results.	Journal provides very little detail of the DNA model, materials used in construction, reasons for materials and model plan with no reflection about the strategies used and the results.

Adapted from Rubistar

Activity Three: Differences Matter Teacher Notes

Focus: Students use their own phenotypes to determine their possible genotypes for specific traits. Using their genotypes, students determine their number on a human genetic wheel. They will compare their genetic numbers with their peers as they relate to genetic variation and the advantages of genetic variation within a population.

Objectives: After completing this activity, students will

- be able to differentiate between genetic and environmental traits
- recognize that genetic traits are inherited from their parents
- understand that DNA is broken up into chromosomes which contain genes that regulate the expression of traits
- understand that genes come in different forms called alleles
- recognize that genetic variation is caused by mutations
- be able to explain why genetic variation is important to the survival of a species
- be able to explain why sexual reproduction contributes to genetic variation of a species and asexual reproduction contributes to increasing a population but may be detrimental over time

Prerequisite Knowledge: Students should have a foundation in evolution as it relates to natural selection and what causes evolution to occur. Additionally, students should understand that asexual reproduction or cloning occurs when an organism makes exact copies of itself (many invertebrates can reproduce this way). Students should also understand that sexual reproduction requires the exchange and fusing of DNA between egg and sperm.

Materials and Preparation: You will need to prepare the following materials before conducting this activity:

- *Checking Out Your Genetic Traits:* 1 copy per student
- *Human Genetic Wheel:* 1 copy per student
- *The Gene Scene Part I and Part II* teacher notes
- 8 fresh bananas, 8 heads of lettuce, 8 green peppers, 2 oranges, 2 apples, 2 black over-ripe bananas, 2 wilted heads of lettuce
- Plastic fruit: 2 of same type (banana, apple, orange)
- 1 tray: large enough to fit 2 lettuce, bananas, peppers

Procedure

1. Begin with students recording traits they have as an individual. Have them indicate which traits they think are genetic vs. environmental? Generate a list of genetic vs. environmental traits. Some traits will be both genetic and environmental. Distinguish between the differences with student generated ideas.

2. Ask students: **What makes us different? How do the differences occur?** Students will hopefully bring up mutations as reasons we are different. Some students may have an idea that mutations can be caused by external factors (x-rays, nuclear radiation, etc.). Students may not know that mutations are part of the normal processes of our bodies. Review what happened when they tried to copy DNA quickly in the activity two.

3. Ask students: **Where do we get our genetic traits?** Students should respond from their parents. Ask students: **Where are our genes?** On chromosomes, which are parts of DNA, in the nucleus of all our cells.

How many copies do we have of most of our genes? 2 copies of each gene, one from Mom, one from Dad.

4. Give each student a copy of **Checking Out Your Genetic Traits**. Explain how to determine their genetic traits. Introduce the words **phenotype** (what they look like), **genotype** (what two copies of genes they have) and **alleles** (flavors of one gene like B or b). See **The Gene Scene Part I and Part II** teacher notes to carry out this activity and continue with **The Human Genetic Wheel**. There is an option for students to go online to do this activity, and then print their genetic wheels. This is part of **The World Wildlife Fund** website: http://www.worldwildlife.org/windows/gene_scene.cfm#1 Go to the link, **Play The Gene Scene Now!**

Note: There is no evidence that supports tongue curling as a genetic trait.

5. Does Sex Matter? Use the following demonstration to reiterate the importance of genetic diversity to the survival of a species.

a. Choose 4 student volunteers, one boy and three girls. Ask them to come to the front of the room. Have a table in front of them where you will place their vegetables (genes). Place two heads of lettuce, 2 green peppers, and two bananas in front of each student. Explain that the vegetables are the genes for each individual. Each student represents a lizard. Female whiptail lizards can carry out asexual (cloning) reproduction only. The other lizard species will be reproducing sexually. Two of the females are cloning female whiptail lizards. Place a large tray between the male and female.

b. Have each student carry out one generation of reproduction by placing the genes of the offspring off to the side.

- Two of the female students represent cloning female whiptail lizards. They will set aside all of their genes to create cloned offspring.
- The other female and the male student represent female and male lizards of another species carrying out sexual reproduction. They will each set together one copy of each of their individual genes. They will place their genes on the tray between them. The tray should now have two green peppers, two heads of lettuce, and two bananas.

c. Ask the class and the participating students: **Why did the male and female group only give one copy of each of their veggies (genes)?** One copy from each parent produces offspring with two copies. Ask: **Which group "wins"?** The female/female group produced two offspring to the one offspring of the male/female group. Cloning is advantageous at this point.

d. Introduce Mutations

Ask: **What creates diversity in a species?** Mutations

Ask: **How can a mutation occur?** Varied responses (environmental, copying mistakes)

Explain that mutations can be beneficial (i.e. lactose tolerance), detrimental (Huntington's disease) or have no affect (neutral) on organisms. Most mutations are neutral. Mutations that are detrimental can cause genes to work poorly. The wilted lettuce and over-ripe banana represent detrimental mutations.

- Replace one of the male's fresh bananas with an over ripe black banana. Do the same for one of the cloning females.
- Replace one of the sexual female's heads of lettuce with wilted lettuce. Do the same for the other cloning female.
- Replace one of the male's lettuces with an apple. Replace one of the sexual female's bananas with an orange. You are adding diversity to their genes over time.

- Have groups carry out one generation of reproduction this time with their new mutations. Sexual reproducing lizards should place their “healthy” genes on the tray.

Ask: Which group wins? Cloning females with the detrimental mutations will pass those mutations on. Through sexual reproduction, the male and female have more genetic options. They have a chance of passing on the detrimental mutations or the non-detrimental genes. Over time, sexual reproduction is good for the survival of a population because there are a greater variety of genes to pass on, some of which will be detrimental, some beneficial, and others have no effect whatsoever.

Ask: What if both groups had beneficial mutations? Which group wins? Replace the wilted lettuce given to a cloning female and sexually reproductive female with plastic fruit. Tell students that the plastic fruit represents beneficial mutations. Have groups carry out one generation of reproduction this time with their new mutations. **Ask: Does sex matter?** Students should see that if organisms have beneficial mutations, reproducing sexually is not necessarily advantageous to the next generation. However, sexual reproduction can potentially create more genetic variety, which will benefit a population in the long run if both detrimental and beneficial mutations are passed on.

Review: Relate the lizard demonstration to the genetic wheel activity. Ask students: **Why does sex matter?**

Extension Ideas: Show the student video segment titled Why Sex?. It can be purchased or viewed on the PBS evolution website <http://www.pbs.org/wgbh/evolution>.

References: for this activity include:

- Page, D. 2001, November. *Deciphering the Language of Sex*. The Meaning of Sex—Genes & Gender. Howard Hughes Medical Institute Holiday Lectures.
- World Wildlife Fund: Windows on the Wild—Biodiversity Basics. 1999. *The Gene Scene*. Tchr: 158-162; Stu: 40-41.
- World Wildlife Fund [Online]. Available http://www.worldwildlife.org/windows/gene_scene.cfm#1.

Activity Three: Differences Matter Gene Scene Teacher Notes

11 The Gene Scene

SUBJECTS

science



SKILLS

gathering (simulating), analyzing (identifying patterns), interpreting (identifying cause and effect, inferring)

FRAMEWORK LINKS

4, 19, 20, 22, 28

VOCABULARY

chromosome, evolution, gene, genetic diversity, herd, inherit, nucleus, population, species, trait

TIME

three sessions

MATERIALS

Part I—copy of the “Human Genetic Wheel” (page 41) and “Checking Out Your Genetic Traits” (page 40)
Part II—15 to 20 index cards
Part III—scissors, copies of “All About Giraffes” (pages 42–43), “Giraffe Genetic Wheel” (page 45), “Giraffe Cards” (pages 46–50) on white paper and colored paper, “Spotting Giraffes” (page 44), “Event Cards” (page 52), and “Giraffe Card Cards” (page 51) on white and colored paper (The copy pages for this activity are all included in the Student Book)

CONNECTIONS

For more on the importance of genetic diversity, follow up with “Diversity on Your Table” (pages 230–237) or “Biodiversity—It’s Evolving” (pages 168–179). To investigate how the loss of genetic diversity affects species, try “The Case of the Florida Panther” (pages 246–251).

World Wildlife Fund

Taken from World Wildlife Fund
Windows on the Wild



AT A GLANCE

Play several different games that introduce genetic diversity and highlight why it’s important within populations.



OBJECTIVES

Identify and classify genetic traits using a genetic wheel. Explain why genetic diversity may be necessary for the long-term survival of a population of animals or plants. Explain that lack of genetic diversity is one of the reasons why small and fragmented populations are vulnerable to extinction.



From a scientific perspective, conserving biodiversity means more than just protecting the variety of different species on Earth. It also means preserving the natural variation that exists among the individuals of each species. Just as humans vary in their appearances and abilities, so, too, do individual fish, mushrooms, oak trees, and amoebae. Preserving variety within populations of species is essential for preserving the ability of that species to cope with environmental change.

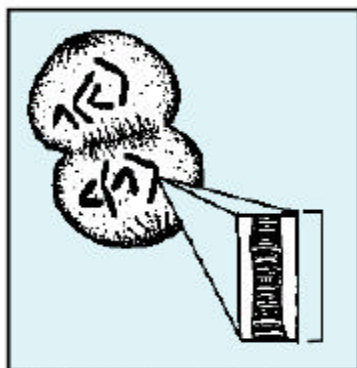
An organism’s ability to adapt to environmental change determines how well it will survive in the long run. The greater the diversity of genes in a population, the greater the chances that some individuals will possess the genes needed to survive under conditions of environmental stress. As wild populations of plants and animals become smaller and more fragmented, it becomes less likely that the remaining individuals will possess the genes needed to survive environmental changes. The individual—and the species—is subject to destruction.

This three-part activity will introduce your students to the concept of genetic diversity within a population. In Part I they will observe and compare human traits within their classroom population. This exercise should demonstrate that each individual has a variety of traits that make him or her unique and that create a diverse population within the classroom. In Part II they will discover through a quick, active demonstration that increased diversity contributes to greater survivability. And Part III will reinforce this idea as your students play a game in which they represent populations of giraffes coping with changes in the environment over time.

What to Do • Part I

1. Introduce genes.

Your students may know that the physical characteristics of all creatures on Earth are determined by their genes. But what are genes and how do they work? Genes are sections of DNA that manifest themselves as visible traits, such as eye color and hair texture, and nonvisible traits, such as a susceptibility to a certain disease. Genes form visible bars on threadlike structures called *chromosomes*, which are inside the central part, or *nucleus*, of every plant and animal cell. Chromosomes contain the genetic material of each cell, made up mostly of DNA. Chromosomes become visible under a microscope when any animal or plant cell divides (see illustration below).



chromosomes and genes during cell division

Taken from World Wildlife Fund
Windows on the Wild

In mammals, most healthy cells have two copies of each chromosome—one from each parent. Reproductive cells (eggs and sperm) have one copy of each chromosome. Different species have different numbers of chromosome pairs. In humans, for example, there are normally 23 pairs of chromosomes.

2. Discuss genetic diversity.

Explain that in a healthy population (a group of organisms of the same species living in a certain geographic area) there is a wide variety of genes that combine in many different ways to form a broad diversity of individuals. If the population is suddenly subjected to stress, such as disease or environmental change, the genetic variety makes it likely that at least some individuals will be adapted well enough to survive and continue the species.

Populations of some species have become so small or fragmented that they have lost much of their original genetic diversity. If these populations are suddenly subjected to a disease or other stress, there might not be any individuals with the genes that provide protection from the disease and enable the individuals to survive.

3. Determine the characteristics of the class population.

Give each student a copy of "Checking Out Your Genetic Traits." Go over the list of traits with your class. Have your students work in pairs to help each other determine their traits and check the traits off their worksheets. As you read the list, instruct your students to check the box that describes the trait they possess. They can also work in pairs to observe the traits in each other. For each trait, there are two possibilities:

Windows on the Wild: Biodiversity Basics

1. Your ear lobes are either hanging loose or they are attached to the side of your head.
2. Your hair is either curly or straight.
3. You can either curl your tongue, or you cannot curl it. (This trait refers to whether you can or cannot roll the sides of your tongue to make it into a tube-like shape.)
4. You either have hair on your fingers, or you don't have it. (Look at the part of your finger between your knuckle and first joint.)
5. You either have light-colored eyes (blue or green), or you have dark eyes.
6. You either have a widow's peak, or you don't have one. (If your hairline comes to a point in the middle of your forehead, you have a widow's peak.)
7. Your little finger is either straight, or it is bent.

Point out to your students that their genes have determined each characteristic on the worksheet.

4. Use the "Human Genetic Wheel."

Pass out a copy of the "Human Genetic Wheel" to each student. Instruct each student to start at the inner band and find the appropriate letter code that describes his or her own ear lobe type (it will be either "L" for loose or "H" for attached). Instruct them to continue moving outward on the wheel, finding their characteristics for each trait, until they have located their little finger type in band seven. Each person should then find the number next to his or her finger type and record this number on the worksheet.

5. Pool the results.

There are 128 possible combinations of the seven traits. To find out how many different combinations are present in the class population, go around the room and have each student give his or her Genetic Wheel number. Record the numbers on the board. If there is more than one student with the same number, place a check next to that number.

6. Discuss your findings.

Are there any two students in the class who have the same seven traits? Then ask the students if they can think of an eighth trait that would set these two people apart. Are there any numbers that have clusters of classmates? Why?

Every individual in any population is different from every other individual. Have students look at the variations among the people in their class as an example. But these variations don't make any individual a different species. Everyone in the class, regardless of his or her differences, is still a human being.



DNA double helix

Taken from World Wildlife Fund
Windows on the Wild

Before You Begin • Part II

You will need 15 to 20 index cards. On each card, write one characteristic that distinguishes one student from another. (See "Indexing Student Characteristics" on page 162.)

What to Do • Part II

1. Introduce the demonstration.

Divide the students into two teams and explain that they're going to do a demonstration that illustrates why genetic diversity is important. Show them your stack of index cards (see box on "Indexing Student Characteristics" on page 162), and explain that each one lists a characteristic that, for the purposes of the game, is going to represent a genetic trait. Tell them that once the game starts they are not allowed to change anything about themselves. Tell them that you're going to read several of these cards aloud and that if anyone on either team has the characteristic listed on that card, he or she will "die." Those students who are "dead" must sit down. The object of the game is to have at least one member of their team "alive" at the end.

2. Do the demonstration.

Have the students get into their teams and then stand facing you. Read one of the index cards you made earlier and ask all the students with the characteristic listed on the card to sit down. Repeat until you have gone through about three or four of the cards. (At least one of the teams should still have members standing.) Tell the students that if there's anyone still standing on their team, they can all regenerate and join back in. If both teams still have members standing, play another round, reading through three or four additional cards. Then go on to step 3.

3. Discuss the demonstration.




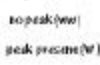


Ask the students what happened. Did any "characteristics" wipe out more people on their team than others? Did one team do better than the other? Why? (Answers will vary depending on what happens with your group. However, students should be figuring out that their team has a better chance of surviving when the characteristics of the team members are more diverse.)

4. Do the demonstration again.

Restore each team to its full number of "live" members. Then tell the teams that they're going to try the demonstration again, but that before you start they are allowed to make any adjustments they want on their teams. (Students should do things that give the group a wider range of traits. For example, some team members may untie their shoes while others may leave them tied, and some may add layers of clothing.) Shuffle the stack of cards and then read through several of them, having students with any of the characteristics "die" and sit down.

Sample Student Sheet

Which of the following traits did you inherit from your parents?
Check the box next to the trait that best describes you.

1 ears lobes attached (A) free (L)		5 pigmented iris light eyes (L) dark eyes (D)	
2 hair type straight (S) curly (C)		6 widow's peak no peak (N) peak present (P)	
3 tongue curling can curl (C) can't curl (N)		7 little finger no ridge (N) has (R)	
4 hair on fingers no hair on fingers (N) hair on fingers (H)		What is your number from the geneticow test?	

Windows on the Wild: Biodiversity Basics

Taken from World Wildlife Fund
Windows on the Wild

Indexing Student Characteristics

To do this demonstration you will need a stack of index cards, each of which has a "genetic" characteristic that can distinguish your students from one another. Because it may be difficult to come up with enough truly genetically-based traits, you should feel free to use traits, such as clothing color or type of shoes, in the demonstration. Below are some possibilities for the cards. You will need to choose characteristics that will weed out your group—but not wipe out the entire class all at once. During the demonstration, each time you read one of these traits, every student who has the trait will "die out" for the rest of the round.

- Light-colored eyes
- Bent little finger
- Not wearing glasses
- Shoes laced and tied
- Shoes without laces
- Not wearing red
- Attached ear lobes
- Not able to curl tongue
- Wearing earring(s)
- Wearing a sweater
- Wearing hair clips of any kind
- Wearing a watch
- A widow's peak
- Wearing a hat

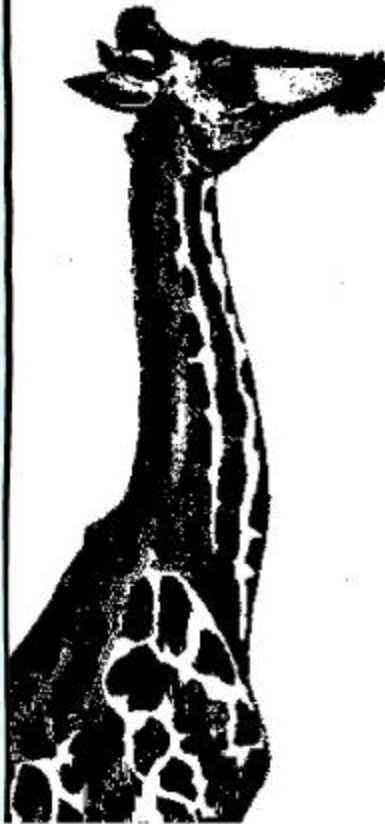


World Wildlife Fund

Taken from World Wildlife Fund
Windows on the Wild

5. Wrap up.

Have the students describe what happened. Did their team last longer or shorter this time? What helped them or hurt them? What can they say about how genetic diversity might help wild populations of animals or plants survive? (Students should understand that the more diverse their team was, the greater the chance it had of having at least one member left at the end of several rounds. They should also be able to generalize that the more genetically diverse a wild population is, the greater its chances of surviving over time. However, if the students can't quite make this leap yet, don't worry. They'll get a chance to apply these ideas in Part III.)



