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Introduction:

Few scientific endeavors have broader implications than the exploration into the human genome. Discovering the secret of how life works has driven scientific explorers for millennia, but only recently has total understanding of the human genome been so close. Within our grasp is the day when diseases like cancer are cured, when disorders like sickle cell anemia are corrected in the womb, and when guilt and innocence in criminal investigations are more certain.

And with the help of the exhibit Genome: The Secret of How Life Works and this guide, an understanding of the human genome is within the grasp of your students! The exhibit gives your students the opportunity to explore the depths of DNA in a way never possible. In turn, this guide is designed for you and your students to discover all there is in the exhibit by providing you with lesson plan ideas that link to your classroom objectives.

Overall Organization:

Within its two distinct sections — one for grades 4-8 and another for grades 9-12 — this guide mirrors the organization of the exhibit. In other words, like Genome: The Secret of How Life Works, this guide follows a path that gradually digs deeper into DNA — beginning with an emphasis on what makes each of us unique and moving to what the future holds for thorough understanding of the human genome.

As a result of this organization, you will find eight science lesson plans that build on and enhance different parts of the exhibit. Each plan is independent, allowing for flexibility. At the same time, the lesson plans complement one another and give you the opportunity to explore the human genome using as many of the lesson plans as you feel are appropriate for your classroom and your goals.

Also, it may well be worth your time, to investigate the "other" curriculum unit (the high school section, if you are a middle school teacher – and vice versa). For example, with only minor modifications, lessons seven and eight in the elementary/middle school unit can be adapted into terrific high school lesson plans.

Lesson Plan Fields:

All of the lesson plans include the following fields to help you pinpoint which are most beneficial for you and your students:

- Curriculum Connection outlines some of the ways a lesson plan can fit into your existing curriculum, often indicating whether students need any specific prior knowledge related to DNA.
- Exhibit Link explains the connection between the lesson plan and Genome: The Secret of How Life Works.
- Extensions & Modifications indicate many ways to tailor a lesson plan to better match your needs and your students' abilities, often including suggestions on how to extend a lesson into other areas of the curriculum. Additionally, the grades 4-8 section clearly delineates suggestions for making a lesson plan appropriate for elementary school or middle school.
- Discussion Questions/Writing Prompts provide topics to discuss and/or write about. In the course of the lesson, you should use them whenever you feel it is most appropriate because some may work best as a way to gauge prior knowledge while others may be better for assessing what students have learned.

In addition to the steps for completing the lesson and the fields mentioned above, you will see that the lesson plans also include helpful information such as:

- clear objectives
- important terms defined in the glossary
- additional resources for you and/or your students*
- materials and time needed for completion
- links to national science standards
- resource lists

A glossary follows the lesson plans.

We hope that this guide provides you with many ideas on how your students can explore the exciting world of the human genome. In the process they are sure to discover more about themselves, more about the quest to crack the code, and more about the important role that science plays in our future.

* All suggested web links were active at the time of this guide's publishing.

UNIT 1

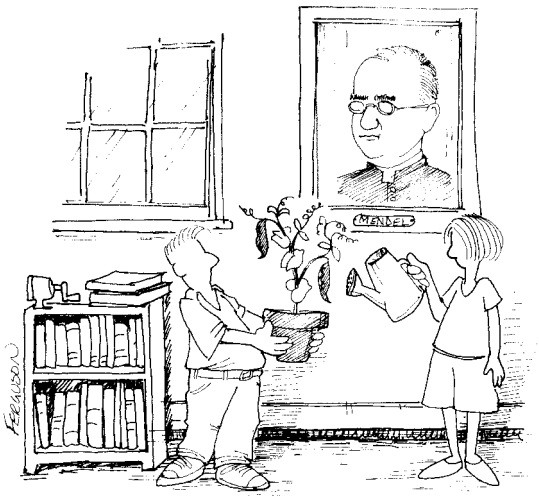
Grades 4-8
Science

EMS Lesson 1: Variety is the Spice of Life

(Pre-Exhibit Visit)

Objective:

After completing this lesson, students will have an understanding that dominant and recessive traits occur in a variety of combinations in any given group of people.



Curriculum Link:

This lesson is designed to reinforce the concepts that 1) human traits are controlled by dominant and recessive genes, and 2) some traits are learned, not inherited. It would work well after an introduction to Gregor Mendel's pea experiments. Students should be familiar with the process of conducting a survey with a random population. This lesson will help build the foundation students will need to work with Punnett squares and to understand the role of probability in heredity.

Exhibit Link:

Heredity: Which of these inherited traits do you have? *Heredity Slots* – Inheritance: A game of chance.
This portion of the exhibit explains how common single-gene traits such as a widow's peak and attached ear lobes are passed from parent to child through the laws of probability.

Time Required:

Teacher Preparation: 30 minutes *Class Time:* 30-45 minutes (allow three days to a week for student surveys outside of class)

Materials Needed:

- A working copy and final copy of the following table for each student.

Trait Survey Data Table				
Total Number of Interviewees:				
	Trait 1	Number	Trait 2	Number
A	Free Ear Lobes		Attached Ear Lobes	
B	Hair on Fingers		No Hair on Fingers	
C	Widow's Peak		No Widow's Peak	
D	Naturally Curly Hair		Straight Hair	
E	Cleft Chin		Smooth Chin	
F	Drive Car		Not Drive Car	
G	Play Gameboy		Not Play Gameboy	

- Small mirror for each student or groups of students
- Generic pictures or simple drawings depicting the traits used in this lesson

Lesson Steps/Activity:

1. Introduce or review Mendel's studies with the class, based on students' abilities. At minimum, students should know that certain visible traits are passed on to offspring and that some traits are dominant and others are recessive.
2. List on the board or an overhead the dominant and recessive traits from the chart that will be used in the survey, and show pictures or describe what each looks like.
   Emphasize that neither a dominant nor recessive trait is more desirable than the other and that different combinations of

both dominant and recessive traits contribute to each person's uniqueness.

3. Divide the class into small groups if you wish. Instruct students to use the mirror to examine their earlobes, hairline, and chin. Call out the traits one at a time and have students stand if they have that trait. You can also call out different combinations of two or more of the traits, so students can see if they share combinations of traits.
4. Distribute the data sheets, and tell students they will each survey 20 people to gather data about certain common traits. Before they begin the survey, have students predict (hypothesize) whether they think there will be more dominant than recessive traits in their sampling, or if the traits will be evenly distributed. (Note: In the general population, the dominant trait of free earlobes is more common, while the recessive traits that are usually more common include smooth chin, straight hair, no widow's peak, and no hair on fingers.)
5. After students have collected their data, have them share results with the whole class. Have a whole class discussion, which can include the "Discussion Questions" listed below. Use a transparency of the student data sheet to compile class totals.

Extensions & Modifications:

Elementary:

- Depending on grade level, you may want to reduce the number of traits in the survey, or the number of persons to be surveyed.
- Have shy students or those with limited access to a sample population work with a partner.
- Arrange with another teacher to allow her class to serve as survey samples.

Middle:

- Expand the discussion of Mendel's work to include purebreds and hybrids.
- Using the class totals, have students calculate what percent of the total sampling had each of the traits. Discuss how these results compare to the common trends mentioned in step #4 above.

Important terms: widow's peak, cleft chin, dominant trait, recessive trait, survey
Additional Middle School terms: hypothesis, hybrids, purebreds

Writing Prompts/Discussion Questions:

1. Were there any traits that you had that you had not noticed before?
2. Describe how your data does or does not support your prediction (hypothesis).
3. Why do you think recessive traits are more common in some cases?
4. How do you think doubling the sample would affect the survey?
5. What factors affected the results of traits F and G?

Additional Resources:

DNA from the Beginning — http://www.dnaftb.org/dnaftb/
A wonderful educational website containing basic information on DNA and genetics. Contains video clips, animations, and great links.
Textbook — Biology: The Dynamics of Life. Glencoe, 2002

National Standards Addressed:

K-4 Content Standard C – Life Cycles of Organisms

- Plants and animals closely resemble their parents.
- Many characteristics of an organism are inherited from the parents of the organism, but other characteristics result from an individual's interactions with the environment. Inherited characteristics include the color of flowers and the number of limbs of an animal. Other features, such as the ability to ride a bicycle, are learned through interactions with the environment and cannot be passed on to the next generation.

5-8 Content Standard C – The Molecular Basis of Heredity

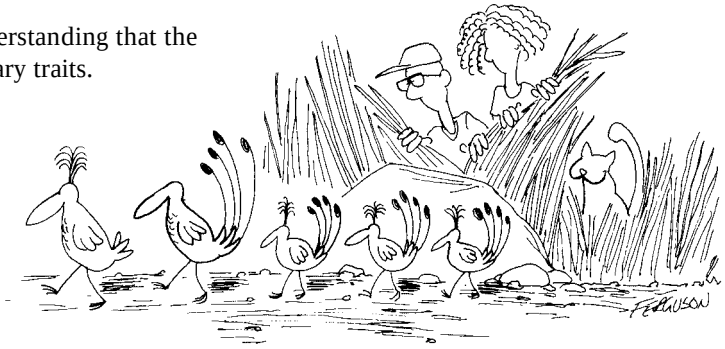
- Every organism requires a set of instructions for specifying its traits. Heredity is the passage of these instructions from one generation to another.
- Hereditary information is contained in genes, located in the chromosomes of each cell. Each gene carries a single unit of information. An inherited trait of an individual can be determined by one or by many genes, and a single gene can influence more than one trait. A human cell contains many thousands of different genes.
- The characteristics of an organism can be described in terms of a combination of traits. Some traits are inherited and others result from interactions with the environment.

EMS Lesson 2: Outrageous Offspring

(Post-Exhibit Visit)

Objective:

After completing this lesson, students will have an understanding that the principles of probability can be used to predict hereditary traits.



Curriculum Link:

This lesson reinforces the concept that inheritance is like a game of chance. It would work well as an introduction to the study of genetics and heredity. Additionally, students will apply prior knowledge of mathematical probability to the process of single gene inheritance.

Exhibit Link:

Heredity Slots: Inheritance: A game of chance
In this part of the exhibit, heredity is compared to a game of chance. Using the Punnett square helps students graphically display the outcomes of chance or probability.

Time Required:

Teacher Preparation: 30 minutes *Class Time:* 30-45 minutes

Materials Needed:

- Box, bag, or basket from which to choose slips of paper with traits written on them
- Generous supply of colored markers or crayons, scissors, double-sided scotch tape
- Two colors of felt material or construction paper; OR stencil letters or small pieces of paper with one upper or lower-case letter per piece of paper
- Enough Outrageous Offspring traits/alleles (either colors or letters) for each pair of students to have 12; (with colors: quarter-sized dominant traits and dime-sized recessive traits for students to use; larger sizes for teacher demonstration)
- Worksheets with a Punnett square large enough to accommodate the felt or letters, and empty space at the bottom for drawings

Lesson Steps/Activity:

1. After reviewing the principles of probability, have partners predict the outcome of 20 coin tosses, (or have each student toss a coin and compare outcomes with a partner) and then proceed with the coin toss, recording outcomes on a simple chart.
2. Have students share and compare the outcomes. Reinforce the concept that since there are two sides to a coin, there is one chance in two (1/2 or 50%) that the outcome will be heads up. Tell students they will see in this lesson how the same law applies to genetic outcomes.
3. Before the lesson, decide on a wacky set of traits generated by matching two imaginary creatures. Example: a Red-breasted Daffy Bird and a Green-breasted Daffy Bird. Red represents the dominant trait, and Green the recessive.
4. Demonstrate how to use upper case letters to represent dominant traits/alleles, and lower case letters for recessive traits/alleles. Tell students that scientists such as Mendel used the Punnett square to demonstrate the probable offspring of two parent's organisms. (While Mendel's traditional pea plant model shows crosses for height (T=the dominant tall trait; t=the recessive short trait), this example uses the Daffy Bird traits. Feel free to substitute the pea plant height traits if you wish.)

Red-Breasted Daffy Bird

Green-Breasted Daffy Bird		R	r
	r	Rr	rr
	r	rr	rr

5. Emphasize that this model shows two forms (alleles) of the same gene, and therefore it is abbreviated with two forms of the same letter R=red; r=green).

6. Explain that in this example there are two letters for each trait, because each parent has two traits but passes only one on to each offspring. Hence, the law of probability. In this case it is a cross between one green parent with two recessive traits (rr) for color and one red parent with a dominant trait and a recessive trait (Rr) for color.
7. Have each pair of students choose four letters from the box/bag/basket at random, and set them up as the parents, using two for Mom and two for Dad. RR or Rr = Red-breasted Daffy Bird, and rr=Green-breasted Daffy Bird. After students have set up the Punnett square, have them return to get the correct letters to complete the problem (or simply have students write in the correct letter). Then, have them draw and color in their four Outrageous Offspring.
8. Have student groups explain their outcomes to the class.