Activity Four: Are Those My Chromosomes? Teacher Notes

Focus: Students will use pipe cleaners and colored beads to build chromosomes with genes for eye and hair color. They will build the chromosomes of parents with given traits and then build the chromosomes for all the potential offspring from different parental crosses. Additionally, students will use the chromosomes in a Punnett square, thus introducing the Punnett square and the probabilities of genotypes and phenotypes of potential offspring. The parental crosses introduced will allow students to experience traits that are regulated by multiple genes (both hair and eye color), traits that are regulated by genes that are found on multiple chromosomes (both hair and eye color), additive expression of genes (hair color), and dominant and recessive alleles (red hair color).

Objective: After completing this activity students will

- understand that genes regulate the expression of traits
- recognize that multiple genes code for traits like eye and hair color
- recognize that hair color is determined by additive expression of genes
- understand that red hair and freckles are the results of a mutation of a gene
- be able to use a Punnett square to carry out a genetic cross
- be able to interpret the results of a Punnett square as they relate to the probabilities of genotypes and phenotypes of the offspring of a cross
- be able to identify the phenotypes of parents and their offspring by interpreting the genes they carry and how those genes are expressed: additive expression or dominant and recessive allele expression
- understand that the gametes (eggs or sperm) of parents have one copy of each chromosome, and thus one copy of each allele
- understand that the gametes of the parents are used to carry out the Punnett square cross
- be able to use the terms heterozygous and homozygous to describe a person's allele types or his or her genotype
- appreciate the complexity of genetics in terms of how genes regulate traits

Prerequisite Knowledge: Students should understand that there are two copies of all chromosomes, thus two copies of each gene. Additionally, students should understand that genes are inherited from parents.

Materials and Preparation: You will need to prepare the following materials before conducting this activity:

- A baggie with the following materials in it: 32 (16 of each color) pieces of pipe cleaner, 6 inches in length, 16 beads of each of the following colors: brown, blue, green, red, 16 beads with tabs of each of the following colors: red, black, 85 black beads, 64 white beads: 1 baggie per student group

NOTE: You can use beads of any color, these are just suggestions. The tab beads are beads with plastic sticking off of them. They can be substituted with other beads, but try to find beads that are red or black but possibly have polka dots on them or stripes or different shapes. The intention is to have the black beads represent alleles that are turned on and the red beads represent the nonmutant MC1R gene.

- Genetic Cross Diagram, laminated: 1 copy per student group
- Punnett Square Diagram, laminated: 1 copy per student group
- Punnett Square Diagrams Student Notes, non-laminated: 2 copies per student
- Are Those My Chromosomes? Student Notes: 1 copy per student

Procedure

1. Ask students: **What are genes? Where are genes found?** Record responses on the board. Students should respond that genes regulate a person's traits or are expressed as different traits like eye or hair color. Genes are found on chromosomes which are the parts of DNA divided into 23 pairs. Genes are segments of DNA that code for proteins.

2. Ask students: **Are any of you blue-eyed with brown-eyed parents? Do any of you have red hair yet have brown-haired parents?**

3. Explain that in the next two activities they will gain a better understanding of how traits are passed on from Mom and Dad to their children.

4. Give each student group of 3 a baggie with pipe cleaners and colored beads and a copy of ***Are Those My Chromosomes? Student Notes***.

5. Ask students: **What do the beads and pipe cleaner represent? What do just the beads represent?**

The entire chromosome includes the pipe cleaner and beads. Be sure that students understand that chromosomes are parts of DNA, chopped up into 23 parts and found in the nucleus of ALL of our cells (except mature red blood cells and gametes). Explain that there are two copies of each chromosome except in sex cells (sperm & egg). The chromosome copies are called **homologous chromosomes**. We have 22 pairs of chromosomes that are **autosomes** (not sex chromosomes). Each chromosome in a pair is called **homologous**. For example: we get one chromosome 1 from Mom and one chromosome 1 from Dad. This is a homologous pair. **Alleles** are different forms (flavors) of the same gene.

- The white beads will represent the non-coding sections of DNA. Less than 5% of DNA has coding sequences that is understood today. This web link from **The Tech Museum of Innovation: *Understanding Genetics*** <http://www.thetech.org/genetics/ask.php?id=25> explains more about nonsense DNA and coding regions of DNA. Noncoding regions are often used to compare the evolutionary timeline for organisms because the mutations in these regions are not affected by natural selection since they do not code for traits. Coding regions of DNA may be affected by natural selection because the traits may or may not be beneficial to the survival of a species.
- Brown beads represent the allele for brown eyes. Blue beads represent the allele for blue eyes, which is basically a mutant brown allele. Blue eyes lack pigment in the stroma of the iris. An albino produces no pigment, thus has red eyes. Green beads represent the allele for green eyes, which produce less pigment than brown eyes but more than blue eyes.
- Black beads represent the genes for hair color other than red. Eumelanin is the pigment produced by various hair color genes. The more genes expressed or turned on, the more eumelanin produced, and thus the darker the hair. The less eumelanin produced, the lighter the hair, the lightest being blonde. Black beads with a tab represent turned on hair color genes. Black beads without the tabs represent turned off hair color genes.
- Red beads without tabs represent the mutant version of the MC1R gene (red bead with tab). MC1R is a gene that converts the pheomelanin proteins for red hair color into eumelanin proteins for black to blonde hair color. If a person has two copies of mutant MC1R, he/she will have red hair and freckles. If only one copy of mutant MC1R, he/she will have freckles with dark to blonde hair depending upon the amount of eumelanin turned on/off.
- These web links from **The Tech Museum: *Understanding Genetics***, explain the complexities of eye and hair color: <http://www.thetech.org/genetics/ask.php?id=2>
<http://www.thetech.org/genetics/ask.php?id=39>

6. Make it clear to students that they will be building only small portions of chromosomes in this activity. Students will build chromosome 15 first. Chromosome 15 carries the alleles for brown or blue eyes. Be sure

to determine what color pipe cleaner you will use for chromosome 15 and what color will be used for chromosome 19. Show students how to build chromosome 15. Place 2 white beads on one piece of pipe cleaner followed by one brown bead, followed by 2 white beads. This is one copy of a section of chromosome 15. Make another exact copy of this chromosome section.

7. Ask students: **Why do we have two copies of this chromosome 15?** Humans have two copies of all chromosomes except in the sex cells. **What color eyes does this person have?** This person has brown eyes because they have two copies of the B allele for brown eyes.

8. Have students draw their chromosomes on their *Are Those My Chromosomes? Student notes* and determine the phenotype and genotype for this individual. Be sure student groups understand phenotype and genotype.

9. Have students build two new copies of chromosome 15, replacing the brown beads with blue beads. Students will draw these chromosomes on their *student notes* and determine this individual's genotype and phenotype.

10. Ask students: **What color eyes does this person have?** This person has blue eyes because he or she has two b alleles which are expressed as blue eyes.

11. Have students build and draw two copies of chromosome 15, one with a brown bead and the other with a blue bead. Have them determine the phenotype and genotype of this individual. Ask students: **What color eyes does this person have?** After students have given responses, explain that this person has brown eyes because he or she has B and b. B (Brown) is the dominant allele, masking/hiding the b (blue) recessive allele. Explain that the blue allele is actually a broken or mutant brown gene.

12. Give students a laminated copy of the *Genetic Cross Diagram*. Explain that they are now going to build the chromosomes of parents and carry out a genetic cross (have them reproduce). Explain that each parent gives only one copy of each chromosome to a child. The sperm contains one copy from Dad, the egg contains one copy from Mom. Ask students: **Why would the egg and sperm only have one copy of each chromosome?** Students should understand that if the egg and sperm each had two copies, the children of these parents would have 4 copies of each chromosome which would be genetically unhealthy for humans. In plants, however, having multiple copies of chromosomes may not be detrimental. The *Genetic Cross Diagram* represents the parents, their eggs and sperm and their possible children.

13. You will have to define the following terms so that students understand what chromosomes to build for the crosses below. **Homozygous** means that both alleles are the same. If both alleles are the dominant form, then that person is **homozygous dominant**. If both alleles are the recessive form, then that person is **homozygous recessive**. **Heterozygous** means that the individual has two different allele forms. For chromosome 15 the following would apply: Homozygous Dominant: BB; Homozygous Recessive: bb; Heterozygous: Bb

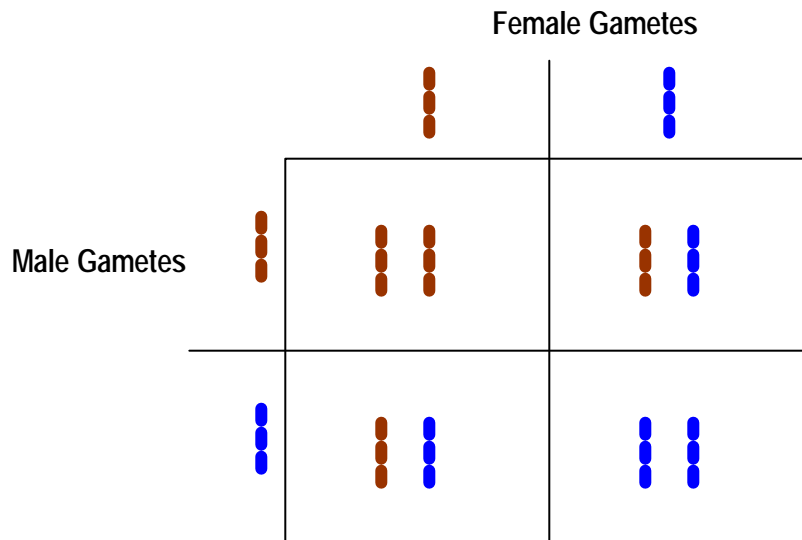
Give students the following scenarios to build with their chromosomes for brown/blue eye color:

- One parent homozygous dominant, one parent homozygous recessive.
- One parent homozygous dominant, one parent heterozygous.
- Both parents heterozygous.
 - a. Go through the first cross with the students, showing them how to use the *Genetic Cross Diagram*. Students build the parents' chromosomes first. Then they will place one copy of each chromosome into one of the gamete boxes for that parent. For example: if the mother is homozygous dominant, she will have both chromosomes with a **B**. One chromosome goes into one female gamete box, the other goes into the other female gamete box. If the father is homozygous recessive, he will have both chromosomes with a

- b. One chromosome goes into one male gamete box, the other goes into the other male gamete box.
- b. Students then build the chromosomes of the offspring, using the arrows to guide them as to what chromosomes go into each box. It is best that they build the chromosomes so that they get a better sense of how the cross works. The intention of using the **Genetic Cross Diagram** is to introduce students to what the possibilities are in a genetic cross and then to use a Punnett square, which represents the crosses they have been carrying out but is a lot easier to use.
- c. Have students determine the genotype and phenotype of the parents and children in this cross. Students answer the questions on their **student notes** for this cross.
- d. Student groups then complete the other two crosses in the same manner as above, recording their results on their **student notes**.
- e. **Remind students not to dismantle the chromosomes from the last cross (heterozygous parents), as they will be using it next.**

14. Give the same student groups the laminated copy of **Punnett Square Modeling**. Students will use the cross from **Part One: C**. On the board or overhead, model how to carry out the cross using the Punnett square. Students should follow along with their chromosome models.

- Place one of each female's chromosomes in a female gamete square near the top of the Punnett square.
- Place one of each male's chromosomes in a male gamete square on the left side of the Punnett square.
- Place the appropriate copies of each chromosome in the boxes below and to the right of the gametes. This is what it should look like, the brown dashed lines represent chromosome 15 with a brown bead (B), the blue dashed lines represent chromosome 15 with a blue bead (b).



Have students determine the probability for each offspring genotype and record it on the non-laminated *Punnett Square Student Notes* handouts. This is what it should look like:

		Female Gametes	
		B	b
Male Gametes	B	B B	B b
	b	B b	b b

Tell them that the Punnett square represents the chance of having a child with those genetic alleles donated from each parent's egg or sperm (gametes). Each square represents a 25% chance. It does NOT represent the genes of 4 children. For example, in the table above, *bb* is present in one of the squares. Each child has a 25% chance of having blue eyes.

15. Have students go through the other crosses from *Part One* in order to become familiar with the use of a Punnett square. For each cross students will record the genotype and phenotype on their **non-laminated Punnett Square Student Notes** and answer the questions on their *Are Those My Chromosomes? Student Notes*.

16. Students will repeat the steps used above doing the Punnett square for eye color with two chromosomes, 19 & 15:

- **Eye Color: Chromosome 19 & 15:** Chromosome 19 has the alleles Green for green eyes and Blue for blue eyes: Green is the dominant allele. Have students build both Chromosome 19 and 15 as described in their *student notes* and then do the cross for chromosome 19 separately from the cross for chromosome 15. The brown allele on chromosome 15 is dominant over the green allele on chromosome 19. Eye color is regulated by several genes. Ask students to try to figure out all the different combinations with the two different chromosomes after they have completed both Punnett squares.
- Ask a few student volunteers to write the Punnett squares for each chromosome cross on the board. Then, ask the class how they could determine the possible genotypes for all the potential offspring considering both chromosomes. You may need to guide them. This is one way you could help them to put both chromosomes on one Punnett square. The Punnett square should have 16 squares.
 - i. Start with one allele on chromosome 15 from Mom (B).
 - ii. Combine it with one allele on chromosome 19 from Mom (b).
 - iii. Place that combination on the top of the Punnett square (Bb).
 - iv. Combine the same allele from chromosome 15 (B) with the other allele on chromosome 19 (b).

- v. Place that combination on top of the Punnett square (Bb).
- vi. Repeat with the other alleles on Chromosome 15.
- vii. Repeat with Dad's alleles.

After completing the 16-square Punnett square, ask students: **How can this Punnett square be simplified?** Because there are multiple allele combinations that are exactly the same, students may see that it can be reduced to a 4-square Punnett square. They will then be more able to determine the phenotypic and genotypic probabilities.

- **The genotype results are: GbBb, bbBb, Gbbb, bbbb each having a 25% chance of occurring or 4/16ths. The phenotype results are: 50% chance of Brown eyes, 25% chance of Green eyes, and 25% chance of blue eyes.**
- Hopefully this set of crosses will give students a sense of the complexity of genetics when considering 25,000 genes have been identified in the human genome. If all those genes are combined in different ways, that would be a lot of work to figure out the possible genotypes and phenotypes without a computer.

17. Students will repeat the process in using a Punnett square for hair color:

- a. **Red Hair & Freckles:** Red hair and freckles are often determined by the mutation of the MC1R gene. If there are two copies of mutant MC1R, the person may have red hair and freckles. If there is one copy of mutant MC1R, the person may have freckles but hair color as discussed in the dark to light cross above. Have students build the chromosomes for red hair color as described in their *student notes* and then do the cross using the Punnett square. Students then complete the questions on red hair color in their student notes. Discuss student results as a class.
- b. **Dark to Light Hair Color:** Hair color, other than red hair, is determined by **additive expression**. The more genes that regulate the pigment eumelanin (black beads), the darker the hair. Have students build the chromosomes for hair color as described in their *student notes* and then do the cross using the Punnett square. Students then complete the questions on hair color in their student notes. Discuss student results as a class before going on to the cross for red hair.
- c. **Make it clear to students that hair color is really not this simple and several chromosomes contain genes that regulate hair color.**

18. **Review** the following terms and concepts: homologous, gametes, chromosomes, genes, alleles, heterozygous, homozygous, dominant, recessive, additive expression, genotype, phenotype, probability, what Punnett square represents.

Extension Ideas: Students visit the *Affymetrix* website <http://www.affymetrix.com> to view the number of genes that are linked to various human conditions. Go to *NetAffx Analysis Center*. Here students will have to register, which is free. Once they have registered they go into the *Quick Query* under *Expression* and highlight a type of array (human, mouse, bacterial) and type in a disease name in the *Search Term* field. All the genes that regulate this disease will be listed. Students will see that there are a great deal of genes that regulate diseases. Diseases that are regulated by one gene are small in number compared to those regulated by multiple genes. Affymetrix manufactures arrays which are like a computer chip with the human genome on it or the mouse genome, etc. An array can be used to measure what genes are being

expressed in an individual, can be used for genotyping individuals, and can be used to identify pathogens. This biotechnology allows for results within 3 days whereas in the past it could take months to gain results though not as comprehensive. Microarrays are presently being used in research, but in the future we may see them being used as diagnostic tools in hospitals. Background information on microarrays can be found on the **Affymetrix** website. Though some of this may be beyond student comprehension, you can guide them and help them to understand some aspects of the biotechnology of microarrays. There is an **Educator Resources** section on this website that can be used for learning about genes and ethics. The curriculum, **GeneChip Microarrays** is geared toward high school students, however is useful in your understanding of microarrays and how they can be use today.

Additionally, <http://www.dnai.org> has a **Genome Tour** which allows one to look at the genes found on different chromosomes, find the location for genes linked to diseases, look at chromosome animations, etc. This tour is comprehensive in its information on chromosomes and genes.

Assessment: The day following the completion of Activity 4, use a journaling activity to recapture some of the main ideas from this activity. Suggestions include giving students several different genetic cross scenarios. Include terms like heterozygous, homozygous, dominant and recessive when introducing the crosses. Have students use Punnett squares to show each cross and the genotypic and phenotypic probabilities. Ask for student volunteers to do the crosses on the board and explain them. Ask if students need more practice and/or clarification.

References: for this activity include:

- Affymetrix [Online]. Available <http://www.affymetrix.com> .
- Bryant, R. 2003, April. Toothpick Chromosomes: Simple Manipulatives To Help Students Understand Genetics. *Science Scope*: 10-15.
- DNA Interactive [Online]. Available <http://www.dnai.org> .
- The Tech Museum of Innovation [Online]. Available <http://www.thetech.org/genetics/ask.php?id=2> and <http://www.thetech.org/genetics/ask.php?id=39> .

Activity Five: Sesame Street Genetics Teacher Notes

Focus: Students will determine the genotypes of Sesame Street dolls, map the dolls' chromosomes and carry out meiosis with recombination with their mapped chromosomes. *Tinker Toys* will be used by students to build the mapped chromosomes so that meiosis with random recombination events can be carried out. Using the end result of meiosis, gametes (eggs or sperm), students will choose another Sesame Street character with whom to have offspring and carry out the cross using a random process for selection of the gametes.

Objective: After completing this activity, students will

- be able to map genes on chromosomes
- understand meiosis is a necessary process for making haploid cells (eggs and sperm) for reproduction
- recognize that parental homologous chromosomes can exchange genetic material through a process called recombination
- appreciate that recombination adds to genetic variation of a species

Prerequisite Knowledge: Students should understand that an individual's phenotype can be determined by his or her genotype and that genotype can be estimated if the individual's phenotype is known. A review of the terms and concepts introduced in Activity 4 will be of benefit prior to beginning this activity.

Materials and Preparation: You will need to prepare the following materials before conducting this activity:

- 10 Sesame Street Character Dolls: 1 per student group
- 10 sets of *Tinker Toys*: 1 box per student student group
- Tubs: 2 per student group
- Roll of Masking Tape: 1 per student group
- Permanent Markers: 1 per student group
- Dice: 1 per student group
- Genetics of Sesame Street Characters: 1 copy per student
- Sesame Street Genetics Student Notes: 1 copy per student
- Sesame Street Genetics Student Data: 1 copy per student
- Eggs & Sperm Templates: 1 copy of each per student group

Procedure

1. Introduce this activity by asking students: **Why does sex matter?** Students may remember from Activity 3 that sex matters because it can contribute to a greater genetic diversity in a species population. Ask students: **Why is genetic diversity important for species survival?** Students may remember that student groups survived better if they had more diverse traits when an *event* occurred that caused some of them with specific traits to survive or die through natural selection. Tell students that in this activity they will see that making eggs and sperm matters as the process also contributes to the genetic diversity of a species.
2. Place students in groups of 3. Give each student a copy of ***Sesame Street Genetics Student Data*** and ***Sesame Street Genetics Student Notes***. Tell students that they will be using Sesame Street characters for this activity. Give each student group a different Sesame Street Character.

Note: You can use duplicates of Sesame Street Characters, but you want to make sure there are an equal number of males and females in order for baby-making in the later stages of this activity.

3. Explain to students that they will use the ***Genetics of Sesame Street Characters*** in **Part One** of their ***Student Data*** to determine the phenotype and genotype of their Sesame Street Characters. If their character has a dominant trait, remind students to flip a coin to determine whether their character is homozygous dominant or heterozygous (heads equals 2 dominant alleles, tails equals one dominant and one recessive allele). Once they have determined the genotype for their character, they will write in the alleles on the appropriate chromosomes which are in their ***Student Data***. This would be a good time to review ***homologous chromosomes***, reminding students that there are two copies of most chromosomes for humans and Sesame Street Characters. These are the Sesame Street character chromosome maps that will be built by student groups.
4. Give each group of students a box of ***Tinker Toys***, masking tape, a die and a permanent marker. Explain to students that they will be building their mapped chromosomes using the ***Tinker Toys*** to represent the mapped chromosomes. The connected pieces represent the chromosome itself. The blocks allow for holding the chromosome together or taking it apart. They do NOT represent genes. Tell students that in this activity they will assume the genes are only one link long, however in reality genes can be much longer. Students write the allele forms for their SS character on the masking tape and place it in the appropriate place on their tinker toy chromosomes. Their ***Student Notes*** give directions as to where each allele should be placed on the Tinker Toy chromosomes. They are as follows:
 - **Chromosome #1** will be 10 links long. The **eye shape** gene will be on link one, the **nose color** gene will be on link six.
 - **Chromosome #2** will be 7 links long. The **body color** gene will be on link one, the **lip color** gene will be on link three.
 - **Chromosome X** will be 10 links long. The **hair type** gene will be on link two.
 - **Chromosome Y** will not have any genes on it in this activity. In reality, there are only about 70 genes on the Y chromosome.
5. Once students have built their Tinker Toy chromosomes, they will go through the process of ***meiosis***. Explain to students that meiosis is the process their bodies go through to make sperm and eggs also called ***gametes***. This process is different than ***mitosis***, a process used when their body makes new skin or hair cells. In meiosis, the cells that are made have only one copy of each chromosome. In mitosis, there are two copies of each chromosome in each new cell. Ask students: **Why would eggs and sperm only have one copy of each chromosome?**

Meiosis is as follows:

- a. **Chromosomes are copied.** Students should make 1 copy of ALL their chromosomes. They will have a total of 12 chromosomes.
- b. **Recombination may or may not occur between *homologous chromosomes*.** In reality, 2-3 sections of each pair of homologous chromosomes are swapped/recombine during meiosis. You will need to model recombination as you explain how to carry it out.
 - i. Students roll a die. For example, a roll of 3 begins crossover at link 3 on the chromosome. Remember, this happens to the two homologous chromosomes next to each other, the other two copies of this same chromosome are on the outside and are not involved in crossing over.

- ii. Students roll the die, again. Rolling a 4 ends crossover at link 7 on the chromosome. Students will have taken the Tinker Toy homologous chromosomes next to each other and swap the links from 3 to 7.
 - iii. Students continue to roll the die for each homologous pair of chromosomes until they roll *off* the chromosome so to speak. This may only be two rolls of the die. Those areas of recombination should be swapped physically with the *Tinker Toys*. Students may end up with one, two, or three areas that have been switched on homologous chromosomes.
 - iv. Students repeat this process with all the chromosomes. The X and Y chromosome will not go through recombination in this activity. In reality, the X and Y chromosomes do recombine a little at the ends. If they have a female Sesame Street character, her two X chromosomes do recombine.
 - c. **Homologous chromosomes separate.** Students now should have two sets of homologous chromosomes for each chromosome type. The homologous chromosomes that are now together will not look alike because one of them went through recombination.
 - d. **Chromosomes (sister chromatids) separate, forming 4 haploid cells.** Now all the homologous chromosomes are separate. Each cell will have one copy of chromosome 1, 2 and an X or Y chromosome. Have students determine which chromosome 1, 2, X and Y to place in each haploid cell, reminding them that this could be a random process in reality.
6. Students will map the chromosomes for the newly produced gametes. Tell students to record the alleles on the appropriate chromosomes in **Part Two of their Student Data**. Remind students these chromosomes are all the possibilities for their Sesame Street character's gametes (sperm or eggs).
7. Give each student group 1 copy of either gamete template (eggs or sperm), depending on the gender of their Sesame Street character. Students can now use the chromosomes produced during meiosis. There will be a multitude of possible chromosome combinations for the gametes. Remind students about all the possibilities that they encountered in Activity 4 with just two chromosomes for eye color. Ask students to number their eggs or sperm, 1-4. To simplify the process, students will use the die to determine which chromosome copies will be part of the **karyotype** (chromosomal make up) of each gamete. Students will assign temporary numbers to each homologous chromosome. There can be only 4 numbers as there are only 4 different homologous chromosomes per chromosome type. The numbers can be any number in the range 1-6. Students roll the die for one chromosome type at a time, until they are done with placing that chromosome into gametes. They will then roll the die for the next set of homologous chromosomes. If they roll a number that has not been assigned to any of that set of homologous chromosomes, they will roll again. When they roll a number that corresponds to a homologous chromosome, that chromosome will be drawn into gamete 1. Students will repeat this process until all four of their gametes have complete karyotypes, one copy of chromosome 1, 2 and either an X or Y.
8. Ask students to select a reproductive mate from the other Sesame Street characters. Give each reproductive student group 2 tubs. Eggs go into one tub. Sperm goes into the other tub.
- Students randomly draw one egg and one sperm. Ask students to record the results of their drawing on their **Student Data Part 3**. Tell them to record the allele types for the egg within the egg, and the allele types for the sperm within the sperm. There is no need for them to redraw the chromosomes.

- Next, the egg and sperm are joined. Students record the alleles for each gene in the circle that represents their new zygote, soon to be an embryo and a baby.
 - Students record the genotype and phenotype of this child on their **Student Data Part 3**.
 - Students repeat the process one more time, creating two children from the SS character cross.
9. Students draw their Sesame Street family portrait with Mom, Dad and their two children.
 10. Ask one reproductive student group for the genotype for chromosome 1 of both parents. Set up a Punnett square with both parents chromosome 1 alleles in the appropriate places. You will have to consider both eye shape and nose color. Remind students that the gametes of Mom and Dad are represented on top and to the left of the Punnett square. Ask for a volunteer to complete the Punnett square and determine the phenotypic and genotypic percent probabilities. There is no recombination in this example
 11. Ask the same student group for the chromosome 1 gamete gene combinations of both parents, resulting from recombination. Set up a Punnett square with all the gamete possibilities for Mom and Dad in the appropriate places. You will have to consider both eye shape and nose color. Ask for a volunteer to complete the Punnett square and determine the phenotypic and genotypic percent probabilities.
 12. Ask students to look at both results. Ask them: **How do the results differ? How are they similar?** Students can hopefully see that through recombination there is more genetic variation.

Extension Ideas: Visit the *Howard Hughes Medical Institute* website: <http://www.hhmi.org/biointeractive> Go to **Animations**. There are two animations that would tie in well with this activity: **Meiosis** and **Sex Determination: The Evolution of the Y chromosome**. The explanation that accompanies the animations might be a bit overwhelming for middle school students, however there are terms with links to their definitions. You may have to define terms or do some explaining. Additionally, the information about how maleness is determined in humans is interesting, especially when discussed around genetic anomalies such as XX males and XY females. The lecture on Deciphering the Language of Sex from The Meaning of Sex—Genes & Gender holiday lectures is helpful in explaining recombination and the SRY gene that regulates maleness in humans. The lecture is geared for high school students, but sections of it could be used with teacher input.

Include a discussion about females having two X chromosomes, yet not expressing twice as many genes. This is called X inactivation. One of a female's X chromosomes gets shut off randomly. In fact, males will have more genes because of their Y chromosomes. Calico cats are multicolored because of the inactivation of hair color genes on the X chromosome. For this reason, calico cats are all female. On *The Tech Museum of Innovation's* website, **Understanding Genetics** there are explanations for calico cats and chimeras (fused fraternal twins). <http://www.thetech.org/genetics/ask.php?id=50>. This is very bizarre!!!

Also found in *Understanding Genetics*, the response to the question **If identical female twins get pregnant by the same man will their children be exactly the same if they are the same sex?** relates to the probability of inheriting genes. Under **More Information**, there is a link for **meiosis** which takes you to the **Access Excellence** website and meiosis diagrams.

Assessment: Have individual students create concept maps on the genetics they have learned thus far. Their maps may show where misinterpretations exist, preconceptions still exist, and what they now understand about genetics. The intent of having students create concept maps is to see where they are in their understanding of:

- **DNA:** structure and function, history of DNA discovery

- **Genetic Diversity:** what causes it and its benefits, sexual vs asexual reproduction as they relate to genetic diversity, mutations as they relate to genetic diversity
- **Heredity:** genes as they relate to traits, the different ways traits can be expressed by genes (i.e: additive expression, dominant/recessive), how traits are passed on, the complexity of heredity
- **Meiosis:** the process, when it is used, what it produces, the affects of recombination and recombination as a vehicle for genetic diversity

Record the above list of concepts on the board. Solicit student input. **Do they have other concepts to add?** Add those to the list. Students will then choose one of the concepts on which to base their concept map. Explain that it is okay if their concept map includes other ideas related to genetics. You will be looking for detailed, accurate maps that show clear understanding of their chosen genetic concept. Give each student a copy of the rubric being used to grade their concept maps. A sample rubric is attached. The point system can be converted to your own where a 4 is 100%, 3 is 85%, 2 is 70% and 1 is 50%.

References: for this activity include:

- Global Perspectives: Concept Mapping [Online]. Available <http://www.cet.edu/earthinfo/classroom/teachers/FTopic6.html>
- Howard Hughes Medical Institute: Biointeractive [Online]. Available: <http://www.hhmi.org/biointeractive>
- Page, D. 2001, November. *Deciphering the Language of Sex*. The Meaning of Sex—Genes & Gender. Howard Hughes Medical Institute Holiday Lectures.
- Raye, S. 2001, February. Genetics of Sesame Street Characters. *Science Scope*: 12-16.
- The Tech Museum of Innovation [Online]. Available: <http://www.thetech.org>
- Vanides, J., Yin, Y., Tomita, M., Ruiz-Primo, M.A. 2005, July. Using Concept Maps in the Science Classroom. *Science Scope*: 27-31.

Concept Map Rubric

Teacher Name:

Student Name:

CATEGORY	4	3	2	1
Organization	Key concepts are clearly linked with a variety of specific details; main ideas are well supported by a multitude of subtopics	Key concepts are linked with some specific details; main ideas are supported by some subtopics	Key concepts are linked with a few specific details; main ideas are supported by a few subtopics	Key concepts are linked to one or two specific details; main ideas are supported by one or two subtopics
Relationships	Meaningful, detailed relationships between each two terms/concepts as shown by the linking line and the words on the link	Meaningful relationships between each two terms/concepts as shown by the linking line and the words on the link	Somewhat meaningful relationships between each two terms/concepts as shown by the linking line; Few words on the link	Inaccurate relationships between each two terms/concepts as shown by the linking line; No words on the link
Connections	Links are labeled to make detailed, valid, accurate connections between terms/concepts in different parts of the map—may be used to create or elaborate on ideas in detail	Links are labeled to make valid accurate connections between terms/concepts in different parts of the map—may be used to create or elaborate on ideas somewhat	Links are labeled to make somewhat valid accurate connections between terms/concepts in different parts of the map—little creation of or elaboration on ideas	Links are labeled yet make inaccurate connections between terms/concepts; one-dimensional connections with no ideas nor elaboration of ideas
Examples/Details	The main idea is extended through subtopics all the way to the level of detail in a specific example	The main idea is extended through subtopics all the way to the level of detail with some specific examples but not for each subtopic	The main idea is extended through subtopics to the level of detail with one or two subtopics with specific examples	The main idea is extended through subtopics with little detail and no specific examples

Adapted from Global Perspectives on Concept Mapping

Activity Six: Making Proteins and Mutations Teacher Notes

Focus: Students use blocks to model how the code of DNA is read in order to make proteins. Through manipulation of those blocks, different types of mutations (point, deletion, insertion, frame shift) will be introduced at both non-coding and coding regions. Using the beta globin gene sequence to compare two different individuals, students will determine the genetic variability between the individuals and extrapolate it to estimate the overall genetic variability among humans. Additionally, a closer look at an individual with beta globin mutations will reveal that a single point mutation in the coding region of this gene causes the disease Sickle Cell Anemia. The positive and negative aspects of this disease will be introduced as an example of potentially lethal mutations that remain in a population's gene pool.

Objectives: After completing this activity, students will

- understand how DNA's code is used to make proteins
- be able to model the process of protein synthesis
- recognize how mutations can occur while making proteins that can be beneficial, detrimental or neutral.
- recognize the types of mutations that can occur (point, deletion, insertion, frame shift)
- appreciate that human DNA varies between individuals by approximately 0.1%, which translates to about 3 million base differences
- recognize that most human genetic variation does not affect function
- be able to explain that some human genetic variation is related to disease and provide an example
- be able to describe a benefit of human genetic variation and relate this benefit to human evolution by natural selection

Prerequisite Knowledge: Students should understand that the non-coding regions of proteins and silent mutations (point mutations) are used to develop evolutionary trees and that evolutionary trees can vary depending on the proteins used to compare species of organisms. In relation to evolutionary trees, students should understand the greater the DNA variation between species, the farther apart they will be on an evolutionary tree. Those organisms with greater mutations in non-coding regions of specific proteins are more recent in terms of evolutionary time. Additionally, students should recognize that scientific theories about evolutionary events are better supported if morphological (looking at physical traits), the fossil record and molecular (looking at DNA) evidence support the same conclusion. However, if morphology, paleontology and molecular evidence suggest different evolutionary conclusions this can lead to re-examining present evolutionary conclusions.

Note: An activity that can be used to review how molecular evidence (DNA sequencing) is used to determine evolutionary relationships can be found on the **Science Buddies** website <http://sciencebuddies.org>. Go to **Project Ideas**, find **Life Science**, go to **Genomics**. The activity **Tree of Life—I (basic)** compares the cystic fibrosis gene of a human, orangutan, chimpanzee and gorilla. Other genes are also available for comparison.

Materials and Preparation: You will need to prepare the following materials before conducting this activity:

- Colored blocks: 4 different colors or shapes: 8 of each color/shape. Each shape/color represents a different nucleotide. Label each color/shape with one of the following letters: A, U, G, C.: 1 set per student group
- Paper: for origami or paper airplane to demonstrate protein folding and function: for teacher only
- *Amino Acid* Template: copy on tag board or laminate, cut out amino acid squares: 1 set per group

- *Making Proteins and Mutations—student notes*: 1 copy per student
- Computer connected to internet: 1 per group

Procedure

Part One: Introduction

1. Introduce this activity by asking students: **What is a protein? What are examples of proteins? What do proteins do?** Tell students that they will be learning about proteins and how they are made by reading the DNA code.

2. Assign each student group (3) a computer. Have them go to the *Genetic Science Learning Center* to view the animation titled **What is a Protein?** Go to <http://gslc.genetics.utah.edu/units/basics/tour/> Give each student a copy of **Activity 6: Student Notes**. Ask students to record their responses to the questions in **part one** as they view this section on proteins.

3. Go over student responses to the questions. **Part one** is an introduction to this activity, so it is not imperative that they completely understand how proteins are made. Basically, students should understand that proteins are used in our body to keep it running, they have specific functions and are made by reading the codes of genes. RNA is used to help decode the gene message.

Part Two: Making Proteins

4. Give each student group a baggie with the colored blocks and amino acid squares. Ask them to look at the DNA segment in **part two** of their *student notes*. Tell them that they will be making a template from that DNA segmented in order to make a protein. The template they will make is called **messenger RNA (mRNA)**. Explain that RNA is a molecule similar to DNA and may have been the precursor to DNA's origins.