Extensions & Modifications:

Once students have worked with the Punnett squares, they could toss two coins at a time in order to see how the probabilities work out with four traits/alleles (the two that each parent has). Heads can represent a dominant trait and tails a recessive trait; thus only when both coins come up tails would the "offspring" display the recessive trait.

Elementary:

- Instead of using letters, use colored shapes (such as circles cut from felt or construction paper) to represent different alleles. Make the circle for the dominant trait (red) larger than the circle for the recessive trait (green). On a large sheet of paper, demonstrate how four combinations of offspring can result by pairing one trait of each parent four different ways.
- Explain that the red circle represents the trait we can see, whether it pairs with another red or with a green. Show the red/green combination by covering the green circle with the red. Show that the green trait can only be seen if there are two of them together.
- If students have already covered conversion of probability to fractions and percent, have them write each phenotype and/or genotype outcome as a fraction and percent.

Middle:

- Have students write each outcome as a fraction and a percent.
- Extend the offspring into an additional generation. Have students pair one of their offspring with the offspring of another pair of students, create a Punnett square for the two birds, and see what possible third-generation offspring could result.

Important terms: heredity, trait, offspring, probability
Additional Middle School terms: gene, phenotype, genotype, homozygous, heterozygous, allele, Punnett square

Writing Prompts/Discussion Questions:

1. Why do you think a dominant gene is referred to as "dominant"?
2. Identify the genotype (genetic makeup) and phenotype (physical appearance) of each of your offspring.
3. What is the probability that your parent sets could produce each of the four offspring?
4. Explain why each offspring is the color that you depict in your pictures.
5. Which of your offspring are homozygous? Heterozygous? Explain.
6. If brown eyes are a dominant trait, how could two brown-eyed parents have a child with blue eyes (a recessive trait)?

National Standards Addressed:

K-4 Content Standard C – Life Cycles of Organisms

- Plants and animals closely resemble their parents.
- Many characteristics of an organism are inherited from the parents of the organism, but other characteristics result from an individual's interactions with the environment. Inherited characteristics include the color of flowers and the number of limbs of an animal. Other features, such as the ability to ride a bicycle, are learned through interactions with the environment and cannot be passed on to the next generation.

5-8 Content Standard C – The Molecular Basis of Heredity

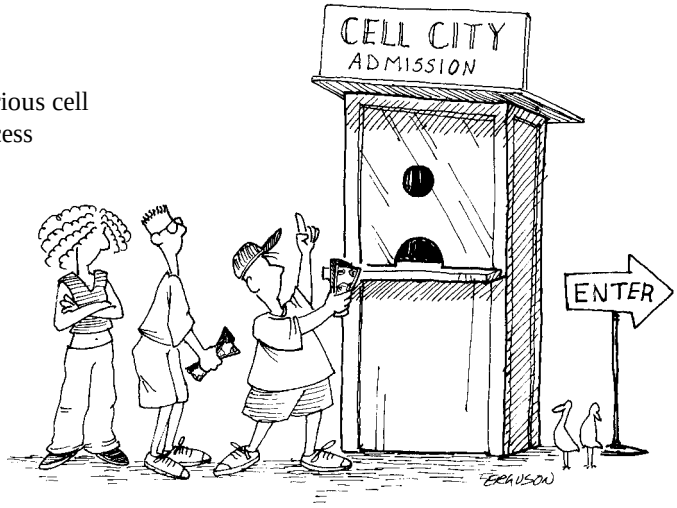
- Every organism requires a set of instructions for specifying its traits. Heredity is the passage of these instructions from one generation to another.
- The characteristics of an organism can be described in terms of a combination of traits. Some traits are inherited and others result from interactions with the environment.

EMS Lesson 3: Cell City

(Post-Exhibit Visit)

Objective:

By the end of the lesson, students will understand how various cell parts function and how they are related to the genetic process by creating a model and symbol to depict the function of the cell parts.



Curriculum Link:

This lesson introduces students to the names and functions of cell parts as a foundation to the study of heredity. Following a visit to the exhibit, teachers may refer to the Cell Explorer as students create their own models of a cell.

Exhibit Link:

Cell Explorer: Cells, Cells, and More Cells
In this section of the exhibit, students are able to view magnified sections of cells and identify the parts.

Time Required:

Teacher Preparation: 20 minutes *Class Time:* 30-45 minutes

Materials Needed:

- Overhead projector, slides, or large diagram of an animal cell with parts labeled.
- Construction paper, yarn, glue, old magazines that can be cut up
- Colored markers, crayons, scissors
- Two pieces of white butcher paper cut approximately three ft. square with a large circle on each

Lesson Steps/Activity:

1. On one large paper circle, have students think of a city and how it operates. Draw and label figures within the circle that represent key buildings and people that are important for a city to run smoothly. Prompt students with questions like the following: Who protects the city? Where do we get electrical power? Where do we get food? How do you know when you are out of city limits? etc.
2. Display a picture or diagram of an animal cell with its parts labeled. (See additional resources.)
3. Discuss the fact that each cell part has an important function, just like parts of a city. Explain that some parts of a cell are directly involved in the genetic process, while other parts take a supporting role but are still necessary to the whole cell. Tailor the complexity of the discussion and the number of cell parts discussed to student ability level.
4. Divide the class into small groups, and assign a cell part to each group. Instruct them to research the cell part to determine its function. Challenge them to think of a creative way to depict the function. Example: the cell membrane could be pictured as a gatekeeper, border guard, etc., because it determines what enters and leaves a cell.
5. Have each group cut out, draw, or construct a picture to represent the cell part's function. When each group is finished, have them attach their creation to another three-foot paper circle, which represents a cell, and explain the function and the symbol to the class. Pay special attention to the cell parts' genetic functions.

Extensions & Modifications:

Elementary:

- Have a supply of resource books available in the classroom for the students to use.
- After each group has attached its part to the large cell diagram, have all the students enter the cell parts and their definitions in a science journal or vocabulary list.
- In the science journal, suggest that each student use an analogy or metaphor that was presented in class for each cell part, or make up their own.

Middle:

- Give all the students the cell part names and have each student group research the function of the parts and come up with a unified theme or metaphor to represent the functions.
- Require each group to compose two test questions and answers from their research. When all the groups are finished, use the questions and/or answers to play a form of Jeopardy! or some other game of team competition

Important terms: cell, nucleus, cell membrane
Additional Middle School terms: organelle, mitochondrion, cytoplasm, ribosome

Writing Prompts/Discussion Questions:

1. What do you think would happen to a cell if (name the cell part) were missing or not functioning properly?
2. How is a cell like a city?
3. What do you think is the most important part of a cell? Why?
4. Why do you think we used analogies in this lesson to learn about the different parts of cells? Was it helpful?
5. A cell is microscopic — much smaller than what we can see with the naked eye. Are you surprised that so much happens in a cell, despite its size?

Additional Resources:

Biotech Adventure: http://biotech-adventure.okstate.edu/low/basics/
CELLS Alive!: http://www.cellsalive.com/
Both of these sites detail the parts of a cell.

National Standards Addressed:

5-8 Content Standard C – The Molecular Basis of Heredity

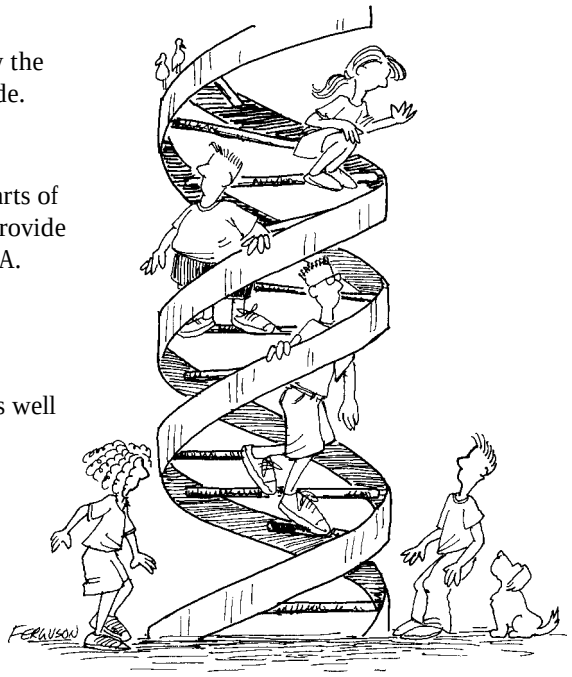
- Living systems at all levels of organization demonstrate the complementary nature of structure and function. Important levels of organization for structure and function include cells, organs, tissues, organ systems, whole organisms, and ecosystems.
- All organisms are composed of cells — the fundamental unit of life. Most organisms are single cells; other organisms, including humans, are multicellular.
- Cells carry on the many functions needed to sustain life. They grow and divide, thereby producing more cells. This requires that they take in nutrients, which they use to provide energy for the work that cells do and to make the materials that a cell or an organism needs.

EMS Lesson 4: Ladders of Life

(Pre-Exhibit Visit)

Objective:

By constructing a paper model of a strand of DNA, students will show the importance of the sequencing of four nitrogen bases in the genetic code.



Curriculum Link:

This lesson should be presented after students are familiar with the parts of a cell. A basic introduction to Mendel's work with genes would also provide a good foundation for understanding the location and function of DNA.

Exhibit Link:

Giant Double Helix; What is DNA?; Zip/Unzip!
These sections of the exhibit depict the double-helix shape of DNA, as well as explain how DNA unwinds and unzips into new strands.

Time Required:

Teacher Preparation: 45 minutes to one hour
Class Time: 45 minutes

Materials Needed:

- For every student, two each of 1-inch-wide strips of construction paper cut into the following colors and lengths: green, 2 inch; yellow, 2 inch; red, 4 inch; blue, 4 inch, (representing DNA's nitrogen bases)
- For every student, one 11-inch strip of paper that alternates black and white — white strips with black stripes drawn one inch apart with a magic marker (representing the sugar-phosphate molecule to which nitrogen bases attach in DNA)
- Glue or tape

Lesson Steps/Activity:

1. Use a chart or transparency to familiarize students with the DNA model. Explore DNA in a way that students recall prior knowledge of DNA and that allows you to gauge their understanding.
2. Before class, figure out a color scheme to represent the nitrogen bases. For example, Thymine = green, Guanine = blue; Cytosine = yellow; Adenine = red; sugar and phosphate molecules = white and black strips. Write this on the board.
3. Explain the rule that Adenine must always pair with Thymine (red with green) and Guanine must always pair with Cytosine (blue with yellow). Emphasize that the sequence of nitrogen bases in a gene forms a code that tells the cell what protein to produce. Traits are the result of actions of proteins in the organism.
4. Pass out two strips of each color to each student, and remind students what each color represents.
5. Have students work in pairs to attach seven nitrogen bases to the paper representing the sugar-phosphate molecule, and point out that the sequence they make is like a portion of the sequence in a gene. They may work out any sequence or code they want, leaving a small space between each colored strip.
6. Have pairs of students exchange strands and assemble a strand that is complementary to the one they receive. Have them attach the two strands with tape or glue.
7. If they have made the correct matches, the finished product should resemble a ladder that is always the same width.

Extensions & Modifications:

Elementary:

- Omit the names of the nitrogenous bases, but emphasize that in order for the code to be correct, red must always pair with green, and yellow with blue.
- Explain that the order of the colors along the gene is the code that makes each of us unique.
- Have pairs of students mount their “ladders” on a large piece of white butcher paper and try to find two completed ladders that are exactly the same.

- Have students look up references on James Watson and Francis Crick and write brief reports on one or both of them.

Middle:

- Instruct students to write the initials of the nitrogenous bases on each of their strips before attaching them to the gene.
- Have students write out the sequence of the nitrogenous bases of the strand they receive in the exchange, and then figure out on paper what the sequence of the complementary strand should be.
- When each group has a finished ladder, compile a chart that lists all the "genetic codes." Challenge the students to find any two ladders that are the same.
- Have students look up references on James Watson and Francis Crick and write brief reports on one or both of them. The report should include how they came to collaborate on the double helix model.