5. Explain that the *A, C, T, G* letters of DNA represent the nucleotide bases that connect the two strands of DNA. Have them look at the diagram of DNA given to them in **Activity Two** as a review of where the nucleotide bases can be found. Tell them *A* represents adenine, *T* represents thymine, *C* represents cytosine and *G* represents guanine. Have students record this information in the appropriate place on **part two** of their *student notes*.

6. Ask students: **Which bases make bonds with each other?** They may remember this from **Activity Two**. Tell them adenine bonds with thymine and cytosine bonds with guanine. Tell them to record this bonding information in the appropriate place on their *student notes*.

7. Have students place the contents of their baggies on their desks. Ask: **What do you notice about the blocks?** Students should notice that there are no *T* blocks, there are *U* blocks instead. Tell them that the *U* represents a nucleotide base called *uracil*. Ask: **What base do you think bonds with U?** Someone may notice that adenine will bond with uracil.

8. Ask students to use what they know about what bases bond together, to build the mRNA from the DNA segment in their *student notes*. Check the mRNA of each group and/or have a volunteer write the both the DNA and mRNA on the board. Ask: **Where does this copying happen in the cell?** It happens in the nucleus of the cell.

9. Ask: **What happens with the mRNA copy?** It goes to the ribosomes in the cytoplasm of the cell. Students may also respond: the mRNA code is read and a protein is made. Have students look at the **Universal Genetic Code** chart on the web at <http://gslc.genetics.utah.edu/units/basics/transcribe>. Explain that there are only 20 amino acids meaning that there are several codes for the same amino acid. There are also codes that stop and start protein manufacturing. Ask: **How long is the code for each amino acid?** The code consists of 3 bases.

10. Students will use their **Amino Acid Coding Chart** (for human DNA and not mitochondrial DNA) and amino acid pieces to build the amino acid sequence from their mRNA. Check group amino acid sequences and/or ask a volunteer to record the amino acid sequence on the board.

Note: The step that includes transfer RNA (tRNA) reading the mRNA and attaching the amino acids is skipped in this activity to simplify the process. You may want to introduce tRNA. The goal is for students to understand the process without getting bogged down.

11. Explain to students that proteins are not chains of amino acids and fold into 3-dimensional molecules. The 3-dimensional structure of a protein is important to protein function. Use a flat piece of paper to represent the amino acid chain prior to folding. Then build a paper airplane out of the flat piece of paper, demonstrating that once the protein is folded correctly, it can function properly. You could also make an origami model to demonstrate the same concept.

12. Review protein synthesis by having students visit the Genetic Science Learning Center website and carry out the animation activity <http://gslc.genetics.utah.edu/units/basics/transcribe>

Part Three: Mutations

13. Ask: **What could happen in the process of copying the DNA? Translating the mRNA code?**

Mistakes or mutations might happen. Tell students they are going to introduce different types of mistakes/mutations into their protein making process. Have them make the changes to the original DNA sequence, which ultimately affects mRNA.

14. Students follow the directions in part three of their **student notes**. They will be carrying out the following mutations: insertion of a base, deletion of a base, and changing a base. These mutations should be independently done beginning with the original DNA sequence for each one.

15. When student groups have completed the mutations and answered the questions related to each mutation, ask: **What happened when you inserted a base? Deleted a base? Changed a base?** Students will have had different specific results, but generally should have seen that the amino acids were impacted, which could translate into a dysfunctional protein, make an unintended protein, or not affect the protein made. Ask: **In what way would a mutation not affect the protein at all?** If the base was substituted by another base (point mutation), but the code was for the same amino acid. Also, if the mutation occurred on a non-coding region of DNA, it might not affect the protein being made.

Part Four: Genetic Variation

16. Ask: **What is the source of variation in humans as investigated in the activities in this unit?** The DNA differences are a major source of variation. Ask: **What are other sources of variation in humans?**

The environment also plays a role in human variation. Identical Twins have the exact DNA but do not have the same fingerprints. Fingerprints are formed at about 6 weeks in development. They are influenced by what the embryo touches within the amniotic sac during development. Tell students that they will be comparing the DNA sequences of two individuals. They will be looking at part of the sequence for a gene called **beta globin**. Explain that **hemoglobin** is the molecule found in red blood cells that carries oxygen. Hemoglobin is made of four chains of amino acids. Two of the four chains are called **beta**. The other two are called **alpha**. The **beta globin** gene codes for the **beta** chains.

17. Tell students to use the sequences for the beta globin gene for person *A* and *B* to answer the questions in **part four** of their **student notes**. You may have to help them with the math and/or review percentages. You will need to tell them that there are 1,691 bases on each page. The entire **beta globin** gene is approximately 1,700 base pairs. The sequences in the **student notes** begin with the first sequences that are translated. Students should calculate that the percent difference is 0.1%. Which translates into

3,000,000 total number of differences in DNA between person *A* and *B*. So, we can expect to find approximately 3 million base differences between any two people.

18. Ask: **What does the percentage calculated indicate about human variation?** Human variation is small between two people and that variation can still mean a big difference in the entire human DNA. Students may also note that a small percent difference looks very different as they look around the room at their classmates.

19. Ask: **Do you think these differences matter?** This question should focus student attention on the importance of the differences rather than the number of differences. Explain that students will now look more closely at the *beta globin* gene of person *A* and *B*. Tell them that the regions grouped into triplets are the coding regions, the other regions are non-coding.

20. Tell students the bases in bold are where the sequences differ between person *A* and *B*. Ask: **Which base difference is most likely going to matter most to the *beta* protein structure and why?** The non-coding region might matter less because it does not include the information used to make the protein, *beta globin*. However, there are **regulatory** regions within the non-coding regions of DNA that could be affected by mutations because they control whether genes are turned on or off. Explain that most DNA variations occur in non-coding regions and do not appear to have an impact. Ask: **Why would non-coding regions have more variation?** Explain that non-coding regions most likely do not have **selective pressures** because they do not affect the survival of an organism. Coding regions will most likely have selective pressures. You may have to review natural selection with examples of selective pressures.

21. Tell students that person *A* has normal hemoglobin and person *B* has abnormal hemoglobin that is related to **sickle cell anemia**. Have each student group watch the segment on sickle cell anemia found on the BSCS/NIH website <http://www.science-education.nih.gov/customers.nsf/highschool.htm>. Select **Human Genetic Variation Web Version, Web Portion of Student Activities, The Meaning of Genetic Variation**. Play the **Sickle Cell Overview**. This can also be read by looking under **Database**. You can also order the CD-ROM that has this video segment on it.

22. Students will answer questions related to sickle cell anemia in **part four** of their notes. Discuss student responses to the questions.

Extension Ideas: Students can view the firefly animation activity on the **Genetic Science Learning Center** <http://gslc.genetics.utah.edu/units/basics/firefly>. This activity explains how fireflies make light through the process of protein synthesis.

Additionally, students can research Cystic Fibrosis, Tay-Sachs, Thalassemia and Lactose Tolerance to find out possible reasons these mutations have persisted in specific populations.

Assessment: Students will draw cartoons that show the process of protein synthesis. Their cartoons should include analogies that represent: DNA transcription by mRNA in the nucleus, mRNA translation in the ribosomes, amino acids linked to make proteins, and introduced mutations during the process. Use attached rubric to assess student understanding.

References: for this activity include:

- Biological Sciences Curriculum Study. 1999. *Human Genetic Variation*. BSCS and Video Discovery, Inc.
- Biological Sciences Curriculum Study [Online]. Available <http://www.bscs.org>
- Genetic Science Learning Center [Online]. Available <http://gslc.genetics.utah.edu>
- Science Buddies [Online]. Available <http://sciencebuddies.org>

Making Proteins & Mutations Rubric

Teacher Name:
Student Name

CATEGORY	4	3	2	1
Protein Synthesis Details	Details include: mRNA being made from one strand of DNA, mRNA being translated by using a 3 base code, final protein made with amino acids folded, specific type of mutation introduced with the consequences of that mutation	Details include: mRNA being made from one strand of DNA, mRNA being translated by using a 3 base code. Protein folding not clear. Mutations are introduced, but not clear how they change the code or the impact of the mutation	Details include: mRNA being made from DNA, mRNA being translated with no details on the 3 base code, no mention of protein being folded or made, mutation is not explained.	Few details. Does not include mRNA being translated by reading a code, no protein folding, no mutations.
Clarity	Easy to follow the process of making a protein. Drawings are neat and appropriate.	Able to follow the process of making a protein. Drawings are a bit disorganized and vague in their relationship to protein making.	Process is correct however drawings are not organized in a way that makes it clear how they represent protein making.	Process is incorrect. Drawings are poorly organized with little effort.
Creativity	Cartoon demonstrates protein making in an innovative, unique manner	Cartoon demonstrates protein making with neat drawings, some of which are analogies	Cartoon demonstrates protein making without using analogies	Cartoon demonstrates protein making with little thought put into the drawings

Adapted from Rubistar

Activity Seven: Mutation Challenge Teacher Notes

Focus: Student teams will design and build models simulating how mutations occur. Their designs will include random processes that produce mutations. Additionally, students will consider the mutation type (point, insertion, deletion), its rate, whether it is beneficial, harmful or neutral and if there are selective pressures for or against it, what they are and how they affect the organism and its population.

Objective: After completing this activity students will

- be able to demonstrate how mutations can occur and at what frequency
- understand that mutations are random events
- be able to distinguish between mutations that are either beneficial or detrimental because of selective pressures and those that are neutral because they are either on non-coding regions of DNA or are not affected by immediate selective pressures
- be able to demonstrate a type of mutation (point, insertion, deletion)
- appreciate that models and simulations enhance scientific understanding

Prerequisite Knowledge: Students should understand that mutations are caused by random events that change the code of DNA. Additionally, they should understand that in order for mutations to be passed from generation to generation, they must exist in the DNA of the gametes (eggs and sperm). A review of how selective pressures can impact a species would be beneficial prior to beginning this activity.

Materials and Preparation: You will need to prepare the following materials before conducting this activity:

- Model building materials can include: straws, paper clips, different colored beads,, string, twist ties, pipe cleaners, toothpicks, colored blocks, dart gun (children's toy) or squirt gun, small light bulbs, wires, batteries, cardboard/tag board, marbles or bearings, wooden dowels, etc. Students will make their own decisions as to what to use for their designs.
- *Mutation Challenge—student notes:* one copy per student
- White paper: used for design journal: as needed for each student
- Color pencils: used for design journal: as needed for each student
- Rulers: one per student
- Stopwatches: one per student group
- Scissors: as needed for student groups

Procedure

1. Introduce this activity by reviewing what mutations are, what causes them, and the types of mutations. Ask students: **Why are some mutations beneficial or detrimental, yet most neutral?** Most mutations are neutral because they occur on non-coding regions of DNA or do not affect the genes of an individual because they are silent mutations. Other mutations are deadly, resulting in miscarriages, which thus go unnoticed. Ask: **What determines whether a detrimental or beneficial mutation is passed on to future generations?** Selective pressures like available diet, competition for limited resources, and/or climate changes contribute to the natural selection of a population. Non-coding regions of DNA may not be affected by selective pressure, thus allowing scientists to estimate the random rate of mutation for those regions of DNA. The mutation rate of coding regions may be affected by selective pressure.

Note: You may want to carry out an activity that reviews selective pressure so that students have it fresh in their minds. Additionally, the following activity relates well to how a mutation (lactose tolerance) was

selected for in different parts of the world where cattle were raised and milk was an important part of the human diet. Lactose tolerance is a mutation of the promoter region of the lactose gene. At some point in a person's lifetime, the lactose gene is turned off, thus causing *Lactose Intolerance*. When the promoter region (controls whether gene is on or off) is mutated, the lactose gene is not turned off, thus allowing the person to continue to drink milk without having intestinal upset. People with the non-mutant promoter vary as to when the lactose gene is turned off within their lifetimes. This activity, *When Milk Makes You Sick* is from the *ENSI/SENSI* website. Go to <http://www.indiana.edu/~ensiweb/lessons/tp.milk3.html>. Students carry out a laboratory exercise using milk and *lactaid* milk. Additionally, students use family trees, data and maps to determine how lactose tolerance is inherited and where it is found throughout the world. This activity is designed for high school students but can easily be used with middle school students with some teacher guidance and defining of new terms.

2. Give each student a copy of ***Mutation Challenge: student notes***. Assign students to groups of 3. Explain that **each group** is responsible for designing a model that represents the mutation process and demonstrating how it works to the rest of the class. **Each student** within a group is responsible for a design journal that includes:

- labeled illustrations of the group's or individual's ideas, accompanied with notes that document the processes of design
- a detailed, labeled illustration of their final design
- a detailed description of how their design works which includes the name of their mutation, its type, its mutation rate, whether the mutation is affected by selective pressures or not, if so, what those selective pressures could be and how the mutation will affect the population of a species over time.
- responses to reflective questions in ***student notes***

3. Remind students that if they do not finish their design within the time constraints given, they can explain what they were attempting to do. This does not mean that they will fail as going through the process of trial and error is what scientists do on a regular basis. You might want to allow students to brainstorm ideas one day and the next day allow them to start building and testing their ideas.

Extension Ideas: Students look into why sunlight or metabolic free radicals cause mutations.

Assessment: There are three components to assess in this activity using the attached rubric:

- group presentation & whether constraints were followed in the design
- individual student journals
- individual student reflective questions

References: for this activity include:

- The Tech Museum of Innovation [Online]. Available <http://www.thetech.org>
- Evolution and the Nature of Science Institutes [Online]. Available <http://www.indiana.edu/~ensiweb/home.html>

Mutation Challenge Rubric

Teacher Name:

Student Name:

CATEGORY	4	3	2	1
Overall Design	Design is creative and complete including all the constraints required for this challenge activity. Presentation includes detailed description of how the model represents mutations as well as the use of appropriate terminology as related to mutations, mutation type and mutation rate, etc.	Design is complete with one constraint lacking. Presentation includes detailed description of how the model represents mutations as well as the use of appropriate terminology as related to mutations, mutation type and mutation rate, etc.	Design is complete with two or more constraints lacking. Presentation includes a detailed explanation of how the model represents mutations but lacks appropriate use of terminology such as mutation type, mutation rate, etc.	Design shows little effort to conform to the challenge constraints and is presented with little to no understanding of mutations.
Process Notes & Sketches	Student journal includes detailed notes and labeled sketches of design process.	Student journal includes detailed notes with few sketches of design process with no labels.	Student journal includes a few notes with no sketches of design process or unlabeled sketches with no notes.	Student journal includes notes or sketches that are not clear and vaguely document the design process.
Final Design Illustration	Design illustration is detailed and labeled with parts used and a way to follow how it works.	Design illustration is detailed and parts are labeled but there are no labels indicating how it works or parts are not labeled but there is an indication of how it works.	Design illustration is detailed without labels or any indication of how it works.	Design illustration shows little effort with few details and no labeling.
Final Design Description	Detailed description of how model works using mutation terms.	Detailed description of how model works with little use of mutation terms.	Description of how model works with no use of mutation terms.	Description of how model works is poor and vague with no use of mutation terms.
Individual Reflection	Complete, detailed, thoughtful responses to reflection questions.	Thoughtful responses to reflection questions lacking some detail.	Responses to some of the reflection questions with some thought but no details.	Responses to some reflection questions with little thought and no details.

Adapted from Rubistar

Activity Eight: Genetic Applications and Ethical Issues Teacher Notes

Focus: Students will apply their genetic knowledge by carrying out one of four activities: *DNA Fingerprinting*, *pGlo Transformation*, *Alu PCR Amplification* or *GFP Purification*. ***DNA Fingerprinting*** is a lab using electrophoresis to compare different human DNA samples (plasmid DNA) to be analyzed for *sickle cell anemia* characteristics. In the ***pGlo Transformation Lab*** students insert the fluorescent gene from jellyfish into bacteria, causing the bacteria to glow. ***Alu PCR Amplification*** is a lab where students amplify their own cheek cell DNA using the polymerase chain reaction (PCR) process. They use electrophoresis, analyze their Alu PV92 gene and compare their Alu to a map with Alu gene distribution around the world. In the ***GFP Purification Lab*** students purify a plant protein using column chromatography that may be a possible cancer cure. After completing one of the above labs, students will read current articles related to genetic applications from various sources. Article topics will include gene chip technology, forensics, evolutionary history, disease and pathogens, and cloning. In a culminating activity, students will use creative means of expressing what the future world will be like with genetic applications. They will consider the ethical issues surrounding present day genetic applications and what that might mean in terms of future possibilities.

Objectives: After completing this activity, students will

- be able to apply genetic concepts in a laboratory activity
- appreciate how genetic applications are being used to understand and treat genetic disease, study human populations and evolutionary history, investigate crimes, study pathogens and their modes of infection, grow food, etc.
- understand that gene chip technology can be used in many applications such as disease diagnosis, gene and drug discovery, agriculture, and toxicology
- appreciate that gene chip technology has allowed scientists to perform comprehensive genetic studies quickly
- reflect on ethical issues related to genetic applications used today and in the future

Prerequisite Knowledge: Students will have a strong foundation of the basic concepts of genetics as covered in the prior activities in this unit.

Materials and Preparation: You will need to prepare the following materials before conducting this activity:

- kit materials and preparation for genetic application lab of choice (***DNA Fingerprinting***, ***pGlo Transformation***, ***Alu PCR Amplification*** or ***GFP Purification***): see **BABEC** <http://babec.org> and **SCCBEP** <http://www.babec.org/SCCBEP> websites for teacher workshops in the Bay Area and to sign up for use of lab materials for appropriate lab
- genetic application articles: suggested resources include: **Affymetrix** <http://www.affymetrix.com>, **Discover Magazine** <http://www.discover.com>, **Science News** <http://www.sciencenews.org>, **The New York Times** science section <http://www.nytimes.com/pages/science/index.html>, **Weekly Reader's Current Science** <http://www.weeklyreader.com>, **San Francisco Chronicle** <http://www.sfgate.com/chronicle>, **Odyssey Magazine** <http://www.odysseymagazine.com> : two articles: 1 copy per student of one of the two articles
- editorial articles: two different articles that argue opposing points related to the ethical issues regarding genetic applications: suggested resources include **National Institute of Health** <http://www.history.nih.gov/exhibits/genetics/sect6f.htm>, **Your Genes, Your Choices**

<http://ehrweb.aaas.org/ehr/books/index.html>, *The American Journal of Bioethics*
<http://www.ajobonline.com> : 1 copy of each article per student

- suggested materials needed for individual student ethics project: drawing paper, color pencils, pens, paint, paint brushes, construction paper, foil, crepe paper, pipe cleaners, beads, magazines, newspaper, video camera, computers with online access and presentation software
- ***Genetic Applications and Ethical Issues—student notes***: one copy per student

Procedure

1. Introduce this activity by asking students to list ways that genetics can be used. Record their responses on the board. Explain that they will be using genetics to carry out an experiment. Carry out 1 of the 4 genetic applications labs suggested (*DNA Fingerprinting, pGlo Transformation, Alu PCR Amplification or GFP Purification*) or something similar that allows students to carry out a laboratory exercise using DNA.

2. Review how genetics was applied in the prior experiment using student-generated input. Choose two current science articles on how genetics is being applied. Include one article on gene chip technology. Choose another article on another genetic application topic. Give half the class one article and the other half the other article. Ask each student to read his or her article and answer the following questions:

- **What is the article generally about?**
- **In what way is genetics used/applied as stated in the article?**
- **What are possible benefits of this genetic use/application?**
- **What are possible detrimental effects of this genetic use/application?**
- **Circle words or parts of the article that you do not understand.**

3. After students have answered the questions individually, discuss each article as a class, asking for student responses to the questions. Ask: **What parts of your article did you not understand?** Solicit explanations and clarification from other students before clarifying any yourself. You may also have to explain how some of the genetic applications work.

4. Write the following scenario on the board: ***The newest genetic technology allows parents to pre-screen egg and sperm DNA for 20 of the most common diseased genes. Parents can choose which egg and sperm to use to make a baby. The egg of choice will be fertilized by the sperm of choice and implanted in the mother to develop. This technology can almost guarantee the child is free from these 20 genetic diseases.*** Assign students to groups of 3. Give them 10 minutes to discuss the situation within their groups and create a list of the pros and cons of this scenario.

5. Make 3 columns on the board for pros, cons and neither. After student groups have finished making their lists, ask one member of each group to record their lists on the board. Allow each group to present their responses and reasoning. Ask: **If a person has the genes that have been known to cause a certain disease, will that person have the disease?** It is important that students understand that having the genes that could cause a disease does not always mean a person will have the disease. Research has been done with mice with the alleles for Huntington's Disease. Mice that were raised in enriched cages had symptoms of a lesser degree than those in un-enriched cages. Environment may also be a factor influencing genes.

6. Ask each group to write their own scenarios. Once each group has written their scenarios, collect them. Then pass out the scenarios, making sure that no group is given the scenario they had written. Now have students create a list of the pros and cons for the scenario they have been given.

7. Ask a few groups to read the scenarios they were given. Have those groups record their list of pros and cons on the board. Now ask the class to help you generate a list of all the ways genetics can be used.

Without consideration as to the ethical implications of that genetic application, make this list on the board. Ask students to comment on the possible negative and positive contributions each genetic application might make. Make note of their comments next to each genetic application.

8. Give each student both editorial articles on genetic applications. Ask them to circle or highlight the points made in the editorials that mirror the pros and cons with one color and use another color for pros and cons that are not listed on the board. Ask: **Why would their ethical concerns differ from the editorials? Why would they be similar?** The point of having the students read these editorials is to get a sense that the ethical issues they have generated are most likely universal. The points that were not discussed as a class, but mentioned in the article may be beyond the students' scope of understanding or not something of concern to them (i.e.: insurance issues).

9. Give each student a copy of ***Genetic Applications and Ethical Issues: student notes***. Explain that they are going to use what they know about genetics and how it can be used and misused to envision the future of our planet. They will be able to choose a creative medium for presenting how they envision the future. It is important to emphasize that their creative project must be focused on how they think genetics will impact the future. Students can use many means of expressing their visions. Suggestions might include: drawing, painting, 3-dimensional art forms, poetry, futuristic laws pertaining to genetics, diary of a person living in the future, 1 scene skit with written script, video or computer presentations, music compilation with detailed explanation of reasoning, music performance with own written composition.

Extension Ideas: Students watch the movie ***Gattaca***. This film portrays a future world where each person's DNA is analyzed to determine where one belongs in life. The main character has genetic flaws that would not allow him to pursue his dream for space travel. He manipulates the system by using another person's DNA in order to live the life he desires. This film ties in well with the ethical discussions generated from this activity.

Students can also take a survey with questions related to cloning, gm crops, and *designer babies*. This survey provides background information and a list of pros and cons for each of the topics of the survey. This survey is found on the website of ***The Tech Museum of Innovation*** <http://www.thetech.org>. Go to ***Understanding Genetics*** and then ***Ethical Issues***.

Additionally, students could view segments of older sci-fi movies that would generate discussions on the ways the movies misrepresent genetics, revisiting the focus of *Activity 1: Genetics or No?*

Assessment: Students will be assessed on their ***Genetics in the Future*** projects for accurate representations of genetics, its potential future applications and ethical considerations, along with creativity and effort. See rubric in ***Activity Eight: Student Notes***.

References: for this activity include:

- Bay Area Biotechnology Education Consortium [Online]. Available <http://babec.org>.
- Greenfield, S. 2005. *Conversations with the Future*. The Tech Museum of Innovation Lecture Series.
- Santa Clara County Biotechnology Education Partnership [Online]. Available <http://www.babec.org/SCCBEP>.
- The Tech Museum of Innovation [Online]. Available <http://www.thetech.org>.
- Zaccheo, R. 2005. Activity #5—Discussion of Ethical Scenarios and Company Ethical Policy Statement. *Gene Chip Microarrays*: 140-145.

Activity One: Genetics or Not? Student Guidelines

Part One

As a conscientious scientist, you will be given an article from an infamous newspaper. It is up to you to read the article and explain the following:

- Explain how your article relates to what you know about DNA and genetics (why you have blue eyes, brown hair).
- Does your article make sense to you as it relates to DNA and genetics? Why or why not?

Part Two

1. Share your responses with your assigned group.
2. Create a concept map as a group based on your group responses.
Use post-it notes to design your group concept map. When you have completed your map, draw your concept map on newsprint provided. Other groups will need to see what you have drawn so draw it in bold colors.
3. Answer the following on the back of your group's final concept map:
 - Title of article
 - What was the article about?
 - How did the article relate to genetics and/or DNA?
 - Does it make sense scientifically?
 - On what ideas did your group members agree?
 - On what ideas did your group members disagree?
 - What was your group unsure or confused about?
 - What additional information did your group need as it relates to the article topic?
4. Present your group concept map to the class.

Activity Two: DNA Model Activity Student Notes

Challenge

Using the items available and hints given, build a model of the DNA molecule.

Draw your model below. Include in your drawing how it copies itself and uses a code to make proteins.

Be sure to include a key that shows what each part represents.

DNA Team Model

Constraints

- DNA has two strands.
- DNA can copy itself.
- DNA has molecules that can be read like a code.

Reasoning For Model

Key

Activity Three: Differences Matter

Student Notes

CHECKING OUT YOUR GENETIC TRAITS

 The Gene Scene

Which of the following traits did you inherit from your parents?
Check the box next to the trait that best describes you.

1 ear lobes

attached (ll)

loose (l)



2 hair type

straight (tt)

curly (T)

3 tongue curling

can't curl (cc)

can curl (c)

4 hair on fingers

no hair on fingers (m^m)

hair on fingers (M)

5 pigmented iris

light eyes (ee)

dark eyes (E)



6 widow's peak

no peak (ww)

peak present (W)

7 little finger

straight (bb)

bent (B)



What is your
number from
the genetic wheel?

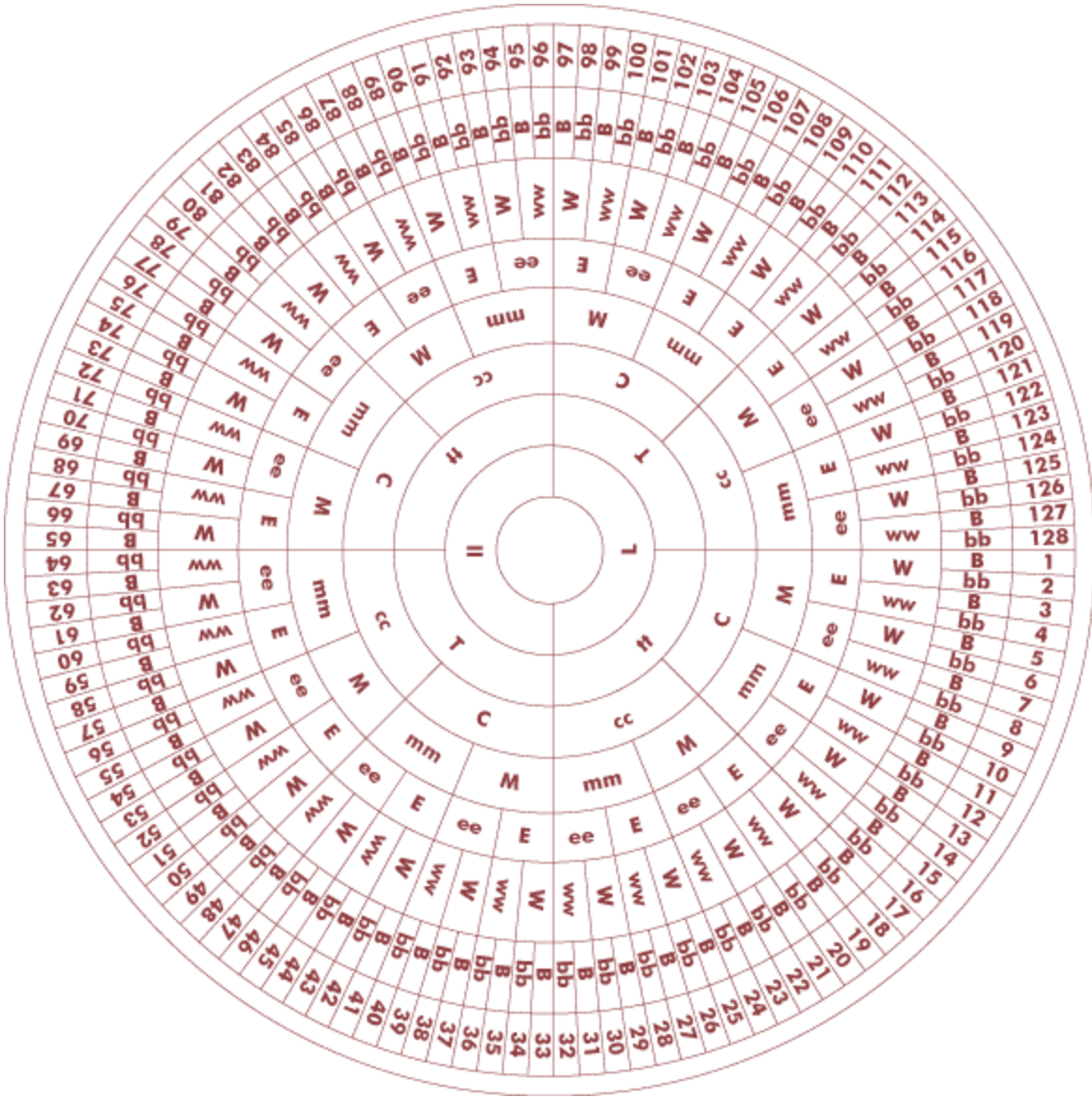


Taken from World Wildlife Fund: Windows on the Wild: Biodiversity Basics

Activity Three: Differences Matter

Student Notes

Human Genetic Wheel



Taken from World Wildlife Fund: Windows on the Wild: Biodiversity Basics

Activity Four: Are Those My Chromosomes? Student Notes

In this activity you will use the materials provided to build chromosomes with different genes for eye and hair color. The chromosomes you build will represent the chromosomes of a Mom and Dad. You will then use those chromosomes to determine all the possibilities of children these parents could have.

Part One: Genetic Cross: Brown vs. Blue Eyes: Chromosome 15

1. Place 2 white beads on white pipe cleaner. The white beads represent non-coding regions of the chromosome. Next place 1 brown bead. Follow the brown bead with 2 white beads. This represents a portion of chromosome 15. Draw this chromosome below. Use color pencils to add appropriate colors for beads. Complete the key in the drawing.
2. Build another chromosome 15 exactly like the 1st. The beads should be in the same location on the two chromosomes so they line up. Draw it next to the other chromosome 15 in the same box. These are called **homologous chromosomes**. Why did you make two of them? Record the genes present under genotype. Record what eye color this individual would have with these two chromosome copies under phenotype.
3. Build two copies of chromosome 15, replacing the brown beads with blue beads. Draw them in the 2nd Chromosome 15 box. Record the genotype and phenotype for this individual.
4. Build two copies of chromosome 15, one with a brown bead, the other with a blue bead. Draw them in the 3rd Chromosome 15 box. Record the genotype and phenotype for this individual.

Chromosomes 15
Genes (genotype) = Eye Color (phenotype) =

Chromosomes 15
Genes (genotype) = Eye Color (phenotype) =

Chromosomes 15
Genes (genotype) = Eye Color (phenotype) =

Genotype = the type of genes (alleles) the individual has (i.e.: Bb, rr)

Phenotype = what the individual looks like with their genotype
(i.e.: Brown eyes, red hair with freckles)

KEY

Non-coding =
Brown eyes/B =
Green eyes/G =
Blue eyes/b =
Mutant MC1R/r =
MC1R/R =
Turned on hair color other than red/D =
Turned off hair color other than red/d =

5. Use the **Genetic Cross Diagram** to produce the possible offspring from Mom and Dad using chromosome 15. Carry out the following cross by building the chromosomes for Mom, Dad and their offspring.
- a. Mom has 1 brown bead on each chromosome 15. Dad has 1 blue bead on each chromosome 15.
 - Place the chromosomes for Mom in the female parent box. Place the chromosomes for Dad in the male parent box.
 - Place one of Mom's chromosomes in one female gamete box and the other Mom chromosome in the other female gamete box. Do the same with Dad's chromosomes, placing them in the male gamete boxes. **Gametes** are the eggs or sperm that carry one copy of each of the parent's chromosomes.
 - Using the arrows as guides, place one chromosome copy from the appropriate gametes into the boxes below. You will have to make more duplicate copies of the chromosomes in order to fill all the possible offspring boxes.
 - Congratulations!! You have now created all the genetic possibilities for potential offspring from this cross.
 - **What alleles for eye color (genotype) does each parent have?**
 - **What color eyes (phenotype) does each parent have?**
 - **What are the genotypes for their children?**
 - **What are the phenotypes for their children?**

Make the chromosomes for Mom and Dad in the cross below repeating the steps you took in the cross above.

- b. Mom has 1 brown bead on one chromosome 15 and a blue bead on the other chromosome 15. Dad has 1 brown bead on each chromosome 15.
 - **What alleles for eye color (genotype) do they each have?**
 - **What color eyes (phenotype) do they each have?**
 - **What are the genotypes for their children?**
 - **What are the phenotypes for their children?**

Make the chromosomes for Mom and Dad in the cross below repeating the steps you took in the cross above.

- c. Dad has 1 brown bead on one chromosome 15 and a blue bead on the other chromosome 15. Mom has the same configuration as Dad for chromosome 15.
 - **What alleles for eye color (genotype) do they each have?**
 - **What color eyes (phenotype) do they each have?**
 - **What are the genotypes for their children?**
 - **What are the phenotypes for their children?**

Part Two: Punnett Square

Using the **Punnett Square Modeling** handout use the chromosomes you just built in **Part One: C**.

1. Place each of Mom's chromosomes on the top where it reads *Female gametes*. Place each of Dad's chromosomes on the left where it reads *Male gametes*. Gametes are eggs or sperm. These are the chromosome possibilities for either Mom's eggs or Dad's sperm.

2. Use the chromosomes you built for the children in **Part One: C**. Place them in the appropriate squares of the Punnett square. Your teacher will help you with this.
3. **Write in the genotypes in all the places you have put the chromosomes.** You should have one set of genes for each female gamete and male gamete. There should be two sets of genes for all the children/offspring.
4. **What does each square for the children/offspring represent?**
5. **What are the percentages of having each of the possible genotypes? What would each genotype look like (phenotype)?**

Part Three: Genetic Cross: Green vs. Blue eyes: Chromosome 19 & Chromosome 15

Chromosome 19 contains the genes for eye color for green vs. blue eyes. Brown alleles produce more of a pigment called *eumelanin* in the iris of the eye than green alleles. Green alleles produce more eumelanin than the blue allele. The blue allele produces little to no pigment. In the following Mom and Dad genetic crosses you will be building two copies of chromosome 15 and chromosome 19 to determine the genotype and phenotype of Mom, Dad, and their children. Use another color pipe cleaner, other than white, to represent chromosome 19. **NOTE: The gene for brown eyes is dominant over blue eye AND green eye genetic expression.**

- Build the chromosomes for both Mom and Dad.

Mom: both her chromosome 19's are the same

Chromosome 19

- 1 blue bead between 2 non-coding beads on either side of it

Chromosome 15

- 1 brown bead between 2 non-coding beads on either side of it on one chromosome 15
- 1 blue bead between 2 non-coding beads on either side of it on the other chromosome 15

Dad

Chromosome 19

- 1 green bead between 2 non-coding beads on either side of it on one chromosome 19
- 1 blue bead between 2 non-coding beads on either side of it on the other chromosome 19

Chromosome 15: both of his chromosome 15's are the same

- 1 blue bead between 2 non-coding beads on either side of it

- Use the Punnett Square to do these crosses. Do each chromosome cross separately. When you are done with your Punnett squares, look for duplicate genetics. You can ignore these in order to figure out all the genotype combinations. Combine the offspring genotypes in all the ways you can. For example: if the offspring for the chromosome 19 cross are Gb and GG and the offspring for the chromosome 15 cross are Bb and bb, then you can get the following combinations: GbBb, Gbbb, GGBb, GGbb. Your teacher will help you to figure out the percent probability for each genotype and phenotype.
 - **What alleles for eye color (genotype) do the parents each have?**
 - **What color eyes (phenotype) do the parents each have?**
 - **What are the genotypes for their children?**
 - **What are the phenotypes for their children?**
 - **What are the percent probabilities for each genotype?**
 - **What are the percent probabilities for each phenotype?**

Part Four: Hair Color

Hair color is poorly understood. What is known is that hair color is determined by additive expression, the more hair color genes turned on, the darker the hair. There is more of the pigment called *eumelanin* being made, which will show up as darker hair color (black). The less *eumelanin*, the lighter the hair (a range from brown to blonde). **So how does red hair fit in?** Additionally, a gene called *MC1R* converts *phomelanin*, a pigment producing red hair, into *eumelanin*. If a person has one mutated *MC1R* gene, he or she will probably have freckles. If a person has two mutated *MC1R* genes, he or she will have red hair (ranging from strawberry blonde to auburn) and freckles. Is this confusing or what?!!!! You will begin by determining whether Mom, Dad and their children have red hair and possibly freckles or not.