Important terms: gene, chromosome, strand, code, ladder, DNA
Additional Middle School terms: nitrogen base, adenine, thymine, guanine, cytosine

Writing Prompts/Discussion Questions:

1. What would happen to the DNA ladder if one of the rungs did not fit correctly?
2. Does it help you to have a visual image that represents DNA and colors that represent the parts of DNA?
3. If someone said that they didn't understand how DNA is like a ladder, how would you explain it to them?
4. If you built a three-dimensional version of the DNA ladder, how would you do it? Explain.

National Standards Addressed:

K-4 Content Standard C – Characteristics of Organisms

- Each plant or animal has different structures that serve different functions in growth, survival, and reproduction. For example, humans have distinct body structures for walking, holding, seeing, and talking.

5-8 Content Standard C – The Molecular Basis of Heredity

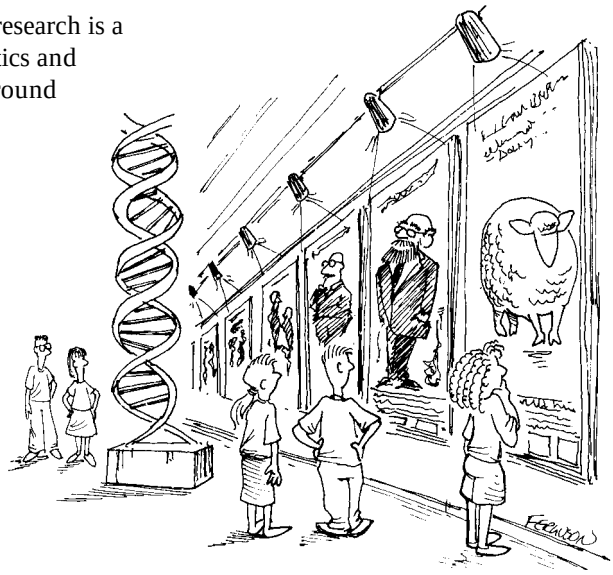
- Every organism requires a set of instructions for specifying its traits. Heredity is the passage of these instructions from one generation to another.
- Hereditary information is contained in genes, located in the chromosomes of each cell. Each gene carries a single unit of information. An inherited trait of an individual can be determined by one or by many genes, and a single gene can influence more than one trait. A human cell contains many thousands of different genes.

EMS Lesson 5: Genetic Hall of Fame

(Pre or Post Visit)

Objective:

By the end of the lesson, students will understand that genetic research is a relatively new field and that our current understanding of genetics and heredity is a culmination of the work of many scientists from around the world.



Curriculum Link:

This lesson could be used in any of three ways: 1) as an introduction to the study of genetics; 2) as an ongoing project during a unit on genetics; 3) as an end-of-unit project.

Exhibit Link:

Discovery Timeline
This part of the exhibit shows how many scientists made important discoveries towards the understanding of heredity, beginning with Mendel in 1865 and ending with the first draft of the human genome in 2000.

Time Required:

Teacher Preparation: One hour *Class Time:* Three to five 30-40 minute sessions

Materials Needed:

- Internet access for student research at web sites and/or printed material for student research
- White butcher paper six feet or longer, with dated timeline
- Slips of paper with topics for research
- Colored markers, crayons, yardsticks, and rulers

Lesson Steps/Activity:

1. Assign topics to students or groups of students, or have them choose from milestones that chart the progression of the understanding of human genetics and heredity. Have them research the subject in order to contribute to a class timeline. Following is a suggested list of milestones that might be included:
   - 1866 – Gregor Mendel discovers "factors," or genes.
   - 1911 – Thomas Hunt Morgan proves genes are carried on chromosomes.
   - 1943 – Oswald Avery discovers genes are made of DNA.
   - 1953 – Watson and Crick discover the structure of DNA (double helix).
   - 1961 – Sydney Brenner discovers messenger RNA.
   - 1973 – Stanley Cohen and Herbert Boyer clone genes by transferring a virus gene to bacteria.
   - 1975 – Fred Sanger and Walter Gilbert develop a technique to read chemical bases of DNA.
   - 1983 – Kary Mullis develops a "copying machine" to make copies of specified regions on DNA quickly in a test tube.
   - 1990 – Scientists propose to decode the human genome within 15 years.
   - 2000 – President Clinton announces that scientists have completed a first draft of the human genome.
2. When students have completed their research, have them write a brief explanation of the milestone and attach it to the appropriate place on the class timeline. Students should also share their findings with the class, likely expanding beyond what is included in their brief write-up.

Extensions & Modifications:

Elementary:
- Focus on events rather than inventors.

- Gather the resource material a week ahead of the assignment, and encourage students to begin browsing through the books/web sites.
- Keep the report to a paragraph or half page, and ensure that all the milestones can be depicted with a picture.
- If possible, ask a middle grade teacher to loan student volunteers to work as "consultants" during one or two of the sessions.

Middle:

- Give students a choice of focusing on the event or the inventor(s).
- Encourage students to come up with an event or date that is not on the timeline.
- If this is an introductory unit, give the vocabulary list a week ahead of time.
- Have students include other important events/people/discoveries from around the same time as the event/milestone that they report on.

Important terms: heredity, genetics, genes, human genome project
Additional Middle School terms: DNA, gene, chromosome, RNA, ribosome, clone, double helix

Writing Prompts/Discussion Questions:

1. Which event or inventor do you think had the most impact on the study of genetics? Why?
2. Are you surprised to learn that we have known about heredity, genes, DNA for as long as we have? Or are you surprised that it hasn't been that long? Explain.
3. Why do you think the human genome was discovered ahead of the original estimate of 15 years?
4. Do you think the study of genetics and heredity is important? Why?

Additional Resources:

Stories from the Scientists: http://www.accessexcellence.org/AB/WYW/wkbooks/SFTS/
The Human Genome Project: http://www.genome.gov/Pages/EducationKit/
Both of these sites are excellent sources for student research.

National Standards Addressed:

K-4 Content Standard C – Science as a Human Endeavor

- Men and women have made a variety of contributions throughout the history of science and technology.
- Although men and women using scientific inquiry have learned much about the objects, events, and phenomena in nature, much more remains to be understood. Science will never be finished.

5-8 Content Standard G – Science as a Human Endeavor

- Individuals and teams have contributed and will continue to contribute to the scientific enterprise.

EMS Lesson 6: Genetic Mistakes

(Post-Exhibit Visit)

Objective:

By the end of the lesson, students will have a general understanding of the characteristics of various genetic disorders, whether they can be cured or treated, and how they are diagnosed.

Curriculum Link:

After students have studied heredity from a cellular perspective, with depth of study having been determined by student abilities, this lesson relates genetic structure to physical manifestations of various disabilities.

Exhibit Link:

Understanding What It All Means; Genetic Testing; Mutation: A Recipe Change By Chance
This part of the exhibit explains what happens when the DNA is not copied correctly during cell division. Mutations make us unique but can also cause genetic disorders and certain diseases.

Time Required:

Teacher Preparation: 20 minutes *Class Time:* Two to three 30-45 minute classes

Materials Needed:

- Teacher and/or student resources on genetic disorders.
- 12x18-inch white construction paper, pencils, rulers for middle-schoolers to make a chart OR
- The following chart, including enough room to include answers, one for each elementary student

Genetic Disorder	Cause	Characteristics	Difficulties	Cure	Treatment
Cystic Fibrosis					
Sickle-cell Disease					
Hemophilia					
Down Syndrome					

Lesson Steps/Activity:

1. According to student ability, review the genetic process of how traits are passed from parents to children. Explain that sometimes mistakes occur in the process, causing mutations or changes in the expected outcome. Discuss mutations and genetic disorders with the class. Pose questions to the class such as: What do you think a genetic disorder is? What are some genetic disorders you have heard about? What experience, if any, have you had with someone who has one of these disorders?
2. Ask students if they know the difference between a cure and a treatment. Work toward definitions of the two terms. Ask how genetic diseases are different from the flu or chicken pox.
3. Divide the class into pairs, and assign the following disorders so that several pairs will work independently on the same one:

   1) Cystic Fibrosis
   2) Sickle-cell Disease
   3) Hemophilia
   4) Down's Syndrome

   None of these can be "cured" since even gene therapy would result in person who still has mutated gene in gamete. Watch difference between therapy (even gene therapy) and cure.
4. Have student groups use the comparative chart and the following questions to prepare a report and present it to the class:
   A. What causes the disorder?
   B. What are the characteristics of the disorder?

C. What difficulties might a person with this disorder experience? Are there any situations where a person with this disorder may have an advantage over one who does not? (SC—heterozygote has resistance to malaria)
D. Can this disorder be cured?
E. What kind of medical treatment is available for a person with this disorder?
F. How is this disorder diagnosed?
G. How do you think this disorder could be effectively treated?
H. How would you draw a diagram or use a Punnett square that illustrates the mutation that causes this disorder?

5. Have a follow-up class discussion, comparing findings of the different groups.

Extensions & Modifications:

Elementary:

- Assemble resource reading in classroom for students to browse in prior to this lesson.
- Omit questions F-H.

Middle:

- Guide students in a computer lab session to research the topics on the Internet using http://www.accessexcellence.org/AB/IWT/Gene_Therapy_Overview.html, and WebMD Web sites.
  http://www.yourgenesyourhealth.org/ygyh/mason/ygyh.html?syndrome=hemo
  http://www.pbs.org/wgbh/evolution/library/01/2/l_012_02.html
- Give students a 12x18-inch piece of construction paper to make a chart using the key words from questions A through F as headings on columns (cause, characteristics, etc).
- Have students respond to questions G and H on the back of the chart.
- Have students look up hemophilia in relation to the royal families of Europe. Pose the question: Do you think this disease had any effect on history in Europe?

Important terms: genetic disorder, mutation, treatment, cure
Additional Middle School terms: DNA, amniocentesis, karyotype

Writing Prompts/Discussion Questions:

1. Describe how you might know if one of your friends had cystic fibrosis.
2. If you had a friend whom you knew had hemophilia, how might it affect the kinds of activities you did together?
3. Do you think you should adjust your behavior around someone who has Down's syndrome? If so, how? Should you adjust your behavior around someone with cystic fibrosis?
4. Why do you think many people feel there will be a cure soon for some genetic disorders?

Additional Resources:

Human Genetics, A Resource for Teachers
http://www.usoe.k12.ut.us/curr/science/core/bio/genetics/home%20page.htm
This site provides basic information on many genetic disorders.

National Standards Addressed:

K-4 Content Standard C – Life Cycles of Organisms

- Many characteristics of an organism are inherited from the parents of the organism, but other characteristics result from an individual's interactions with the environment. Inherited characteristics include the color of flowers and the number of limbs of an animal. Other features, such as the ability to ride a bicycle, are learned through interactions with the environment and cannot be passed on to the next generation.

5-8 Content Standard C – The Molecular Basis of Heredity

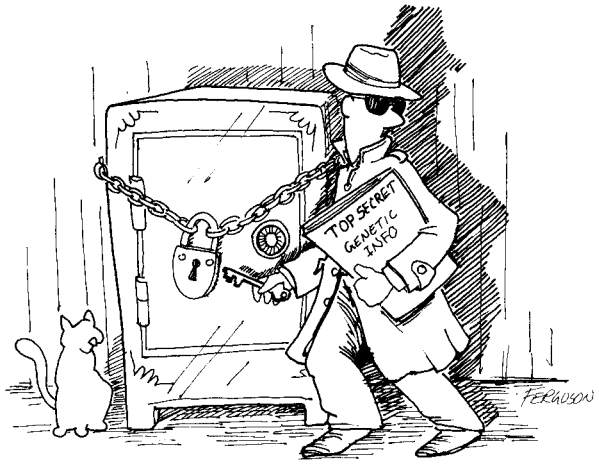
- Every organism requires a set of instructions for specifying its traits. Heredity is the passage of these instructions from one generation to another.
- Hereditary information is contained in genes, located in the chromosomes of each cell. Each gene carries a single unit of information. An inherited trait of an individual can be determined by one or by many genes, and a single gene can influence more than one trait. A human cell contains many thousands of different genes.

EMS Lesson 7:
Whose Genes Are These, Anyway?

(Post-Exhibit Visit)

Objective:

By the end of the lesson, students will be introduced to some of the ethical questions raised by genetic testing.



Curriculum Link:

After students have studied and discussed the genetic process of inheritance, including dominant and recessive traits, this lesson introduces the question of who (if anyone) has rights to knowledge of each person's genetic make-up.

Exhibit Link:

Action; Genetic Testing
These sections of the exhibit show that a new age of medicine is approaching with the help of genetic discoveries. It also mentions new methods of treating certain illnesses and understanding congenital defects — all of which raise ethical issues regarding privacy of genetic information.