1. Build the following chromosomes for red hair color for Mom and Dad. Place 2 non-coding beads on either side of the given genes below.

Mom & Dad

- 1 chromosome has 1 red bead without a tab
- 1 chromosome has 1 red bead with a tab

2. Do the cross, using the Punnett square, with the chromosomes for Mom and Dad.

- **What are the genotypes of the parents? Do they have red hair? Freckles?**
- **What are the genotypes for their children?**
- **What are the phenotypes for their children?**
- **What are the percent probabilities for each genotype?**
- **What are the percent probabilities for each phenotype?**

Now you are going to figure out how dark the hair is for Mom, Dad and their children.

3. Build the following chromosomes for hair color for Mom and Dad. Place 2 non-coding beads on either side of the given genes below.

Mom

- 1 chromosome has 5 black beads with tabs, 2 black beads without tabs
- 1 chromosome has 1 black bead with a tab, 6 black beads without tabs

Dad

- 1 chromosome has 7 black beads with tabs
- 1 chromosome has 5 black beads with tabs, 2 black beads without tabs

Assume that 14 total black beads with tabs are expressed as black hair. The hair color becomes lighter as there are fewer than 14 black beads with tabs. If a person has 7 total black beads with tabs, he or she will have brown hair. If a person has 2 or fewer black beads with tabs, he or she will have blonde hair.

4. Do the cross, using the Punnett square, with the chromosomes for Mom and Dad.

- **What color hair (phenotype) does each parent have?**
- **What are the genotypes for their children?**
- **What are the phenotypes for their children?**
- **What are the percent probabilities for each genotype?**
- **What are the percent probabilities for each phenotype?**

Note: Hair color is not this simple. There are several chromosomes with genes responsible for hair color.

Part Five: Your Family

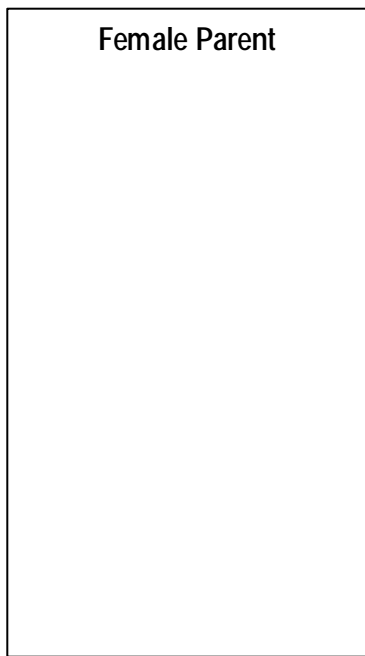
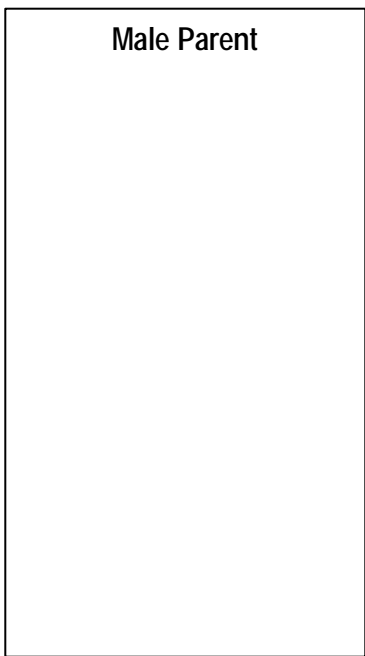
Can you figure out your hair and eye color genes going backwards from what you look like? What phenotypes for hair and eye color do your parents have? Do your siblings have? Do your grandparents have? What about freckles?

You can also use the following websites to help you with eye color:

<http://www.thetech.org/genetics> Go to: *What color eyes will your children have?*

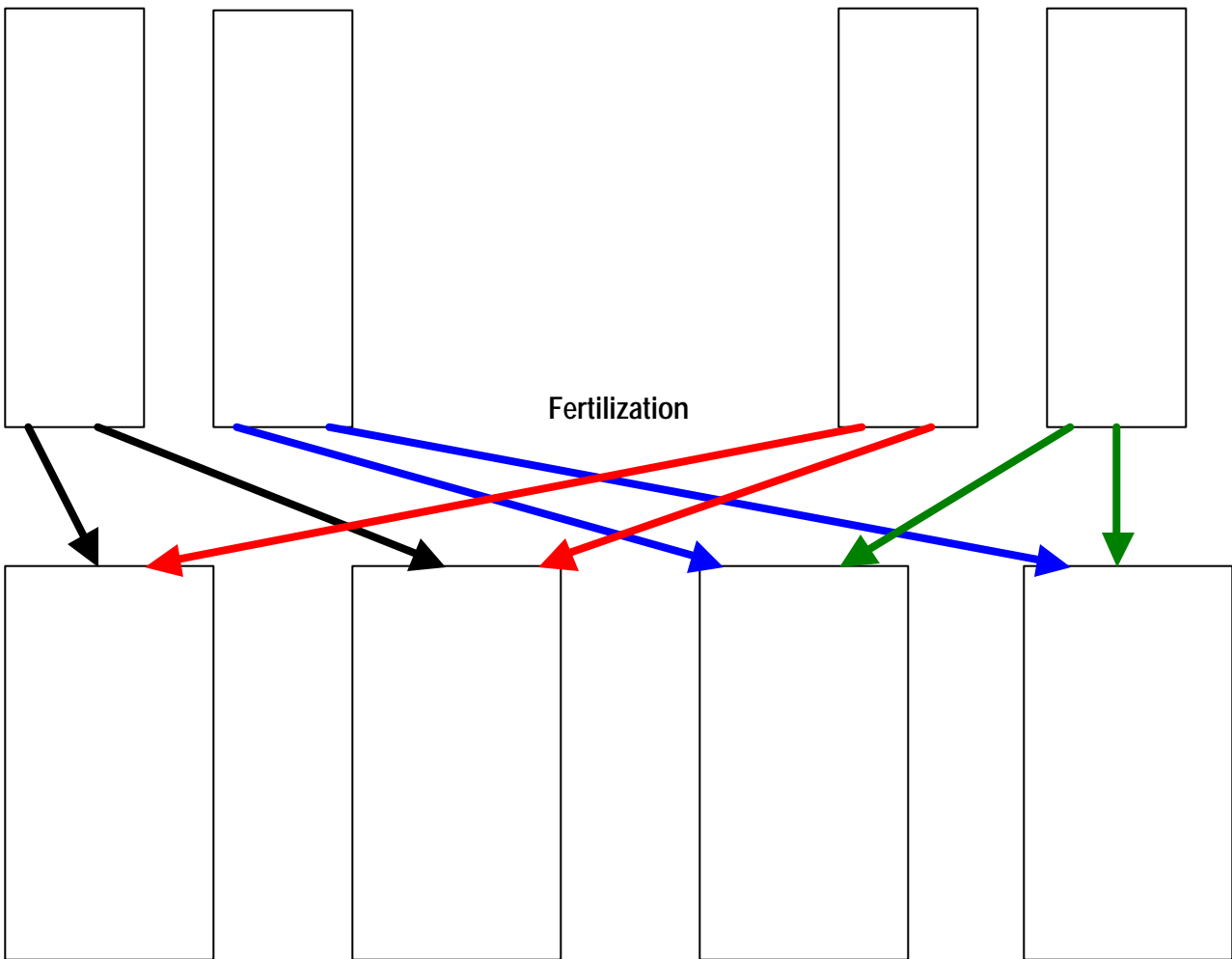
<http://www.athro.com/evo/inherit.html>

Activity Four: Genetic Cross Diagram



Female Gametes

Male Gametes



Activity Four: Punnett Squares For Modeling

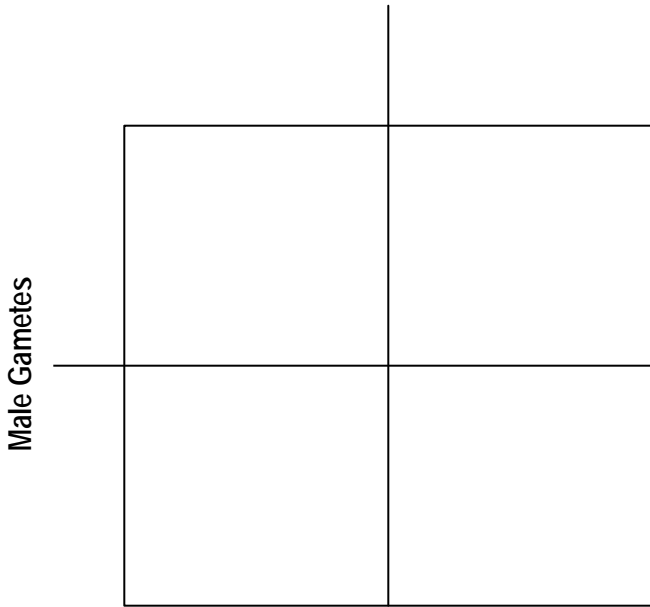
Female Gametes

Male Gametes

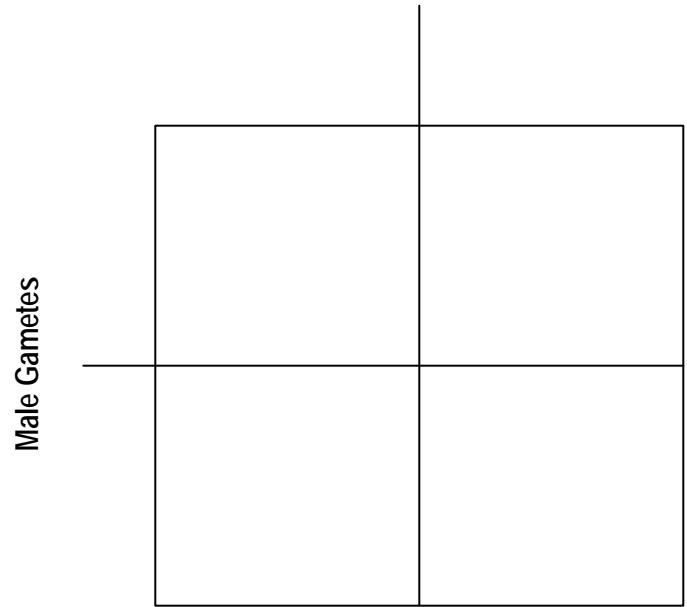
Taken from Toothpick Chromosomes

Activity Four: Punnett Squares: Student Notes

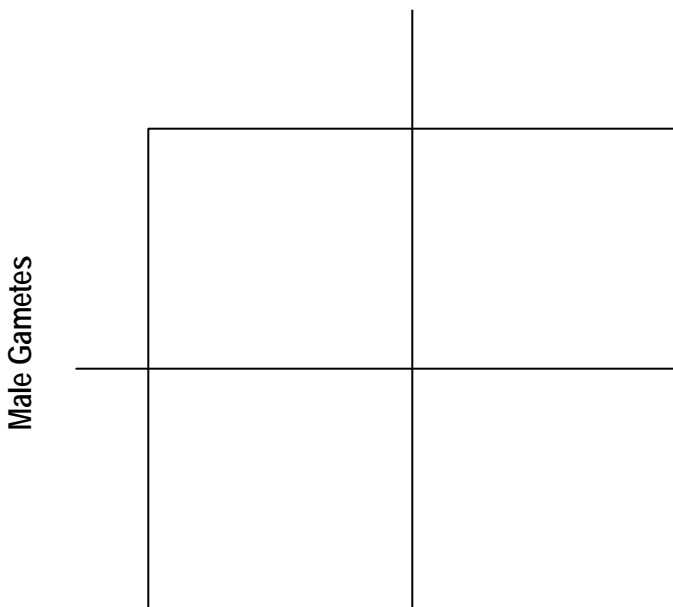
Female Gametes



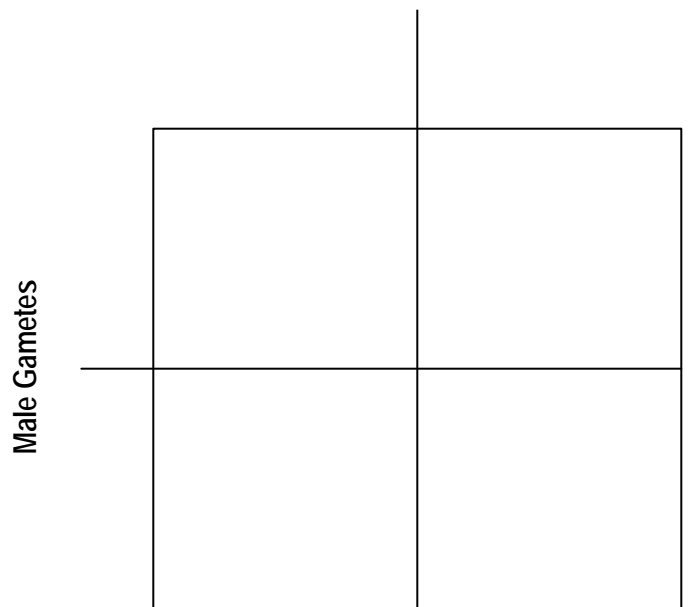
Female Gametes



Female Gametes



Female Gametes



Activity Five: Sesame Street Genetics

Student Notes

In this activity, your group will be assigned a Sesame Street character doll. You will determine his or her genotype from his or her phenotype, map his or her genes on chromosomes 1, 2, and X. You will use *Tinker Toys* to model your Sesame Street character's chromosomes as they go through a process called **meiosis**. In the end, you will choose another Sesame Street character with whom to have babies, carrying out their reproductive cross, and produce a lovely family portrait.

Part One: Phenotype, Genotype, Mapping

1. Choose one Sesame Street character. Using the **Genetics of Sesame Street Characters** found in your **Sesame Street Genetics Student Data** record his or her phenotype and genotype for eye shape, hair type, nose, lip and body color in the **Phenotype & Genotype Table**. Use the given **General Gene Map** for *Sesamus muppetis* in your **Student Data**, to draw the gene map for your Sesame Street character. For example, if your Sesame Street character has EE for eye shape, one E will be mapped on the top of chromosome 1 and the other E will be mapped on the top of the other copy of chromosome 1. Sesame Street characters have two copies of chromosomes just like humans. If your SS character has a dominant phenotype (i.e. exo for eye shape), flip a coin (heads = dominant, tails = recessive) to determine if he/she is heterozygous (i.e.: Ee) or homozygous dominant (i.e.: EE).
2. Build a model of each of your SS character's chromosomes using *Tinker Toys*. Build both copies of each chromosome. The connecting pieces represent the chromosome. The purpose of using the blocks is to hold the connecting pieces together. The blocks DO NOT represent genes. Here is what you need to know in order to build each chromosome:
 - **Chromosome #1** will be 10 links long. The **eye shape** gene will be on link one, the **nose color** gene will be on link six.
 - **Chromosome #2** will be 7 links long. The **body color** gene will be on link one, the **lip color** gene will be on link three.
 - **Chromosome X** will be 10 links long. The **hair type** gene will be on link two.
 - **Chromosome Y** will not have any genes on it in this activity. In reality, there are a few genes on the Y chromosome.
3. Write the appropriate allele forms for the genotype of your Sesame Street character on the masking tape given to you by your teacher. Place each masking tape allele on the appropriate chromosome, in the correct location as noted above.
4. Your group should now have two copies of each mapped chromosome made out of *Tinker Toys*. Check to see if you have built the chromosomes correctly by looking at your drawn chromosome maps as well as the information about the set-up of the chromosomes in #2.

Part Two: Eggs & Sperm (Gametes): Meiosis

1. You will now carry out a process called **meiosis** in order to make the eggs or sperm required for reproduction of Sesame Street characters. **Meiosis** is the process your body goes through to make sperm or eggs which are called **gametes**. This process is different than **mitosis**, a process used when your body makes new skin or hair cells. In **meiosis**, the cells that are made have only one copy of each chromosome. In **mitosis**, there are two copies of each chromosome in each new cell. **Why would eggs and sperm only have one copy of each chromosome?**
2. Using the chromosome models you just built, carry out the process of meiosis as follows:

- **Chromosomes are copied in nucleus of the cell.** Build duplicate copies of all the chromosomes you built in **Part One**. You should now have 4 copies of each chromosome, 2 copies of each **homologous** chromosome. What is a **homologous** chromosome? Line up the chromosomes so that the copies you just made are next to the original chromosomes, with the original chromosomes in the middle. Ask your teacher for clarification if you are confused as to how to line up the chromosomes.
- **Recombination occurs**(exchange homologous alleles on homologous chromosomes):
 - i. Roll the die.
 - ii. Using one of the homologous chromosomes, count down from the top, the number of tinker toy links rolled (i.e.:if you roll a "3" count down to the 3rd connecting part, this is where the recombination (crossing over) will begin. Disconnect this chromosome at this point.
 - iii. Roll the die again.
 - iv. Count down the same chromosome from where you left off from the 1st roll (i.e.: if you roll a 4, count down 4 from the 3, which will be 7 tinker toy links from the top of the chromosome. This is where the recombination ends. Disconnect this chromosome section.
 - v. Physically take this section of the homologous chromosome and exchange it with the other homologous chromosome.
 - vi. Repeat the rolling of the die until you have no more room on the chromosome.
 - vii. Repeat the above steps for recombination for all the chromosomes. Note: The Y chromosome does not crossover with the X chromosome in this activity. In reality, X and Y can recombine at their ends.
- b. **Homologous chromosomes line up at nucleus.**
- c. **Homologous chromosomes separate.** You now have one of the recombined homologous chromosomes and its original copy (you did nothing with this copy) on the opposite side of the nucleus from their counterparts (same chromosome, one homologous recombined chromosome and the other its original copy). Remember that you recombined one pair of the original 4 copies of each chromosome type, unless you had a male. Two of those 4 copies do NOT recombine. Each chromosome, 1, 2, X should go through this process if you have a female. If you have a male character, the two copies of X will separate from the two copies of Y.
- d. **Chromosomes (sister chromatids) separate at center of nucleus forming 4 haploid (one copy of each chromosome) cells.** You will now have 4 sets of chromosomes, one of each type (1, 2, X, Y). If you have a female, you will not have a Y chromosome. There can be multiple ways to combine the chromosomes. Do not worry about this now. In reality, it would likely happen randomly. You should have 4 cells with 1 copy of chromosome 1, 2 and either an X or Y.

3. Complete the chromosome maps for each copy of chromosomes 1, 2, X and/or Y in your **Student Data Part Two**. These are the chromosomes for your Sesame Street character's gametes (eggs or sperm) produced through **meiosis**.

4. Your teacher will give your group 1 copy of a gamete template with 4 eggs or 4 sperm depending on the sex of your Sesame Street character. Number each of the eggs or sperm, 1-4. You can now use the chromosomes produced during meiosis. There will be a multitude of possible chromosome combinations for the gametes. Remember all the possibilities you encountered in Activity 4 with just two chromosomes for eye color?

- You will use the die to determine which chromosome copies will be part of the **karyotype** (chromosomal make up) of each gamete. Assign temporary numbers to each homologous

chromosome 1. There can be only 4 numbers as there are only 4 different homologous chromosomes per chromosome type. The numbers can be any number in the range 1-6. Roll the die for chromosome 1 until you have one chromosome 1 drawn in each egg or sperm. If you roll a number that has not been assigned to any of that set of homologous chromosomes, roll again. You should now have drawn chromosome 1 in all your egg or sperm cells.

- Roll the die for chromosome 2, repeating the same process as above. When you roll a number that corresponds to a homologous chromosome, that chromosome will be drawn in either the egg or sperm numbered 1. Roll again, that homologous chromosome 2 goes into egg or sperm numbered 2. Repeat this process until all four eggs or sperm have 1 copy of chromosome 2.
- Repeat the above process for the X chromosome. If your Sesame Street character is a female, you will have all eggs with 1 X chromosome. If your Sesame Street character is a male, you will have two sperm with X chromosomes and two sperm with Y chromosomes.
- You should now have either 4 eggs each with 1 copy of chromosomes 1, 2 and X or 4 sperm, two with 1 copy of chromosomes 1, 2 and X and two with 1 copy of chromosomes 1, 2 and Y.

Part Three: Making Babies

Now that you know all the possible gametes for your Sesame Street character, you are ready to choose a Sesame Street character mate. You will determine the genotype and phenotype of their children.

1. Cut out the gametes you made in **Part Two**. Place your Sesame Street character's gametes into a tub. Your Sesame Street character's mate's gametes will be in another tub.
2. Take out one of your Sesame Street character's gametes without looking. Take out one of his or her mate's gametes without looking.
3. Instead of drawing the chromosomes, write the alleles from the drawn egg and sperm in the 1st egg and sperm in **Part Three** of your **Student Data**.
4. This egg and sperm join to become a zygote, which will become a baby. Record the alleles for each gene in the circle that represents the baby. The baby should have two copies of each gene, one from the egg (Mom) and one from the sperm (Dad).
5. Record the genotype and phenotype of this 1st child in **Part Three** of your **Data**. Place the egg and sperm used for this child back into the appropriate tubs. **Why do you do this?**
6. Repeat steps 2-5 for the 2nd egg and sperm.
7. Draw your Sesame Street family portrait with Mom, Dad, and their two children. Accentuate their genetic characteristics determined by this activity.

Activity Five: Sesame Street Genetics Student Data

Genetics of Sesame Street Characters

Characteristic	Phenotype	Genotype	Type of Inheritance
Eye Shape	exo (pops out) endo (flat)	EE, Ee ee	dominant/recessive
Nose Color	pink orange	PP, Pp pp	dominant/recessive
Lip Color	magenta red purple	MM Mm mm	incomplete dominance
Body Color	red purple yellow blue magenta orange	RR RB RO BB BO OO	multiple alleles: R, B, O incomplete dominance
Hair Type	hairy bald	HH, Hh hh	dominant/recessive sex-linked

Taken from *Genetics of Sesame Street Characters*

Part One: Phenotype, Genotype, Mapping

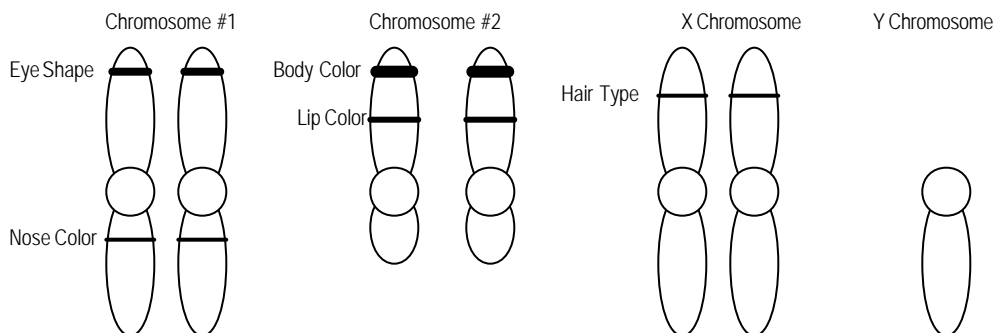
Record the phenotype and all the possible genotypes of your Sesame Street character in the table below.

Phenotype & Genotype Table

Sesame Street Character Name	Eye Shape	Nose Color	Lip Color	Body Color	Hair Type
	Phenotype:	Phenotype:	Phenotype:	Phenotype:	Phenotype:
	Genotype:	Genotype:	Genotype:	Genotype:	Genotype:

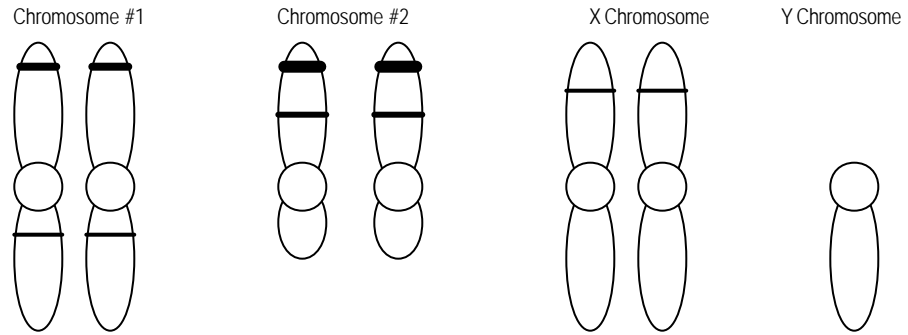
Adapted from *Genetics of Sesame Street Characters*

Sesame Street characters, *Sesamus muppetis*, have six chromosomes: two homologous pairs and one pair of sex chromosomes. Sex is determined by X and Y chromosomes just like the species *Homo sapien*. Through gene mapping, geneticists have found the specific locations of the genes for eye shape, hair type, nose, lip and body color. The genes are shown mapped on the chromosomes below.



Taken from *Genetics of Sesame Street Characters*

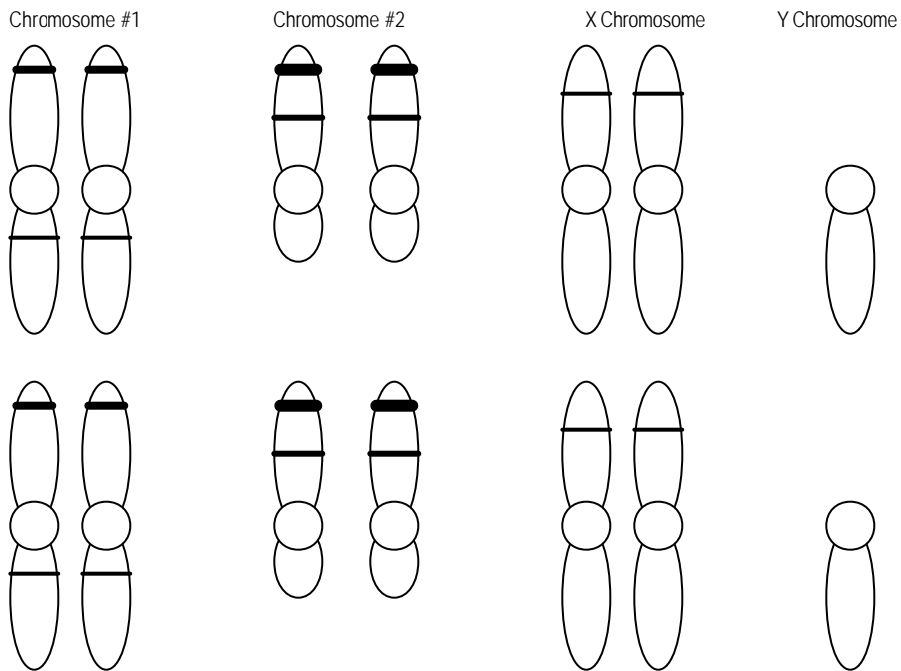
Complete the following gene map for your Sesame Street character.



Taken from *Genetics of Sesame Street Characters*

Part Two: Eggs & Sperm (Gametes): Meiosis

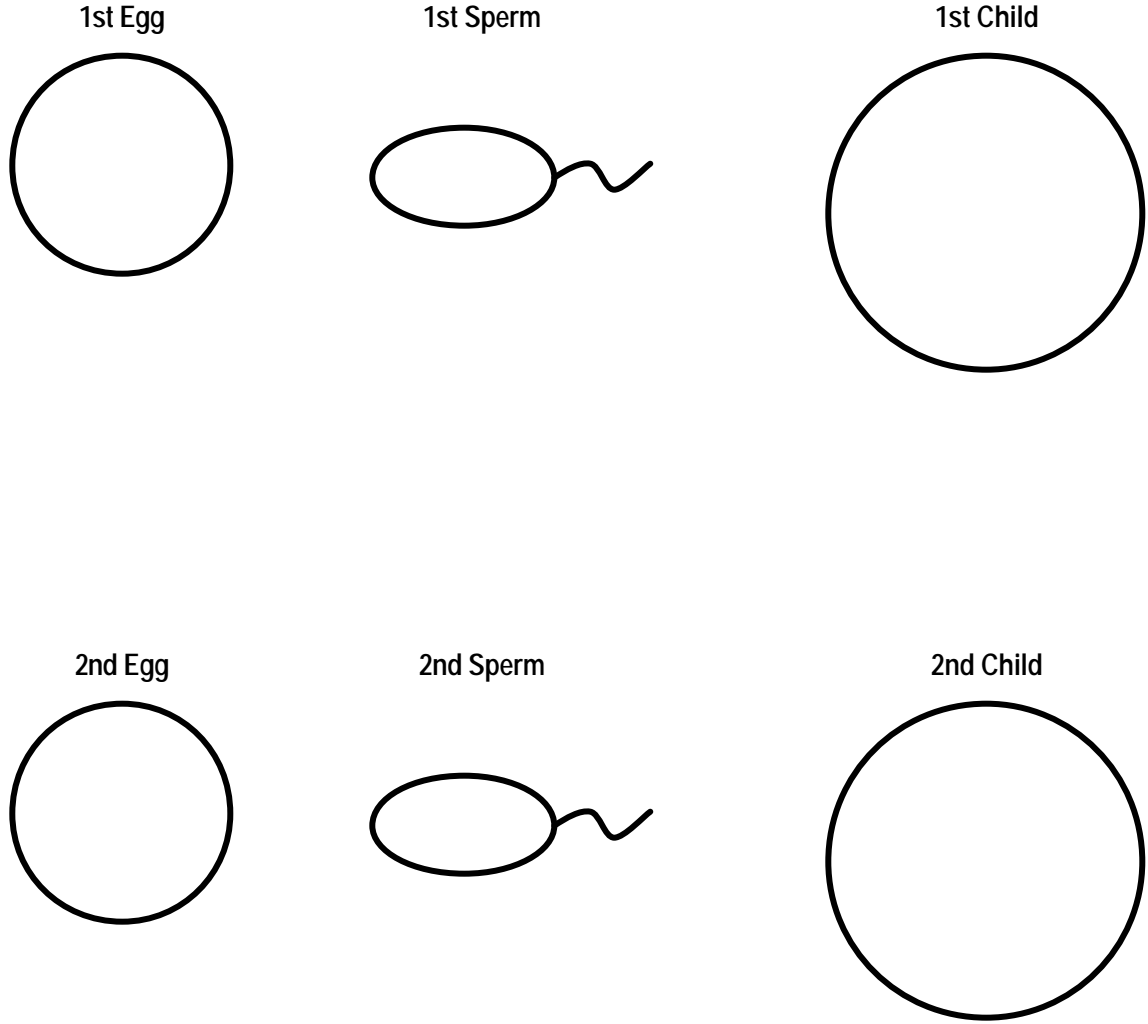
After carrying out **meiosis** with your chromosome models made from *Tinker Toys*, complete the gene map below for all his sperm or her eggs made during meiosis.



Taken from *Genetics of Sesame Street Characters*

Part Three: Making Babies

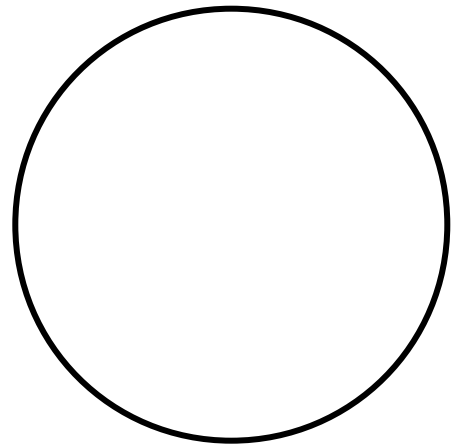
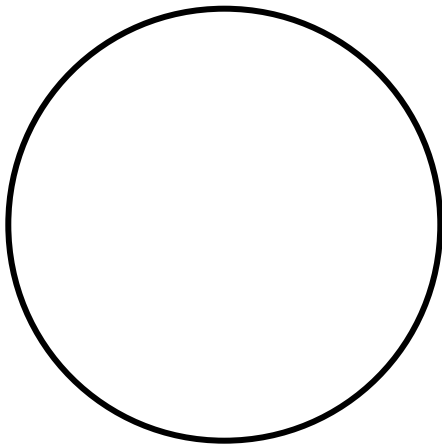
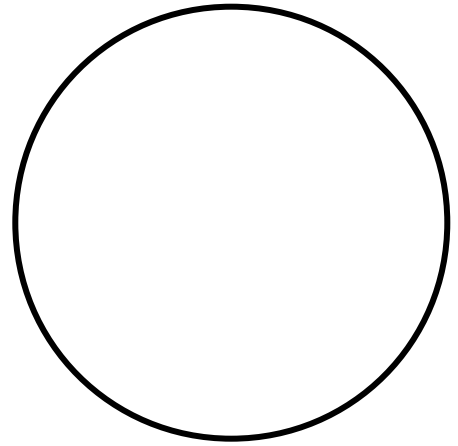
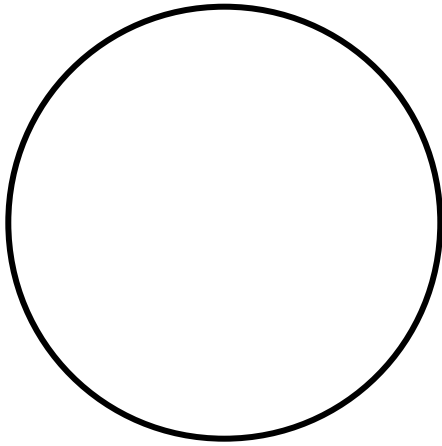
Record the alleles for the 1st egg and sperm taken from each tub, in the egg and sperm below. Record the combination of alleles from the 1st egg and sperm in the circle representing a child.



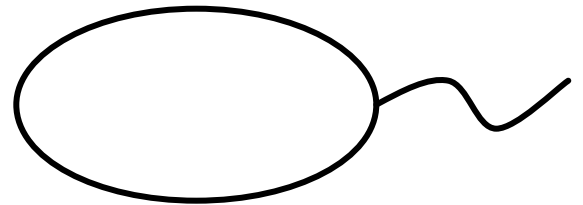
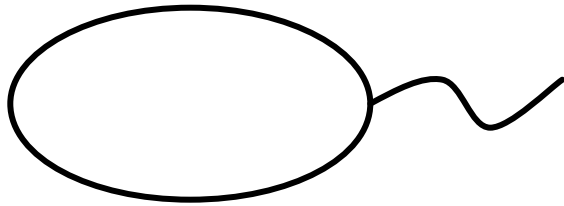
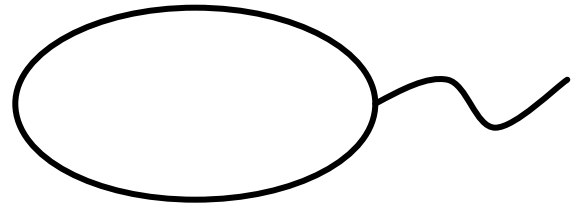
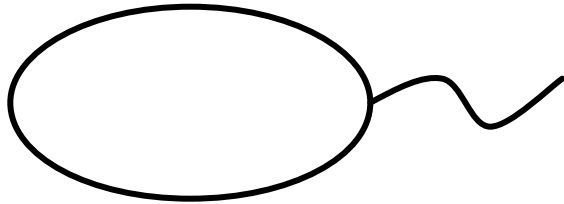
Name of Child	Eye Shape	Nose Color	Lip Color	Body Color	Hair Type
	Phenotype: Genotype:	Phenotype: Genotype:	Phenotype: Genotype:	Phenotype: Genotype:	Phenotype: Genotype:
	Phenotype: Genotype:	Phenotype: Genotype:	Phenotype: Genotype:	Phenotype: Genotype:	Phenotype: Genotype:

Adapted from *Genetics of Sesame Street Characters*

Egg Gamete Template



Sperm Gamete Template



Activity Six: Making Proteins & Mutations

Student Notes

What is a protein? Why do we need proteins? What exactly does a protein do? How are proteins made? How do proteins become mutated? You are probably wondering why you are being asked all these questions about proteins!!! Proteins are extremely important to you! Your DNA is like a cookbook. The genes are the recipes. The proteins are the ingredients. Without the ingredients for a recipe, you wouldn't be able to cook! They run your body, not exactly like your brain controls your body, but on a smaller scale. Proteins can be messengers, building materials, help you to build muscle, to see, to think, change your eye color and speed up digestion to name a few. In this activity, you will be making proteins just like cells do which will include making some mistakes. You will see that all of us are a bit different because of copying errors (mutations) in our DNA but not really a whole lot different. Most of the mistakes that make us who we are don't seem to affect our health, either. So, now let's get started.