Time Required:

Teacher Preparation: One hour *Class Time:* Two to three 30-45 minute sessions

Materials Needed:

- Teacher resources that deal with genetics-related ethical issues.
- Optional: An insurance agent, an employer from the community, a parent, a high school student, or others working in the field of genetics who are willing to speak to the class, or provide their point of view on rights to genetic information; or, adults willing to role-play these points-of-view.

Lesson Steps/Activity:

1. Lead a class discussion that emphasizes how each person is a unique individual, and that no two people are made up of the same combination of genes.
2. Discuss how doctors are now able to test patients to see if they are at a higher risk for certain conditions or diseases.
3. Have the class brainstorm ways that the results from genetic testing could affect the patient. If students do not generate negative effects on their own, introduce one such as the possibility that someone who tests positive for a higher risk of getting a certain disease may develop constant fear of getting the disease.
4. Have students offer opinions on who should have access to the test results and why. For example, should your employer need to know if you have hemophilia? What about your future husband or wife?
5. Assign groups of students to research and develop an argument for or against access to genetic test results for one of the following roles: insurance agent, employer, parent, high school graduate looking for a job. Make sure students understand the job description of each role and why a person in that position would be interested in having the results of genetic testing. Charge them with coming up with the most persuasive argument they can for the view they are assigned.
6. When the research is completed, have each group present a position paper and elect a representative to a class panel discussion. Have those who remain seated take notes and participate in questioning the panel.

Extensions & Modifications:

Elementary:

- Keep the lesson limited to a class discussion in which you raise questions for students to consider the pros and cons of knowing genetic information. When possible, give real-life examples that illustrate both sides to the question of knowing genetic information.

- Social Studies extension: If possible, arrange for an insurance agent and employer to speak to the class.

Middle:

- Social Studies extension: As an alternate approach, have students go in groups of two to interview various insurance agents, parents, and employers, and high school graduates looking for jobs. When they return, have students summarize the position the interviewee took, and take a stand agreeing or disagreeing with that position.
- Have student groups write or act out a story in which someone benefits from genetic testing or someone uses genetic information for evil purposes.

Important terms: genetic counselor, privacy, rights, unique, genetic make-up, genetic testing
Additional Middle School terms: ethics, bioethics, legality

Writing Prompts/Discussion Questions:

1. Discuss reasons why a person would seek genetic testing.
2. Why do you think the results of genetic testing should or should not be available to anyone who wants to see them? Defend your opinion.
3. Often topics like genetic testing have strong arguments for them and strong arguments against them. Can you think of another situation that has strong arguments on both sides of the debate?
4. Do you think that those who know the most about DNA should make decisions on how genetic testing should be used, or do you think the general population — who may know very little about DNA but are likely most affected by genetic testing — should make the decisions? Explain.

Additional Resources:

Genetics Lesson Plans
http://www.kumc.edu/gec/lessonpl.html
This site offers teacher resources on “ethical, legal, and social implications of the Human Genome Project.”

National Standards Addressed:

K-4 Content Standard C – The Characteristics of Organisms

- The behavior of individual organisms is influenced by internal cues (such as hunger) and by external cues (such as a change in the environment). Humans and other organisms have senses that help them detect internal and external cues.

Life Cycles of Organisms

- Many characteristics of an organism are inherited from the parents of the organism, but other characteristics result from an individual's interactions with the environment. Inherited characteristics include the color of flowers and the number of limbs of an animal. Other features, such as the ability to ride a bicycle, are learned through interactions with the environment and cannot be passed on to the next generation.

5-8 Content Standard C – The Molecular Basis of Heredity

- Every organism requires a set of instructions for specifying its traits. Heredity is the passage of these instructions from one generation to another.
- Hereditary information is contained in genes, located in the chromosomes of each cell. Each gene carries a single unit of information. An inherited trait of an individual can be determined by one or by many genes, and a single gene can influence more than one trait. A human cell contains many thousands of different genes.

EMS Lesson 8: And The Verdict Is...

(Pre-Exhibit Visit)

Objective:

By the end of this lesson, students will have a greater understanding of the unique pattern DNA forms in each individual, and how that pattern can be used to identify criminals.

Curriculum Link:

This lesson would work well following a discussion of genetic testing (see elementary/middle school Lesson 7) and patients' rights to privacy.

Exhibit Link:

DNA Detective
In this section of the exhibit, viewers will see samples of real DNA and have the opportunity to manipulate an interactive display to simulate the process of matching DNA samples to those taken at a crime scene.

Time Required:

Teacher Preparation: One hour *Class Time:* 30 minutes

Materials Needed:

- Enough commercial bar codes with numbers cut off for each pair of students to have seven — six that are different, plus a seventh that is the same as one of the six (mounted on heavy paper for re-use)
- Lab sheets or paper with room for recording observations.
- Hand magnifiers
- Ink pad(s)
- baby wipes or moistened paper towels

Lesson Steps/Activity:

1. Introduce the lesson with a discussion about the unique identity contained in an individual's genes.
2. Discuss the fact that DNA is like a fingerprint, in that it is unique to each individual and can be used to identify them, even though it is not visible to the naked eye.
3. Have students make their own fingerprints on the lab sheet. Have them get with a partner to compare fingerprints for similarities and differences.
4. Give each pair of students six bar codes, and tell them these represent the DNA samples of six suspects in a crime. Have them use the hand magnifiers to study the specimens and note the similarities and differences.
5. Give each pair of students one more bar code, representing the DNA of the blood found at the scene of a crime.
6. The bar code representing the crime scene sample will match that of one of the suspects.
7. Have a follow-up discussion that focuses on how DNA assists in solving crimes and in exonerating those who are accused but are innocent.

Extensions & Modifications:

Elementary:

- Make enlarged copies of the suspect bar codes and copy or glue them onto a piece of paper.
- Use fewer than six suspects.
- Emphasize that the genetic "fingerprint" is seen only with a powerful microscope.
- Math extension: Extending on the idea that a bar code is a series of geometric shapes, have students use geometric shapes — not limited to lines or elongated ellipses — to create a design on paper and exchange with another student. Have students try to recreate a "match" to the design without tracing the original.

Middle:

- It may not be necessary to do the introductory activity of student fingerprints.
- To increase the challenge, do one of the following:
    - Give the matching set to only one group of students.
    - Tell students the case is “urgent” and set a time limit.
    - Give one set one-half of the bar code (left or right) and ask if they can say with certainty who did it.
- Have student groups come up with scenarios for a crime involving six suspects but only one is guilty of the crime, and thanks to DNA evidence, the guilty party is convicted.

Important terms: bar code, genetic code, fingerprint, DNA

Writing Prompts/Discussion Questions:

1. Name some ways genetic fingerprinting could save lives.
2. How might genetic fingerprinting influence the outcome of a murder trial? How would the case be affected if the suspect whose DNA matched the evidence was an identical twin?
3. There are many examples of people in prison who were convicted without the aid of DNA evidence. For many, there is the ability today to test the evidence for DNA samples and compare it with samples of the convicted person; however, it is expensive to do so. Do you think that people who were convicted without DNA evidence should have their cases reexamined and DNA tested?
4. In your opinion, who should have easier access to your DNA, a trial judge or your employer? Why?

National Standards Addressed:

K-4 Content Standard C – Life Cycles of Organisms

- Many characteristics of an organism are inherited from the parents of the organism, but other characteristics result from an individual's interactions with the environment. Inherited characteristics include the color of flowers and the number of limbs of an animal. Other features, such as the ability to ride a bicycle, are learned through interactions with the environment and cannot be passed on to the next generation.

5-8 Content Standard C – The Molecular Basis of Heredity

- Hereditary information is contained in genes, located in the chromosomes of each cell. Each gene carries a single unit of information. An inherited trait of an individual can be determined by one or by many genes, and a single gene can influence more than one trait. A human cell contains many thousands of different genes.

UNIT 2

Grades 9-12
Science

HS Lesson 1: A UNIQUE INDIVIDUAL

(Pre-Exhibit Visit)

Objectives:

1. Students will know that DNA is the molecule that causes each individual to be different.
2. Students will relate the size and location of DNA to other parts of the body, such as the cell, nucleus, and tissues.

Curriculum Connection:

This lesson is a great introduction to a unit on DNA and genetics. Students will discuss differences and similarities among members of the class and connect these differences to their DNA. They will build on prior knowledge of DNA and complete an activity where the many words associated with the unit will be put into context. While this lesson will build on students' preconceptions about DNA, it does not require prior knowledge of DNA. However, students should have knowledge about the parts of the cell, enzymes, and organic molecules.

Exhibit Link:

This lesson connects with *The Secret of You* in the exhibit, by helping to put into perspective the fact that your genes and your DNA are the secret of you.

Class Time Required:

45 minutes

Materials Needed:

Enough for each pair of students to have one set of:

- Index Cards with the words: HUMAN BODY, ORGAN, TISSUE, CELL, NUCLEUS, GENOME, CHROMOSOME, GENE
- Index Cards with the words: ENZYME, NUCLEIC ACID, MONOSACCHARIDE, and NUCLEOTIDE

Focus Activity:

Have students work in pairs to make a list of ten differences between the two of them. This should be purposefully left open-ended. Have students also come up with three reasons behind these differences.

Lesson Steps:

1. Listen to answers from several sets of partners. If no one gives the answer, lead students to the idea that DNA is the major cause of the differences between them.
2. Have students make a simple DNA circle map. (This is a great way to find out how much students already know about the topic you are about to present.) To make their maps, students should draw a small circle with the word DNA in it and then draw a much larger circle around the first circle. Inside the outer circle, have students write down ten things they associate with DNA. Encourage them to write down any ideas they have, even if they are afraid the ideas might be wrong.
3. Discuss their answers and any misconceptions.
4. Allow students to work with the same partner as previously. Give each pair a set of index cards with the following words on them: HUMAN BODY, ORGAN, TISSUE, CELL, NUCLEUS, GENOME, CHROMOSOME, and GENE. The cards should not be in order.
5. Have students attempt to put them in order from largest to smallest. Students will probably not know ALL the answers, but resist the temptation to help them too much. Instead, answer their questions with questions such as: "Where is the

nucleus found?" "How big is a cell?" "What is a genome?" "What is a chromosome?" (Remember: A single human cell's DNA stretched out is 2 meters long so some orders may cause a debate depending on what students know.)

6. When students have finished, discuss answers, and have them make any necessary corrections.
7. Now give the groups an additional four cards: ENZYME, NUCLEIC ACID, MONOSACCHARIDE, and NUCLEOTIDE.
8. Instruct students to add the four cards to the other set of cards they have sequenced. This part will be more challenging. Chromosomes are smaller than the nucleus, but most molecules will be larger than enzymes, which are proteins. A chromosome is made up of BOTH nucleic acid and a histone protein. A nucleotide contains a monosaccharide, phosphate group, and a nitrogen base. The monosaccharide should be the smallest of all.
9. When students have finished, discuss correct answers, and again have them make any necessary corrections.
10. Have students define all words that have not been presented previously. (See important terms.)

Extensions & Modifications:

- Students could make a diagram of the human body and illustrate each of the words on the index cards in their diagram with the appropriate sizes, showing where each would be found. You may include a targeted, "zoomed in" section on the diagram that allows students to get to the components in a cell
- For more advanced students, skip Step 7 and instead have them come up with five to six related concepts and terms from previous units they have already studied.
- For lower level students, skip Steps 7 through 9.

Important terms: DNA, genome, chromosome, gene, nucleic acid, nucleotide

Writing Prompts/Potential Discussion Questions:

1. The major differences between you and someone else can be attributed to your DNA. However, twins have identical DNA yet do not always exhibit the same behavior and skills. Why?
2. When you were first conceived, you were made up of only one cell with only one copy of the DNA that make you who you are today. However, today you are made up of millions of cells, most of which contain copies of your DNA, the same DNA in that first cell. Talk about some things that had to happen to the original cell and DNA molecules from the moment of conception until present day. (Ex: growth, division)
3. The DNA that makes you who you are was passed to you by your parents. Discuss some ideas about why you and your brothers and sisters are not identical although you may have the same parents.
4. Were there any traits of your partner's that you had never noticed before? Any of your own traits that you had never noticed before?

Additional Resources:

DNA from the Beginning
http://www.dnaftb.org/dnaftb/
A wonderful educational website containing basic information on DNA and genetics. Contains video clips, animations, and great links.