Part One: Introduction

You will visit the **Genetic Science Learning Center** website as an introduction to proteins <http://gslc.genetics.utah.edu/units/basics/tour>. Go to **What is a Protein?** Answer the questions below as you look at this link.

1. What is a protein?
2. How do proteins work in the body?
3. Give one example of a protein and how it works from the animation.
4. How are genes related to proteins?
5. What role does RNA have in protein making?

Part Two: Making Proteins

1. You will be given a baggie with colored labeled blocks and amino acid squares. Use the colored blocks to build a mRNA complementary copy for the DNA sequence below. Before you can begin there are a few things you will need to know.

DNA is the blueprint for all the proteins made by your body.

A specific area on DNA is for building a specific protein. What are these areas called?

In order to make a specific protein, a copy must be made of the gene or DNA area for that protein.

Messenger RNA (mRNA) makes a complementary copy of one strand of the DNA. This happens in the nucleus of the cell.

The DNA sequence you see is just the bases that link both strands of DNA. A = _____, T = _____, G = _____, C = _____.

A pairs with ___ or ___, G pairs with ___.

DNA sequence: T A C G T G A G T C T A T G G G A C G C T T G A A C T
mRNA: _____

Amino Acids:

Now that you have made the mRNA complementary strand to DNA you are ready to make a protein. The mRNA moves to the ribosomes in the cytoplasm of the cell. Here the mRNA strand is read or decoded. Three (3) bases make up a code for an amino acid. Because there are only 20 amino acids but more than 20 combinations of bases, several codes can be for the same amino acid. There are also **STOP** and **START** codes to start protein manufacturing or stop it. Use the Universal Genetic Code chart found at <http://gslc.genetics.utah.edu/units/basics/transcribe> to read mRNA and place the appropriate amino acid squares under the mRNA. Record the abbreviated names for each amino acid above.

Congratulations! You have made a chain of amino acids, but not yet a protein. Proteins are 3-dimensional and their 3-d shape is important to how they work. Your teacher will demonstrate the 3-d folding of the amino acids of a protein.

Review the process of making a protein. Go to <http://gslc.genetics.utah.edu/units/basics/transcribe>, then play the animation activity

Part Three: Mutations

In this part of the activity, you will be making proteins the same way as you did in *part two*, however you will be adding mutations. You will be carrying out 3 different types of mutations. Carry out each one independently, making the chain of amino acids. Then begin with the original DNA again when you make the next type of mutation which will lead to a chain of amino acids.

1. Insertion of a base: Insert/Add an extra base (you choose which one you want to add) to anywhere on the original DNA. Rewrite this mutated DNA sequence below. Underline the base you added. Build the mRNA strand for this mutated DNA. Record its sequence below. Place the appropriate amino acid squares under the mRNA. You will need to use the **Universal Genetic Code** you used in *part two*. Record the amino acids below.

DNA with extra base: _____

mRNA: _____

Amino Acids: _____

Did you make the same protein? Reading from left to right, circle the amino acids in the above chain that are different from the original amino acid chain from *part two*.

2. Deletion of a base: Delete a base anywhere on the original DNA from part two. Rewrite this mutated DNA sequence below. Underline the bases on either side of where you made the deletion on your mutated DNA. Build the mRNA strand for this mutated DNA. Record its sequence below. Place the appropriate amino acid squares under the mRNA. You will need to use the **Universal Genetic Code** you used in *part two*. Record the amino acids below.

DNA less one base: _____

mRNA: _____

Amino Acids: _____

Did you make the same protein? Reading from left to right, circle the amino acids in the above chain that are different from the original amino acid chain from *part two*.

3. Point mutation: change any base to a base of your choosing anywhere on the original DNA from *part two*. Rewrite this mutated DNA sequence below. Underline the new base you swapped on the mutated DNA. Build the mRNA strand for this mutated DNA. Record its sequence below. Place the appropriate amino acid squares under the mRNA. You will need to use the **Universal Genetic Code** you used in *part two*. Record the amino acids below.

DNA one base change: _____

mRNA: _____

Amino Acids: _____

Did you make the same protein? Reading from left to right, circle the amino acids in the above chain that are different from the original amino acid chain from *part two*.

4. **What does this activity show you about how mutations affect proteins? In what way would a mutation NOT affect a protein at all?**

Part Four: Genetic Variation

What makes humans different from one another? You will be comparing the DNA sequences of two individuals. The part of DNA you will be looking at is the sequence for a gene called *beta globin*. Beta globin is one type of amino acid chain that makes up the *hemoglobin* molecule, which is found in red blood cells.

What is the function of hemoglobin? Use the *beta globin* sequences for person A and person B to answer the following questions.

1. **How many bases are different between the sequence for person A and person B?** Look for the bases that are in **bold type**. _____

2. **How many total bases are in the *beta globin* sequence?** Ask your teacher. _____

3. Divide the number of different bases by the total number of bases in the sequence, then multiply by 100. **The percentage difference is** _____.

4. The human DNA (genome) has about 3 billion bases. Assume that the percentage of difference you just calculated exists for the entire DNA. **How many total base differences would you possibly find between person A and person B?** $3,000,000,000 \times \underline{\hspace{2cm}} = \underline{\hspace{2cm}}$ total differences.

5. **What does this percentage calculated indicate about human variation? Do you think these differences matter?**

6. The regions grouped as triplets are the *coding* regions of the sequence. The other regions are *non-coding*. **Which base difference is most likely going to matter to the protein structure and why?**

7. View the video segment on **Sickle Cell Anemia**. Answer the following questions as they relate to the video (Adapted from BSCS: *Human Genetic Variation*):

- What are the symptoms of *sickle cell disease*? What happens to the red blood cells of a person with *sickle cell disease*?
- Which person in this activity has *sickle cell disease*? How does his or her DNA differ from the other person's DNA?
- What is the difference between the *sickle cell disease* and the *sickle cell trait*? How is *sickle cell disease* inherited?

- Why would Africans found in Cameroon have a higher percent of *sickle cell disease* than those living in the United States?

Beta Globin Gene—Person A Student Notes

Read the sequence from left to right across the page.

ATG GTG GAC CTG ACT CCT GAG G **A**G AAG TCT GCC GTT ACT GCC CTG TGG GGC AAG GTG AAC
GTG GAT GAA GGT GGT GTT GAG GCC CTG GGC AGGTTGGTATCAAGGTTACAAGACAGGTTTAAG
GAGACCAATAGAACTGGGCATGTGGAGACAGAGAAGACTCTTGGGTTTCTGATAGGCACTGACTCTC
TCTGCCTATTGGTCTATTTTCCCACCCTTAG G CTG CTG GTG GTC TAC CCT TGG ACC CAG AGG
TTC TTT GAG TCC TTT GGG GAT CTG TCC ACT CCT GAT GCT GTT ATG GGC AAC CCT AAG GTG
AAG GCT CAT GGC AAG AAA GTG CTC GGT GCC TTT AGT GAT GGC CTG GCT CAC CTG GAC AAC
CTC AAG GGC ACC TTT GCC ACA CTG AGT GAG CTG CAC TGT GAC AAG CTG CAC GTG GAT CCT
GAG AAC TTC AGG

GTGAGTCTATGGGAC **G**CTTGATGTTTTCTTTCCCCTTCTTTTCTATGGTTAAGTTCATGTCATAGGAAGG
GGAGAAGTAACAGGGTACAGTTTAGAATGGGAAACAGACGAATGATTGCATCAGTGTGGAAGTCTCAG
GATCGTTTTAGTTTCTTTTATTGCTGTTCCATAACAATTGTTTTCTTTGTTAATTCTTGCTTTCTTTTTT
TTCTTCTCCGCAATTTTACTATTATACTTAATGCCTAACATTGTGTATAACAAAAGGAAATATCTCTGA
GATACATTAAGTAAC TAAAAAAAAAACTTTACACAGTCTGCCTAGTACATTACTATTTGGAATATATGTGT
GCTTATTTGCATATTCATAATCTCCCTACTTTATTTTCTTTTATTTTAAATTGATACATAATCATTATACATA
TTTATGGGTTAAAGTGTAATGTTTTAATATGTGTACACATATTGACCAAATCAGGGTAATTTTGCATTTGT
AATTTTAAAAAATGCTTTCTTCTTTTAAATACTTTTTTGTAT CTTATTTCTAATACTTTCCCTAATCTCT
TTCTTTCAGGGCAATAATGATACAATGTATCATGCCTCTTGCACCATTCTAAAGAATAACAGTGATAATT
TCTGGGTTAAGGCAATAGCAATATTTCTGCATATAAATATTTCTGCATATAAATTGTAAGTACTGATGTAAGAG
GTTTCATATTGCTAATAGCAGCTACAATCCAGCTACCATTCTGCTTTTATTTTATGGTTGGGATAAGGCT
GGATTATTCTGAGTCCAAGCTAGGCCCTTTGCTAATCATGTTCCATACCTCTTATCTTCCCTCCCACAG
CTC CTG GGC AAC GTG CTG GTC TGT GTG CTG GCC CAT CAC TTT GGC AAA GAA TTC ATC CCA
CCA GTG CAG GCT GCC TAT CAG AAA GTG GTG GCT GGT GTG GCT AAT GCC CTG GCC CAC AAG
TAT CAC TAA

GCTCGCTTTCTTGCTGTCCAATTTCTATTAAGGTTCCCTTTGTTCCCTAAGTCCAAC TACTAACTGGGG
GATATTATGAAGGCCTTGAGCATCTGGATTCTGCCTAATAAAAAACATTTATTTTCTTGCATGATGT
ATTTAAATTATTTCTGAATATTTTACTAAAAAGGGAATGTGGGAGGTCAGTGCATTTAAACATAAAGAAA
TGATGAGCTGTTCAAACCTGGGAAAATACACTATATCTTAAACTCCATGAAAGAA

Taken from BSCS: *Human Genetic Variation*

Beta Globin Gene—Person B Student Notes

Read the sequence from left to right across the page.

ATG GTG GAC CTG ACT CCT GTG GAG AAG TCT GCC GTT ACT GCC CTG TGG GGC AAG GTG AAC
GTG GAT GAA GGT GGT GTT GAG GCC CTG GGC
AGGTTGGTATCAAGGTTACAAGACAGGTTTAAGGAGACCAATAGAACTGGGCATGTGGAGACAGAGA
AGACTCTTGGGTTTCTGATAGGCACTGACTCTCTGCCTATTGGTCTATTTTCCCACCCTTAG G CTG
CTG GTG GTC TAC CCT TGG ACC CAG AGG TTC TTT GAG TCC TTT GGG GAT CTG TCC ACT CCT
GAT GCT GTT ATG GGC AAC CCT AAG GTG AAG GCT CAT GGC AAG AAA GTG CTC GGT GCC TTT
AGT GAT GGC CTG GCT CAC CTG GAC AAC CTC AAG GGC ACC TTT GCC ACA CTG AGT GAG CTG
CAC TGT GAC AAG CTG CAC GTG GAT CCT GAG AAC TTC AGG
GTGAGTCTATGGGAC CCTTGATGTTTTCTTTCCCCTTCTTTTCTATGGTTAAGTTCATGTCATAGGAAGG
GGAGAAGTAACAGGGTACAGTTTAGAATGGGAAACAGACGAATGATTGCATCAGTGTGGAAGTCTCAG
GATCGTTTTAGTTTCTTTTATTGCTGTTCAACAATTGTTTTCTTTGTTAATTCTTGCTTTCTTTTTT
TTCTTCTCCGCAATTTTTACTATTATACTTAATGCCTAACATTGTGTATAACAAAAGGAAATATCTCTGA
GATACATTAAGTAACCTTAAAAAAAACCTTACACAGTCTGCCTAGTACATTACTATTTGGAATATATGTGT
GCTTATTTGCATATTCATAATCTCCCTACTTTATTTTCTTTTATTTTAAATTGATACATAATCATTATACATA
TTTATGGGTTAAAGTGTAATGTTTTAATATGTGTACACATATTGACCAAATCAGGGTAATTTTGCATTTGT
AATTTAAAAAATGCTTTCTTTAATACTTTTTGTTTATCTTATTTCTAATACTTTCCCTAATCTCT
TTCTTTCAGGGCAATAATGATACAATGTATCATGCCTCTTGCACCATTCTAAAGAATAACAGTGATAATT
TCTGGGTTAAGGCAATAGCAATTTTCTGCATATAAATTTCTGCATATAAATTGTAAGTACTGATGTAAGAG
GTTTCATATTGCTAATAGCAGCTACAATCCAGCTACCATTCTGCTTTTATTTTATGGTTGGGATAAGGCT
GGATTATTCTGAGTCCAAGCTAGGCCCTTTGCTAATCATGTTTCATACCTCTTATCTTCCCTCCACAG
CTC CTG GGC AAC GTG CTG GTC TGT GTG CTG GCC CAT CAC TTT GGC AAA GAA TTC ATC CCA
CCA GTG CAG GCT GCC TAT CAG AAA GTG GTG GCT GGT GTG GCT AAT GCC CTG GCC CAC AAG
TAT CAC TAA
GCTCGCTTTCTTGCTGTCCAATTTCTATTAAGGTTCCCTTGTCCCTAAGTCCAACACTAAACTGGGG
GATATTATGAAGGCCCTTGAGCATCTGGATTCTGCCTAATAAAAAACATTTATTTTTCATTGCAATGATGT
ATTTAAATTATTTCTGAATTTTTACTAAAAAGGGAATGTGGGAGGTCAGTGCATTTAAACATAAAGAAA
TGATGAGCTGTTCAAACCTTGGGAAAATACACTATATCTTAAACTCCATGAAAGAA

Taken from BSCS: *Human Genetic Variation*

Activity Seven: Mutation Challenge

Student Notes

Challenge

Here is your chance to demonstrate all that you know about mutations by designing and building a simulation/demonstration for the Genetic Technology with a Twist exhibit at The Tech Museum of Innovation. Your simulation will demonstrate the mutation process with the materials provided. In designing your model the following constraints must be considered:

Constraints

- the process that causes the mutation
- the type of mutation that occurs: point, insertion and/or deletion
- how often the mutation occurs which is called the mutation rate
- whether the mutation is neutral, beneficial or detrimental
- if selective pressures affect the mutation, what they are and how do they affect the mutation
- how the mutation will affect the population of a species over time
- the name of your mutation and on what chromosome it is found

Requirements

Presentation

- As a group, you will demonstrate to the class how your model works to fulfil all the above constraints.
- Each person within a group must make contributions to the design, building and presentation of their model.

Design Journal

As an individual you will be responsible for turning in a design journal that contains the following:

- labeled illustrations of the group's and your design ideas
- notes that accompany the illustrations include reasons for trial designs, performance of trial designs as you tested them, outcomes of testing trials
- a detailed, labeled illustration of your group's final design
- a detailed description of how your design works which includes the name of the mutation, its type, its mutation rate, whether the mutation is affected by selective pressures, what those pressures are and how the mutation will affect a species population over time

Reflective Questions

As an individual you are responsible for completing the reflective questions related to this design challenge. Include your responses at the back of your design journal.

- What specifically did you contribute to the design of your group's mutation model?
- In what way did designing and building your mutation model help your understanding of mutations?
- What problems did your group encounter in this activity? How were those problems solved?
- Describe something new that you learned from other groups as they were presenting.
- Name one thing you would do differently if you were to repeat this activity.

Activity Eight: Genetic Applications and Ethical Issues

Student Notes

Genetics in the Future

Mission

You have been chosen to represent Earth on a time travel mission. Using wormholes that connect the fabric of space and time, you will be traveling to the future. It is the year 2050. There are 9.1 billion people on the planet Earth. What is this world like? How has biotechnology impacted the world? What role does genetics play in this future world? Your report will help present day Earth inhabitants as they consider if changes should occur today on Earth in order to avoid or improve the future Earth.

You have been asked on this mission because of what you know about genetics. Most importantly, you will be using your expertise to determine how genetics is being used and/or misused in the year 2050. How has genetics impacted our future? When you return to present day Earth, you will present your confidential findings to The Genetics and Ethics Council. The code name for this mission is **Genoethos**. Refer to it by its code name ONLY as it is imperative that it remain confidential. These instructions will self-destruct in 10 minutes.

Guidelines

Your *Genetics in the Future* report can be presented in many forms which include the following:

- drawing, painting, 3-dimensional art form
- poetry, 2005 recored laws related to genetics, diary or log from a 2005 inhabitant
- skit—1 scene with written script
- video or computer presentation
- music compilation with detailed explanation of the reasoning behind the music
- music performance with written composition

It is important to remember that you are reporting on the genetics of the future. There will be other operatives investigating other aspects of the future. Keep in mind how genetics is being used and what its impact is or will be in the future world. The council expects **accurate representations of genetics, its potential applications (how it is being used) and ethical (pros & cons) considerations**. We have chosen you because of your expertise and creative mind. We are confident in your ability to help us to secure the genetic information that will enhance the lives of The Earth's inhabitants.

Council Report Assessment

The council will be assessing your success in the following ways:

Areas of Interest

Council Notes

Accurate Genetics Concepts	_____	10 pts
Future Genetic Applications	_____	10 pts
Ethical Considerations	_____	10 pts
Creativity & Effort	_____	10 pts
Mission Total Points	_____	40 pts

Good luck on your mission. We look forward to your safe return in 3 days. If you encounter any emergency situations, abort the mission and return to present day Earth immediately. We can not risk your death or *Genoethos* getting into the wrong hands. Be safe!