Textbook — Biology: The Dynamics of Life. Glencoe, 2002

National Standards Addressed:

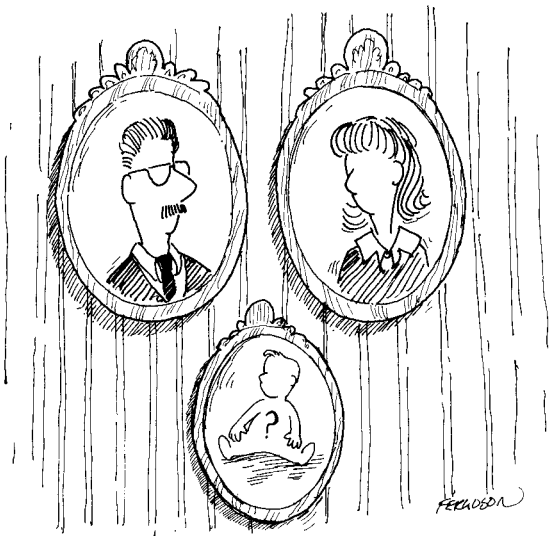
Standard C – The Molecular Basis of Heredity
In all organisms, the instructions for specifying the characteristics of the organisms are carried in the DNA.

HS Lesson 2:
How You Became a Unique Individual

(Post-Exhibit Visit)

Objectives:

1. Students will understand how traits are passed from parents to offspring via meiosis and fertilization.
2. Students will understand that the combination of alleles forming a gamete is random.



Curriculum Connection:

This lesson should be taught before teaching students how to do Punnett squares. Students should have a basic understanding of meiosis and the words gamete, gene, allele, dominant, recessive, homozygous, heterozygous, phenotype, and genotype.

Exhibit Link:

This lesson connects with *Heredity and Heredity Slots.* It reinforces the concepts of chromosome pairs and the random inheritance of traits from parents.

Class Time Required:

75 minutes

Materials Needed:

Each student needs to have two pairs of two 1”x1” squares stapled together of the following:

- Red construction paper labeled Chromosome A
- Green construction paper labeled Chromosome B
- Blue construction paper labeled Chromosome C
- Yellow construction paper labeled Chromosome D

Focus Activity:

Ask students to list some traits that could be passed from parents to offspring.

Lesson Steps:

1. Discuss their answers and tell students that they will focus on four traits in particular. List four traits on the board: hitch-hiker's thumb, widow's peak, tongue roller, freckles. Find students to use as models for the traits students are unfamiliar with.
2. Divide students into pairs. Distribute the handout, which has students identify whether they have the traits on the board and determine the traits of two hypothetical babies. Show students how to determine their own genotypes and phenotypes by modeling the procedure. Make connections between what they already know about meiosis and how gametes are made. Steps 2 and 3 of the handout represent the steps of meiosis, while Step 4 represents fertilization.
3. End class with discussion questions either verbally or written.

Extensions & Modifications:

- Classes could research further physical traits and repeat the activity with them.
- More advanced students could explore how the activity would change if two of the traits had been located on the same chromosome.
- For lower level students, write the alleles on each piece of construction paper ahead of time, then have the students fill

in the table and complete the activity.

Important terms: meiosis, gametes, heterozygous, genotype, phenotype, allele, hitch-hiker's thumb, widow's peak, tongue roller, chromosome

Writing Prompts/Potential Discussion Questions:

1. The process of meiosis produces sex cells, and fertilization is the combination of male and female sex cells to produce a baby. Explain what parts of this activity modeled meiosis and which steps modeled fertilization.
2. Discuss how the processes of meiosis and fertilization always ensure the number of chromosomes in a species stays the same.
3. Some humans are born with too many or too few chromosomes. How could this happen? Use the process of meiosis in your discussion.
4. Look at the two children you produced in this activity. It is unlikely that they are exactly the same. Human beings inherit thousands of traits from their parents. Using this activity, explain why it is unlikely that any two human beings that are not twins will be identical.

Additional Resources:

Human Traits Information Page
http://www.edquest.ca/Projects/GHTS/traits.html
Contains all traits in this activity plus many more with pictures of the traits

Hitchhiker's Thumb
http://www.ncrtec.org/tl/camp/gene/thumbs.htm
An excellent picture of the difference between hitchhiker's thumb and a normal thumb

National Standards Addressed:

Standard C – The Molecular Basis of Heredity

Most of the cells in a human contain two copies of each of 22 different chromosomes. In addition, there is a pair of chromosomes that determines sex: a female contains two X chromosomes and a male contains one X and one Y chromosome. Transmission of genetic information to offspring occurs through egg and sperm cells that contain only one representative from each chromosome pair. An egg and a sperm unite to form a new individual. The fact that the human body is formed from cells that contain two copies of each chromosome — and therefore two copies of each gene — explains many features of human heredity, such as how variations that are hidden in one generation can be expressed in the next.

HS Lesson 2 Student Handout: GENETICS OF PARENTHOOD

Name: _____

Date: _____

1. In this activity, we will be looking at four traits:
   - HITCH-HIKER'S THUMB – Don't have it (S) (straight thumb) Have it (s)
   - WIDOW'S PEAK – Have it (P) Don't have it (p)
   - TONGUE ROLLER – Roller (R) Non-roller (r)
   - PRESENCE OF FRECKLES – Freckles (F) Non-freckled (f)

   For each of the traits, you need to determine whether you have or do not have the trait. Record this information under phenotype. For example, if you do not have a hitchhiker's thumb you would write Don't Have it. Then, record your genotype. If you have the dominant trait, for the purpose of this activity make your genotype heterozygous. For example, if you do not have a hitchhiker's thumb, you could be SS or Ss. For our purposes you will record a Ss since that is the heterozygous genotype.

YOUR TRAITS		PARTNER'S TRAITS	
Phenotype	Genotype	Phenotype	Genotype

2. Now, write your genotype allele on the squares of construction paper given to you by your teacher. These squares represent chromosomes, which are made up of two identical sister chromatids. Use a different color for each trait and put one allele per pair of squares. For example, if your genotype is Ss, you would write an 'S' on each of one pair of red squares and write an 's' on each of the other pair of red squares. Your partner should do the same for his or her traits. Be sure to color coordinate with your partner so that if you chose red for your freckle trait that your partner also chooses red for freckles.
3. Now, "do meiosis" with your alleles, by making two stacks. Each stack gets one one pair of each color of squares. Choose your alleles randomly – without looking! You have just completed Meiosis I. Now, separate each stapled pair into individual squares so that you end up with four stacks. You have just completed Meiosis II and each stack represents the gametes for your possible baby! Write your alleles chosen below:

   _ _ _ _, _ _ _ _, _ _ _ _, & _ _ _ _

4. Choose one of your gametes from #3 and fill in your column in the table below. Share your gamete information with your partner, fill in the table and determine the phenotype of your first child (congratulations!).

   Randomly choose another gamete and repeat this step to determine the characteristics of Baby #2.

	BABY #1				BABY #2			
	Allele From You	Allele From Partner	Genotype	Phenotype	Allele From You	Allele From Partner	Genotype	Phenotype
Hitchhiker's Thumb								
Widow's Peak								
Tongue Roller								
Freckles								

HS Lesson 3: The Structure of DNA

(Pre-Exhibit Visit)

Objective:

Students will describe the structure of the double helix, explain how DNA copies itself, recognize that the sequence of DNA is what makes each individual unique, and recognize that similarities in the sequence of DNA indicate relationships and similarities between species.

Curriculum Connection:

This lesson should be taught at the beginning of a unit on DNA. It requires only basic knowledge that DNA is the hereditary material. Building on this knowledge, students will construct a model of DNA and model the process of replication.

Exhibit Link:

This lesson directly relates to *What is DNA?* in the exhibit, which explains the connection between DNA and genes and allows students to twist the double helix structure and connect new bases to create two new copies of DNA. It also connects with *How Similar Are You? and Zip/Unzip!*, which talk about similarities between DNA sequences in humans and various species.

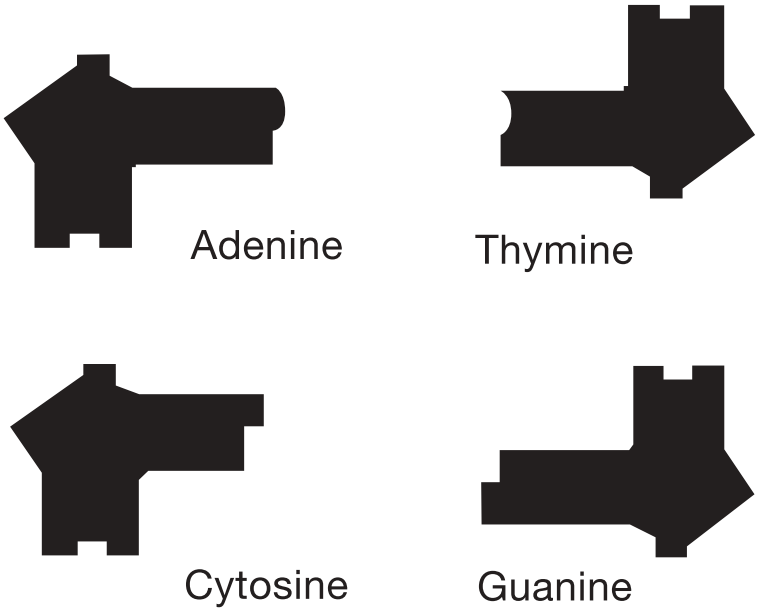
Class Time Required:

90 minutes

Materials Needed:

For each student:

- Crayons or markers
- Scissors
- Tape
- Paper
- Two copies of nucleotide pairs shown here



Focus Activity:

Divide students into pairs. Write the following sentences on the board:

1. Each cell's DNA would be six feet long if spread out.
2. Your DNA is 99.9% the same as the person sitting next to you.
3. Your DNA is 90% the same as a mouse.
4. Your DNA is 60% the same as a fruit fly.

Have students decide and provide reason why each of the statements is true or false. (All are true.)

Lesson Steps:

1. Tell students all statements are true. Ask what it is about DNA that makes them 99.9% similar to other humans. Have students contribute their own ideas, then lead them to the idea that the structure and sequence of DNA makes you unique. The more similar the DNA, the more closely related the species (or individual in a species) are evolutionarily.

2. Once you have established that the structure of DNA makes us both unique and similar to others, give students basic information about the structure. DNA is made up of nucleotides. Each nucleotide has three parts: five-carbon sugar (deoxyribose), phosphate, and a nitrogen base. There are four nitrogenous bases: adenine, thymine, cytosine, and guanine. These nucleotides join together to form two strands, with the nitrogenous bases connecting in the middle of the two strands. Adenine binds to thymine, cytosine to guanine. The two strands twist around each other to form what is known as a double helix. Show students a picture of a double helix.
3. Distribute the paper nucleotide replicas, crayons/markers, scissors, and tape to students. Students should still be in pairs; however each person will color, cut out, and construct his or her own model. Instruct them to color each part of the nucleotide a specific color. That is, color all phosphates one color, all deoxyriboses another color, all adenines another, etc. Then, instruct students to cut out each nucleotide and piece them together like a DNA molecule. One partner should tape his or her strands together but not tape them in the middle. (Students should be able to open and close the DNA strand that they build.) The other partner's model should be put together, but not taped anywhere. Let them know that they may have to be creative to get the helix to fit together (e.g., they may need to flip over some of the bases to get the other strand).

4. When finished, tell students you will use their structures to model the way DNA copies itself through replication. Have students take the model with the taped sides and separate the two strands. (This is the first step of replication, where the DNA molecule unzips.) Then they should use their partner's untaped nucleotides, bringing in each nucleotide and binding it to the appropriate base. (This is the second step of replication where free floating nucleotides come and bind to each of the old strands.) Finally, ask students to check their two new DNA strands to ensure they did not make any mistakes. (This is the third step of replication, where an enzyme checks for errors.)
5. When finished, have all students tape their models to a white piece of paper to display them. Talk about how to make strand with template and how each strand is part "old" and part "new" and think about why that might be a good way to copy and proofread.

Extensions & Modifications:

- Use all the DNA molecules built by the class to construct a giant molecule of DNA to display in your classroom.
- For lower level students, skip Step 4 and simply have students tape their models to a piece of paper for display.
- For more advanced students, do not write in adenine, thymine, cytosine, and guanine. Allow them to fill in the appropriate nitrogen bases in order to construct the model.

Important terms: DNA, nucleotide, nitrogen base, replication, adenine, thymine, cytosine, guanine

Writing Prompts/Potential Discussion Questions:

1. Your DNA is 98.4% similar to a chimpanzee and 50% similar to a banana. How can your genome be so similar to theirs? What do your cells have in common with banana cells? What is the same about the DNA? What does this suggest about your relationship to other species?
2. Every cell in your body, except your red blood cells contains a copy of your DNA. When you were first conceived, you were made of only one cell. Explain how important the steps of replication are in the growth and maintenance of your body.
3. Discuss why specific base pairing is essential in the process of replication.
4. Discuss the importance of the final step of replication where the enzyme checks for mistakes.

Additional Resources:

DNA Workshop – DNA Replication
http://www.pbs.org/wgbh/aso/tryit/dna/replication.html
This website sponsored through PBS, gives excellent basic information about DNA structure and replication.

DNA Replication
http://www.eurekascience.com/ICanDoThat/dna_rep.htm
This website is designed for younger kids, and gives an excellent simple explanation for the process modeled in this lesson.

National Standards Addressed:

Standard C – The Molecular Basis of Heredity

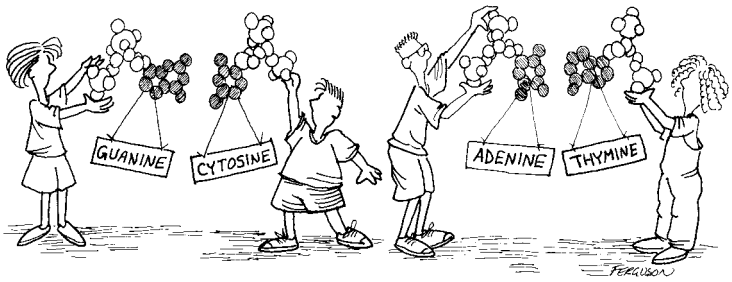
In all organisms, the instructions for specifying the characteristics of the organism are carried in DNA, a large polymer formed from subunits of four kinds (A, G, C, and T). The chemical and structural properties of DNA explain how the genetic information that underlies heredity is both encoded in genes (as a string of molecular "letters") and replicated (by a templating mechanism).

HS Lesson 4: Proteins, Proteins

(Pre or Post-Exhibit Visit)

Objective:

By completing this lesson, students will be able to explain how DNA directs the production of proteins.



Curriculum Connection:

This lesson should be taught after a lesson on transcription and translation. It is a supplemental lesson to reinforce the concepts of transcription and translation by modeling the processes. Students should know the steps of both processes and understand the words codon and anticodon. Students should have prior knowledge of the differences between RNA and DNA and the function of enzymes.

Exhibit Link:

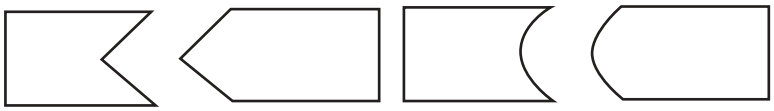
This lesson reinforces the ideas presented in *The Cookie Factory*, where the steps of protein synthesis are compared to the parts of the cookie factory. It also reinforces the importance of proteins as outlined in *What Are Proteins?*

Class Time Required:

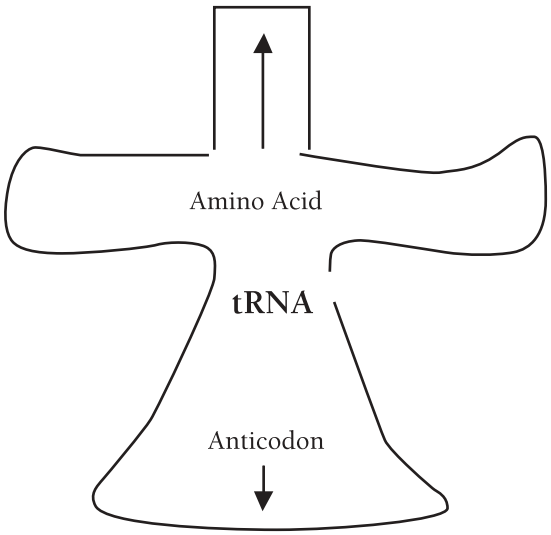
90 minutes

Materials Needed:

- For each student:
  a copy of the following shapes:



- Four different colors of construction paper – one sheet of each color
- 1”x12” strip of construction paper (a different color than the four above)
- Scissors
- Tape or Glue
- Paper clips
- Provide templates for tRNA (below)



Focus Activity:

Put students in pairs. Write the following words on the board in the following order: SUGAR, PROTEIN, DNA, FATS, WATER

With their partner, have students list the items from most abundant to least abundant in the human body. (They will not know the answer, but should just give it their best guess.)

Lesson Steps:

1. Ask students about their answers. In discussing their answers make sure that students know that the most abundant molecule in the body is water; second is protein. The relative amounts of DNA, sugar, and fats vary depending on the person, but you could discuss which one they suspect would be most abundant and why.
2. Discuss the importance of proteins. Many proteins act as enzymes, some serve as passageways into the cell, and some help provide structure in a variety of places in the body.
3. Review the processes of transcription and translation. Stress that

DNA is so important because it directs the production of proteins.

4. Write the following sequence on the board, and ask students if it is DNA or RNA: TACGGCACGATT. Have students copy the DNA sequence onto a piece of paper.
5. Review the process of transcription. Have students write down the RNA sequence that would come from the DNA on the board.
6. Pass out the supplies: base templates, paper, scissors, and glue or tape. Using their templates of the four RNA nitrogen bases, have students cut out the correct number of shapes that they need for their RNA strand. Use a different color for each different type of base. In order, have them tape the bases to the 1"x12" strip. (The sequence should be AUGCCGUGCUAA). They have just completed transcription.
7. Use a picture of a tRNA molecule to review with students what the tRNA molecule does. Have them cut out three tRNA-shaped molecules to help conduct translation.
8. Review what an anticodon is. For the first codon of AUG, ask students what the anticodon would be. Then, have them cut out a U an A and a C and tape them at the bottom of the tRNA molecule. Tape the bases so they will bind to the mRNA strand.
9. Ask what would be found at the top of the tRNA. Use the codon table in their books, and have them find that AUG is the codon for the amino acid methionine. Have them cut out a square and write methionine and paper clip it to the top of the tRNA molecule.
10. Repeat Steps 9 and 10 with the second codon. The anticodon should now be GGC and the amino acid should be glycine. With two tRNA molecules bound to the mRNA, tape or glue the first amino acid to the second amino acid. Once they have done this, that first tRNA is free to leave. Put it aside.
11. Repeat Steps 9 and 10 for codon three: anticodon AGC and amino acid cysteine. Staple or glue the first two amino acids to the third amino acid. Now, the second tRNA is free to leave.
12. The students should notice that the last codon is a stop codon. There is no tRNA molecule for a stop codon, so the process is now complete. Release the protein from the last tRNA.

Extensions & Modifications:

- For lower level students, make the mRNA sequence and tRNA molecules for the students, and allow them to simply model the steps.
- For more advanced students, type up a set of instructions for the students to follow and do the process more independently.
- To speed up the process, cut out the bases for the students and make the tRNA molecules ahead of time. They should still build the mRNA strand on their own.

Writing Prompts/Potential Discussion Questions:

1. Compare the steps of transcription and translation to the processes that take place within a cookie factory. Make analogies for each step along the way.
2. If you are made up of thousands of unique proteins in your body, what conclusions can you make about your DNA sequence? What could happen if your DNA sequence were disrupted in some way? Why might it be a good idea to use mRNA to direct protein synthesis. Rather than copying DNA directly?
3. Discuss the importance of each tRNA molecule carrying a specific amino acid. What would happen if the amino acid were not always the same for each anticodon?
4. What could happen if the DNA that resulted in a start or stop codon were damaged or mutated into something else?

Additional Resources:

Protein Synthesis – Power Point Slide Show
http://www.ccds.charlotte.nc.us/richards2/Protein%20Synthesis/sld001.htm
This gives a good overview of the whole process, but the graphics also represent very well the process that the students are modeling in this activity.
Textbook: Miller, Kenneth and Joseph Levine. Biology. Prentice-Hall, 2002.

National Standards Addressed:

Standard C – The Molecular Basis of Heredity

In all organisms, the instructions for specifying the characteristics of the organism are carried in DNA, a large polymer formed from subunits of four kinds (A, G, C, and T). The chemical and structural properties of DNA explain how the genetic information that underlies heredity is both encoded in genes (as a string of molecular "letters") and replicated (by a templating mechanism).

HS Lesson 5: Disproving the Proof

(Pre or Post-Exhibit Visit)

Objectives:

1. Students will realize that a progression of discoveries have led to the genetics knowledge that scientists currently have.
2. Students will understand how genetic experiments disproved previous theories on inheritance.

Curriculum Connection:

This lesson is best taught at the end of a unit on genetics. Students should have prior knowledge of Mendel's experiments and basic principles on the structure of DNA and how it controls the synthesis of proteins.

Exhibit Link:

This activity connects with *Discovery* and helps students better understand the purpose and sequence of discoveries made. It also connects with the stages of discovery as set forth in the exhibit: Discovering the Secret, Cracking the Code, Cut and Paste, and Racing to the Frontier.

Class Time Required:

One hour

Materials Needed:

- Paper & Pencil
- Biology Textbook

Focus Activity:

Review with students the current understanding of how genes are passed from parents to offspring. Each parent donates half of the chromosomes. The traits are passed as discreet units, etc. Remind them that we have not always believed or understood this to be the case. Have the students work in groups of two and come up with some alternative ideas that people might have once believed about how people got their characteristics.

Lesson Steps:

1. Discuss the students' answers. Then, write on the board the following ideas that people used to believe about heredity:
   A. (384 BC – 1800s) – Aristotle – Eggs and sperm formed from particles in the body called pangenes, which come together from all parts of the body, mainly the blood.
   B. (1600s) - Leeuewenhoek – All inherited traits come from the father; the mother is only the incubator of the offspring.
   C. (1600s) – Regnier de Graaf – All inherited traits come from the mother; the sperm is only the catalyst which stimulates the growth of the egg.
   D. (early 1800s) – Blending Theory – Traits of the parents are blended irreversibly, much as paints do, to form the traits of the offspring.
   E. (mid 1800s) – Darwin & Lamarck – Changes that occur in various parts of the body during a person's life could be passed on to the next generation.
2. Have students use their textbooks and/or other resources you select to find statements that show these ideas to be incorrect. Also have students find specific aspects of Mendel's experiment that showed these theories to be incorrect.
3. After discussing some of the students' answers, have them take on the roles of some of these scientists. (Assign each pair of students a scientist, or allow them to choose.) When Mendel's evidence was published, what kind of response might he have had? Have the students list questions that they would have asked Mendel. This can lead to a good discussion of how Mendel's work was received in real life.

Extensions & Modifications:

- As an extension to Step 3, you could become Mendel, and each student could come up with questions they would ask Mendel when he is presenting his findings.
- For lower level students, you could list some of the major principles from Mendel's experiment and allow them to match up these ideas with the theories that they disproved.
- More advanced students could come up with an experiment that might disprove our current understanding of inheritance.
- Discuss how science is built on experimental evidence and how all theories are both testable and falsifiable

Important terms: Gregor Mendel, heredity

Writing Prompts/Potential Discussion Questions:

1. One of the challenges of being a good scientist is to ensure that one's experiments answer a specific question and can be repeated with the same results. Every scientist studied in this activity is still revered because the evidence in their experiments was considered credible. With this in mind, what would you consider credible evidence in science?
2. It has taken over two thousand years to come to our current thinking about inheritance. Discuss the possibility that in two thousand years we could have a very different understanding of inheritance. Use the scientific method in your discussion.
3. Discuss how misperceptions of genetic traits might have affected people's attitudes and behaviors. For example, if 200 years ago people believed that all traits came from women, would that have raised women's perceived standing in society?
4. By the early 1900s, it was firmly established that both parents contribute equally to the child's traits and that acquired traits such as loss of a leg are not passed down to the children. Discuss ways that such discoveries might have changed decisions that parents might have made about having kids.

Additional Resources:

Taking a Chance on Heredity: How Gregor Mendel Solved a Basic Mystery of Heredity
By Stan Dick
http://classweb.gmu.edu/mgabel/unit2-math-web/mendel.pdf
This PDF available online provides information about various theories of heredity, focusing on Mendel.

National Standards Addressed:

Standard G – Nature of Scientific Knowledge

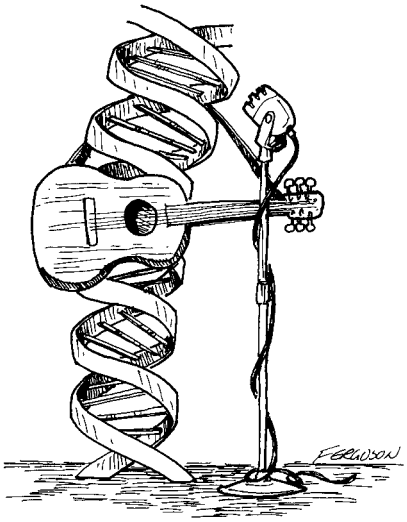
Because all scientific ideas depend on experimental and observational confirmation, all scientific knowledge is, in principle, subject to change as new evidence becomes available. The core ideas of science such as the conservation of energy or the laws of motion have been subjected to a wide variety of confirmations and are therefore unlikely to change in the areas in which they have been tested. In areas where data or understanding are incomplete, such as the details of human evolution or questions surrounding global warming, new data may well lead to changes in current ideas or resolve current conflicts. In situations where information is still fragmentary, it is normal for scientific ideas to be incomplete, but this is also where the opportunity for making advances may be greatest.

HS Lesson 6: Genome's Greatest Hits

(Post-Exhibit Visit)

Objective:

Students will realize that a progression of discoveries have led to the genetics knowledge that scientists currently have.



Curriculum Connection:

This lesson is best taught late in a unit on genetics. Students should have prior knowledge of Mendel's experiments and know that Watson and Crick discovered the structure of DNA. In this lesson, they will build on this knowledge learning the vast numbers of other scientists and experiments that were involved in understanding the human genome.

Exhibit Link:

This lesson connects to all of *Discovery* as a review of the contributions of the many scientists involved.

Class Time Required:

90 minutes

Materials Needed:

- Overhead transparency of the list of scientists and their discoveries

For each student:

- Markers or crayons
- Construction paper
- Scissors

Focus Activity:

Divide the class into teams of two or three depending on the size of the class. Show the accompanying reproducible on the overhead. Then, have the teams choose 10 of the scientists that they believe made the most important contributions to understanding the molecules behind heredity.

Lesson Steps:

1. Each team should now design a CD labeled "Genome's Greatest Hits." They should include the name of the artist or scientist and a song name that describes his or her contribution, e.g. Watson and Crick's "Twist that Helix."
2. They should design their CD out of construction paper and write in the names of each of the songs and artists.
3. They should then write a short refrain for two of the songs with lyrics related to the specific discoveries of the scientists.
4. If time permits, students should present their songs to the class and/or post them in the classroom.

Extensions & Modifications:

- After the lesson, students could write an entire song for one of the scientists as an individual project.
- For more advanced students, give each group one scientist, and have them research that scientist's major contribution to the field of genetics. Have each group summarize their findings in two sentences or less. Each group can write their information on the board, then proceed with the activity.
- For lower level students, skip Step 3.

Important terms: genome, RNA, gene, chromosome, codon, double helix, transgenic

Writing Prompts/Potential Discussion Questions:

1. If you were to exchange CDs with another group, their CD would probably contain a number of different scientists than the ones your group chose. Discuss the characteristics that make one discovery more important than another and why no two groups will agree on exactly the same ten scientists.
2. In the year 2000, the entire human genome was sequenced. Discuss how scientists as far back as 1865 contributed to this great feat.
3. Discuss some of the things scientists might be working on now that they have sequenced the entire genome. What might be some future "greatest hits"?

Additional Resources:

Human Genome Project Information
http://www.ornl.gov/hgmis/
Basic information sponsored by the U.S. Department of Energy.

Genetic Discoveries
http://www.cs.stedwards.edu/~kswank/HistoryTable.html
An extremely detailed table of all discoveries related to genetics. Contains more scientists than the ones listed in this activity.

National Standards Addressed:

Standard G – Science as a Human Endeavor

- Individuals and teams have contributed and will continue to contribute to the scientific enterprise.

Standard G – Historical Perspectives

- In history, diverse cultures have contributed scientific knowledge and technologic inventions.
- The daily work of science and engineering results in incremental advances in our understanding of the world and our ability to meet human needs and aspirations. Much can be learned about the internal workings of science and the nature of science from study of individual scientists, their daily work, and their efforts to advance scientific knowledge in their area of study.

HS Lesson 6 Reproducible

1865 – Gregor Mendel

1909 – Wilhelm Johannsen (coined the term “gene,” replacing Mendel’s word “factor”)

1911 – Thomas Hunt Morgan (proved chromosomes contained genes)

1939 – Rosalind Franklin, as a 19-year-old student, made the first sketch of a nucleic acid in the shape of a helix.

1943 – Osward Avery (Suggested genes are made of DNA, not protein)

1944 – Barbara McClintock (Some genes aren’t fixed on chromosomes, but can move around as “jumping genes”)

1952 – Hershey and Chase (Genes ARE DNA)

1953 – Watson and Crick (DNA’s structure is a double helix)

1957 – Elliot Volkin & Lazarus Astrachan (RNA involved in the making of proteins)

1961 – Sydney Brenner (RNA acts as a messenger in the making of proteins)

1961 – Marshall Nirenberg (discovered codons code for amino acids)

1968 – Hamilton Smith (discovered restriction enzymes that can snip pieces of DNA)

1973 – Stanley Cohen & Herbert Boyer (a gene from a virus can be snipped out and pasted in bacteria)

1975 – Fred Sanger (invented a way to sequence long DNA sequences)

1977 – Phillip Sharp & Richard Roberts (within genes are long pieces of unused DNA)

1981 – Frank Costantini & Elizabeth Lacy (injected rabbit genes into fertilized eggs of mice & created the first “transgenic” mammal)

1983 – Kary Mullis (invented a fast and cheap way of making lots of copies of a small piece of DNA)

1986 – Leroy Hood (invented the first automated DNA sequencing machine)

1990 – Human Genome Project (a number of scientists undertook the project of sequencing the entire human genome)

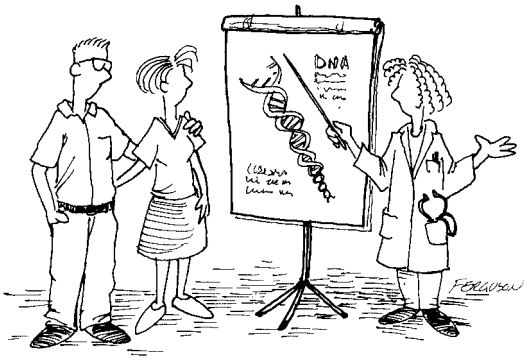
2000 – Human Genome Project (the first draft of the human genome completed)

HS Lesson 7: Where Can We Go From Here?

(Pre-Exhibit Visit)

Objectives:

1. Students will be aware that genetic issues impact many areas of life, such as medicine, food and agriculture, and law.
2. Students will be aware that there are many ethical issues related to genetics.



Curriculum Connection:

This lesson is best taught at the end of a unit on genetics but before talking about genetic technologies. However, it does not require extensive prior knowledge of genetics terminology.

Exhibit Link:

This activity connects well with *Genetic Testing*. Having students role play the decision-making process will create interest in the area of the exhibit discussing the same kinds of ethical choices that people currently face or will likely face.

Class Time Required:

90 minutes

Materials Needed:

For each group:

- A slip of paper with a genetics ethical scenario
- Biology textbook and/or book or Internet sources for research (Teachers without easy access to the Internet could print off some handouts from various websites to give to the students in lieu of using the actual world wide web.)

Focus Activity:

Divide students into groups of three. Have them begin the activity by making a list of genetic technologies they are aware of.

Lesson Steps:

1. Discuss their answers and clarify any misconceptions.
2. Give each group one of the following scenarios:
   A. Both you and your spouse have each lost a brother to Tay-Sachs disease. You hope to have kids, but are referred to a genetic counselor before deciding for sure. Your combined income is $50,000, but you have health insurance that gives you full coverage.
   B. You and your spouse are in your early forties and have decided you would like to have another child. You have heard there is a higher risk of Down's syndrome for women over the age of 40. Your combined income is $150,000 and your insurance provides 80% coverage. You already have two healthy children, a girl who is eight and a boy who is six.
   C. You and your partner are both Caucasian. You have two children, both of whom have a rare disorder known as Fragile X. You are considering another child, so you seek the advice of a genetic counselor. You wish to know the chance that your next child will also have the disorder. Your combined income is $90,000, but you have insurance that provides full coverage.
   D. You have one child, age three, who has cystic fibrosis. You are two months pregnant with your second child; you and your husband separated a month ago. You have been referred to a genetic counselor. Your income is $25,000. You will be receiving some money for child support, but you do not have insurance.
   E. You have just married. You and your spouse are healthy, but the husband's brother has two children with sickle cell anemia and the wife's sister has the same disease. You are thinking of having children and have sought the advice of a genetic counselor. You and your spouse do not currently have insurance and your combined income is $51,000.

Teacher's Note: Scenario D regarding cystic fibrosis could lead to a discussion of abortion. If you wish to avoid this possibility, simply omit this particular scenario.

3. Ask students what they know about genetic counseling. Discuss what a genetic counselor does. For example, in many of the scenarios, a genetic counselor provides information and offers advice to a couple regarding their chances of having a baby, the potential health risks involved in having a baby, the costs associated with having a child who has a genetic disorder, and so on.
4. Have the groups designate roles in their group depending on the situation — e.g., parent, genetic counselor, spouse)
5. Give each group a different scenario and have one student read it aloud.
6. Using resources available in their textbooks, the "parents" should research the basics about their disorder. Those members of the group designated as the "genetic counselor" should join up with other members of the class selected for the same role and research possible options available to the parents such as genetic testing, gene therapy and amniocentesis. You may even have the counselor research the costs. Then, each member will return to his/her original group and will role play the decision making process based on the information about the disorder, family history, income, insurance, etc. For example, the parents could come in and tell the genetic counselor their concerns about the potential disorder. The counselor could present the parents with their options. Then, as a group they would make a collective decision on what to do. They should end the process by writing down the decision their group made and the reasons why.
7. Have students defend their positions to the other members of the class.

Extensions & Modifications:

- For further scenarios, see additional resources, "Genetics Role Play."
- For lower level students, eliminate the economic aspects — income and insurance — of the scenarios. You can also do the research on the disorders for your students and supply them with some basic information.
- For more advanced students, have them also research the role of genetic counseling and what it can be used for.

Important terms: genetic counselor, amniocentesis, gene therapy

Writing Prompts/Potential Discussion Questions:

1. Using the situation you role played in class today, come up with an alternate decision and provide reasons why a person might make this decision. What kinds of issues do people struggle with in making such decisions?
2. In this activity, many people decided to have a child, while others felt it wasn't worth the risk. Discuss the pros and cons of governmental laws requiring genetic testing for parents with a family history of genetic disorders. Discuss problems with implementing such legislation.
3. Currently genetic counseling is only available to those who can afford it. Should this service be available to everyone? Should the government pay for it?
4. The US government is currently requiring phenylketonuria (PKU) testing of all infants and supports testing for cystic fibrosis (CF) for all couples before conception. Should tests be required (knowing that the test doesn't look for all CF mutations)?

Additional Resources:

Your Genes, Your Health
http://www.ygyh.org/
An excellent educational web site containing information about all the genetic disorders discussed in this lesson.

Genetics Role Play Lesson
http://www.accessexcellence.org/AE/ATG/data/released/0350-SharonNelson/description.html
This lesson contains additional scenarios.

National Standards Addressed:

Standard F – Science and Technology in Local, National, and Global Challenges

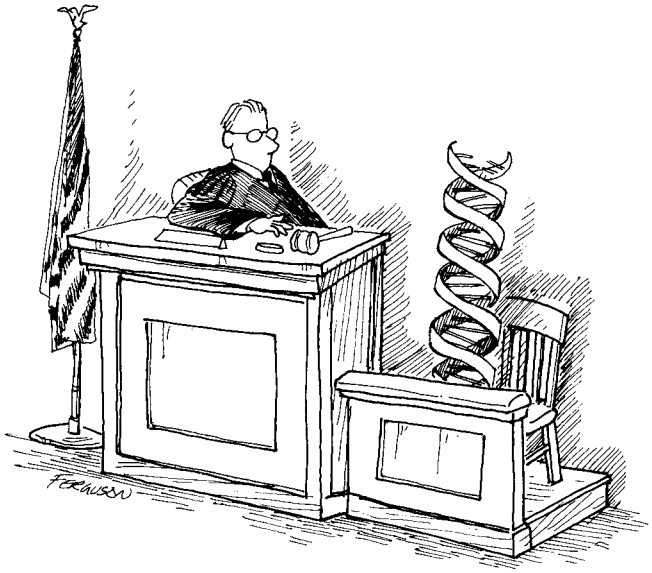
Individuals and society must decide on proposals involving new research and the introduction of new technologies into society. Decisions involve assessment of alternatives, risks, costs, and benefits and consideration of who benefits and who suffers, who pays and gains, and what the risks are and who bears them. Students should understand the appropriateness and value of basic questions — "What can happen?" — "What are the odds?" — and "How do scientists and engineers know what will happen?"

HS Lesson 8:
Understanding DNA Fingerprinting

(Post-Exhibit Visit)

Objective:

Students will be able to explain how the process of DNA fingerprinting works and several uses of the technology.



Curriculum Connection:

This lesson is best taught after an overview of genetic technologies. Students should have prior knowledge of DNA structure, replication, and base pairing. This lesson gives students a more detailed idea of how DNA fingerprinting works and how it can be useful. There is a large amount of "junk DNA" – DNA that does not code for protein – in the human genome. Junk DNA is made up of repeated sequences that are called repeats. Although individuals may have identical genes, there may be different numbers of repeats between these genes. For example, one person may have 7 repeats while another has 12. The more repeats, the longer the junk DNA between genes. One method of DNA fingerprinting — which produces a Southern Blot — begins by taking a DNA sample from something such as skin, saliva, blood, or hair. The DNA is cut into pieces using restriction enzymes. The resulting collection of DNA pieces will consist of some pieces of junk DNA and some genes. The sample DNA pieces are placed into a clear gelatin, where an electric current pushes the DNA pieces through the gel. Short pieces move farther than long ones, so a piece of DNA that had 7 repeats would move faster than a piece of DNA with 12 repeats. Since DNA has no color more steps must be completed so scientists can "see" particular DNA pieces. The sequences are denatured so only a single strand remains. They are transferred onto a nylon sheet where the strands are permanently fixed. A radioactive probe with a known sequence is then added. After a radioactive probe of single stranded DNA has been allowed to bond by basepairing with the denatured DNA on the paper, an X-ray reveals only the areas where the radioactive probe sits. These are the only things that will show up on the film. This allows researchers to identify, in a particular person's DNA, the occurrence and frequency of the particular genetic pattern contained in the probe. For more information see additional resources.

Exhibit Link:

This activity builds on *DNA Detective* of the exhibit that explains DNA fingerprinting and allows students to match the DNA sample from a crime scene to a sample from the person convicted of the crime.

Class Time Required:

90 minutes

Materials Needed:

For each student:

- Handout
- Highlighter or Light Colored Marker
- Tape
- Scissors

Focus Activity:

Write the following information about DNA fingerprinting on the board:

DNA fingerprinting is a technology that looks for similarities in specific sections of DNA samples. Since each person's DNA is unique but every cell in that individual contains the same DNA, this technique can be used to identify an individual from such samples as skin, saliva, blood, or hair, which contain DNA.

Put the students in pairs, and have them make a list of five scenarios where DNA fingerprinting would be a useful technology.

Lesson Steps:

1. Discuss the students' answers, and clarify any misconceptions.
2. Read the students the following story:
   Within a span of three months, Haywood and Clark counties suffered eight bank robberies. The banks were mostly small and rural, with minimal security. The robber wore a ski mask, carried a large gun, and got in and out within minutes. However, the robber got more bold in his last robbery. He chose a larger bank with new surveillance cameras and a security guard. The robber still escaped, but not before he was chased by the guard. When the guard caught the robber, the robber shot and killed him, but not before the guard managed to pull off the robber's ski mask, revealing his face to the surveillance cameras. Meanwhile, a woman leaving a hair salon across the street witnessed it all.
   Police Chief Harry Gilford felt pressure from the state to make a quick arrest. Using the pictures from the tape, he brought in two possible suspects, both with prior arrests. The woman identified Suspect 1, who could not account for his whereabouts at the time of the robbery. Within weeks, Gerald Walker was convicted and sentenced to life in prison, despite his plea of innocence. Chief Gilford was pleased to close the case, but he couldn't help wondering if they really got the right man.
   Four years later, a new governor was elected. With advancements in genetic technologies, he soon signed a law that allows prisoners on death row or life sentences to demand a retrial that would use DNA testing on the evidence. Gerald Walker hired a lawyer and pressed for a new case. Using hair samples from the ski mask recovered by the security guard, the crime lab did a Southern Blot test. During the investigation, hair samples were also taken from both suspects. Use the suspects' hair samples to determine if the right man was convicted.
3. Explain to students how a Southern Blot test works (see curriculum connection). Also, There is a great animation of a Southern Blot at http://www.dnalc.org/shockwave/southan.html
4. Distribute the handout, and tell students that it shows the results of the Southern Blot test done on the hair sample found in the ski mask recovered from the robbery. Have students cut out the DNA fragments for Gerald Walker and for Suspect 2 and tape them in the correct places on the blot. If the direction of electricity is going up, students should understand that the shortest pieces would be found toward the top. They should then cut out the probe sequence and try to match the probe sequence with those on each suspect. Have students highlight any probe sequence that finds a perfect match (but not other sequences) For example, the probe sequence of AGGT binds perfectly to any segment containing a TCCA sequence. Any sequence with TCCA should be highlighted. The suspect with the match from the hair sample is most likely the one who committed the robbery. (They should find that it wasn't Gerald Walker!)

Extensions & Modifications:

- Have students write a police report regarding their findings.
- For lower level students, do the ordering of the sequences on the board as a class and simply have them copy the information onto their paper.
- Have more advanced students do research to find out how a Southern Blot works and then do the activity based on this information.

Important terms: Southern Blot, DNA fingerprinting, probe

Writing Prompts/Potential Discussion Questions:

1. DNA fingerprinting is widely used in court cases today. Discuss the pros and cons of relying on such technologies to make convictions.
2. What kinds of future genetic technologies can you imagine that would aid the police in solving crimes?
3. Using such technologies in court cases would be more beneficial if there were a database containing every person's DNA sequence. Discuss the pros and cons of creating such a database.
4. What are some of the advantages of DNA fingerprinting has over traditional fingerprinting?

Additional Resources:

Basics of DNA fingerprinting
http://www.biology.washington.edu/fingerprint/dnaintro.html
Very easy to understand!

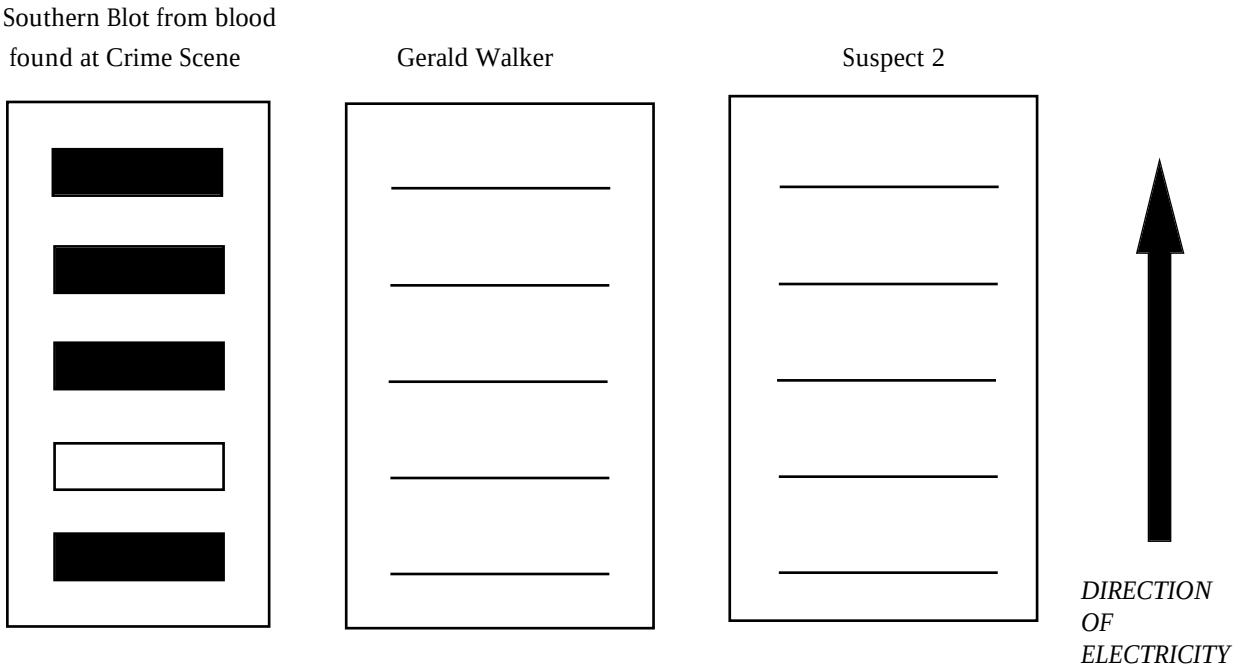
Understanding a Southern Blot test
http://www.biology.washington.edu/fingerprint/blot.html
This page from the same site above gives step by step explanations about how a Southern Blot test is done.

National Standards Addressed:

Standard E – Understandings about Science and Technology

- New technologies often extend the current levels of scientific understanding and introduce new areas of research.
- Sometimes scientific advances challenge people's beliefs and practical explanations concerning various aspects of the world. Sometimes scientific advances challenge people's beliefs and practical explanations concerning various aspects of the world.

HS Lesson 8 Handout:
The Case of Gerald Walker



Gerald Walker
TCCATCCA / TCCATCCATCCA / TCCA / TCCATCCATCCATCCA / TGGATGGATGGATGGATGGA
Suspect 2
TCCATCCA / TCCATCCATCCA / TCCA / TCCATCCATCCATCCATCCA / TGGATGGATGGATGGA
Probe
AGGT

Glossary

Allele – one of a number of different forms of the same gene for a specific trait

Amniocentesis – prenatal diagnostic technique that requires the removal of a small amount of fluid from the sac surrounding the embryo

Anticodon – a set of three tRNA nucleotides that binds to the codon

Chromosome – structure in the cell that contains the genetic information that is passed on from one generation of cells to the next. Made of DNA and protein

Codon – a set of three mRNA nucleotides that codes for an amino acid or signals the end of an amino acid sequence

DNA – deoxyribonucleic acid. A chain of nucleic acid molecules that contains your genetic information

DNA fingerprinting – technique for identifying individuals, generally using repeated sequences in the human genome that produce a pattern of bands that is unique for every individual

Double helix – term used to describe the structure of DNA; two strands that are coiled

Gamete – specialized reproductive cell involved in sexual reproduction. They have one half the total number of chromosomes as the organism's normal body cells.

Gene – section of DNA that codes for a trait

Gene Therapy – an approach to treat, cure, or ultimately prevent disease by changing the makeup of a person's DNA

Genetic Counselor – health professional academically and clinically prepared to provide genetic services to individuals and families seeking information about the occurrence, or risk of occurrence, of a genetic condition or birth defect

Genome – all the genes that an organism possesses

Genotype – genetic makeup of an organism

Gregor Mendel – Austrian monk who conducted the first experiments on heredity using pea plants, discovering that parents pass on specific traits to offspring by ways of "factors" as Mendel called them

Heredity – the passing of traits from parents to offspring

Heterozygous – an individual having two alleles for a trait that are different

Hitchhiker's Thumb – a recessive trait in humans where the end joint of the thumb can be bent at an angle of at least 45 degrees

Meiosis – process that produces gamete; cells with half the number of chromosomes as the organism's normal body cells

mRNA – messenger ribonucleic acid or messenger RNA. It carries the code from the DNA to the ribosome where the sequence is decoded into a protein

Nitrogen Base – component of a nucleotide that can bind to other nitrogen bases through a hydrogen bond

Nucleic Acid – large, complex organic molecules composed of carbon, oxygen, hydrogen, nitrogen, and phosphorus atoms. A chain of nucleotides.

Nucleotide – building block of a nucleic acid; composed of a sugar, phosphate, and nitrogen base

Phenotype – physical appearance of an organism

Probe – A radioactive strand of DNA often used to find particular sequences in a Southern Blot

Replication – the process by which a second copy of DNA is made using the first as a template

RNA – ribonucleic acid. A nucleic acid made of a single chain of nucleotides that helps carry out protein synthesis

Southern Blot – a DNA technology that uses a radioactive probe to match with specific DNA fragments

Transcription – the process by which the DNA code is copied onto mRNA

Transgenic – an organism that contains foreign genes

Translation – the process by which the mRNA code is converted to a sequence of amino acids (a protein)

tRNA – transfer RNA; molecule that binds to an mRNA codon and brings in the appropriate amino acid for that codon

Tongue Roller – a dominant trait in humans where individuals can roll their tongues into a tube-like shape

Widow's Peak – a dominant trait in humans resulting in a pointed hairline