



PROMISE & PERILS



Dear Educator

On September 25 and 26, 1992, the University of California San Francisco and the San Francisco Exploratorium presented a public symposium entitled "Winding your way through DNA." This program was designed to educate the public and to encourage a dialogue about the scientific possibilities and the social puzzles of recombinant DNA technology.

Following the symposium, a team of high school and college teachers, ethicists, historians, and scientists decided to create a series of videos that would encourage a dialog about recombinant DNA technology and the ethical, legal, and societal issues that have emerged in its wake. The third in this series is *Winding your way through DNA: Promise & Perils of Biotechnology: Genetic Testing*, a videotape intended for high school and college biology classes and public education programs.

This videotape provides a personal approach to ethical and societal issues that encompasses human genetics and genetic testing. The goals for this tape include:

- Presenting up-to-date information on human genetics, genetic testing, and their applications and implications.
- Showing dynamic real-life situations that provide opportunities for thoughtful, open-ended decision making.
- Giving contemporary examples of how genetic information can be applied to personal, career, and societal issues.
- Increasing student awareness and understanding of the changes brought about by DNA science and technology.

The projects and activities in this teacher's guide supplement and complement the basic concepts and decision-making processes illustrated in the videotape.

We invite you to use these materials to introduce the revolutionary field of recombinant DNA technology to your students.

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Supporters

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Video Guide

Video Objectives/About the Video	2	Milestones in Biotechnology	2
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Activities

Activity 1 Genes, DNA, and Mutations	4	Activity 4 Genetic Testing	10
Activity 2 Genetic Inheritance	6	Activity 5 Genetic Counseling	12
Activity 3 Predicting Genetic Combinations	8	Activity 6 Gene Therapy	14

Handouts

Handout 1 DNA and mRNA Patterns	16	Handout 5 Genetic Profile Worksheet	20
Handout 2 tRNA Patterns and Amino Acid Codes	17	Handout 6 Pedigree and Punnett Square Worksheet	21
Handout 3 Genetic Trait Chart	18	Handout 7 Genetic Testing Worksheet	22
Handout 4 Genotype and Phenotype Record Sheet	19	Handout 8 Gene Therapy Project Summaries	23

Resources

Genetic Disorder Profiles and Organizations	24	Glossary	32
References	28	Credits	33

Milestones In Biotechnology

1953 James Watson and Francis Crick discover the molecular structure of DNA.

1973 Stanley Cohen and Herbert Boyer perform the first experiments in genetic engineering. They develop a technique to clone segments of DNA molecules.

1976 Genentech, the first company devoted to producing genetically engineered products, is established in San Francisco, California.

1979 Genetic engineering is used to synthesize human insulin.

1981 At Ohio University, scientists transfer genes from other organisms into mice.

1983 Kary Mullis conceives of the polymerase chain reaction (PCR), a method of multiplying copies of parts of DNA. This process will become one of the key tools in genetics.

1984 Robert Sinsheimer proposes mapping all of the genes in a human being. This proposal leads to the development of the Human Genome Project.

1989 The Human Genome Project is launched on January 3. James Watson is the first director.

1990 The first gene therapy experiment is performed on a four-year-old girl with adenosine deaminase deficiency. The procedure involves inserting genetically altered cells into the veins of the patient.

1995 First bacterial genome, *Haemophilus influenzae*, was completely sequenced by The Institute for Genomic Research.

1996 Genetic maps of human and mouse completed by teams of U.S. and international scientists.

1996 A yeast known as *Saccharomyces cerevisiae* is the first eukaryotic genome to be sequenced, by more than 100 laboratories collaboratively around the world.

Video Objectives

- To give a basic understanding of genetics and genetic testing.
- To introduce the Human Genome Project.
- To show the difference between inheriting a genetic disorder and inheriting a predisposition to a disorder.
- To convey some of the ethical and societal issues that result from the use of biotechnology.
- To stimulate discussion about how the information generated by genetic profiles can affect a person's life, career, and society as a whole.

About the Video

Advances in biotechnology are helping us identify more and more genetic conditions—traits and disorders that are passed on from parent to child.

Instructions for these different genetic conditions are found in our genes, each of which is a segment of a molecule of DNA. In the past ten years, scientists have made amazing strides in determining which genes or combinations of genes are responsible for certain genetic disorders, such as cystic fibrosis, fragile X, and Huntington disease. Scientists also have discovered genes which may predispose a person to a condition such as alcoholism or depression. Armed with this information, medical researchers have developed a number of genetic tests that allow peo-

ple to determine if they or their children have inherited or are carriers for a potentially harmful or fatal disorder. Some of these tests can be performed prenatally, others can be performed on newborns, children, or adults.

In the coming years, the number of available genetic tests will increase dramatically due to the information gained from the Human Genome Project. The Human Genome Project (HGP) began in 1990, led by the Department of Energy and the National Institutes of Health.

The goal of this project is to identify the role of all 100,000 genes stored in human DNA. At the same time, the HGP began to explore and anticipate the ethical, legal and social implications which might arise once these genes are identified. Such implications often are best considered through real-life case studies like these presented in *Promise & Perils of Biotechnology: Genetic Testing*.

Understanding the role of each gene will produce information that can help people, but it also can pose personal and societal dilemmas. Some of the many questions currently being asked include: Should genetic testing for certain disorders be mandatory? Should genetic tests be performed if there is currently no treatment or cure for the disorder? Who should pay for the tests? How will the information provided by a test be used? Do employers and insurance agencies have the right to know about the results of a genetic test?

Promise & Perils of Biotechnology: Genetic Testing presents a personal look

at inherited diseases, their prevalence in society, and the ethical, legal, and social implications of genetic testing. The video follows Jennifer Jones as she is tested for Huntington disease, a disorder that runs in her family. The symptoms of this debilitating fatal disease most often appear when a person is in his or her 30s or 40s. Jennifer knows that if she tests positive for the disease, there is no cure. She then risks passing the gene on to her children, should she decide to have any.

The program also examines the lives of Lily Ann and Laura Sholer, who already have been diagnosed as having a gene that leads to dangerously high cholesterol, known as familial hypercholesterolemia. Unlike Jennifer, the Sholers have the opportunity to reduce their risk of heart attack by changing their lifestyles. However, they still grapple with how the knowledge of their condition will affect their ability to get certain jobs and insurance.

Promise & Perils of Biotechnology: Genetic Testing is an excellent resource for examining complex issues in genetics. Because of the nature and complexity of the human problems discussed, it demonstrates why scientific information must be combined with other forms of knowledge and personal values in order to come to a more complete understanding of the problem. A framework that includes the elements in the diagram on this page can be used in considering any big decision, such as Jennifer's.

Along with genetic testing, other examples of complex human problems that could be addressed using this framework include the growth of the human

population, the potential for global climate change, and the question at every grocery store check-out line, "Paper or plastic?"

Discussion Questions

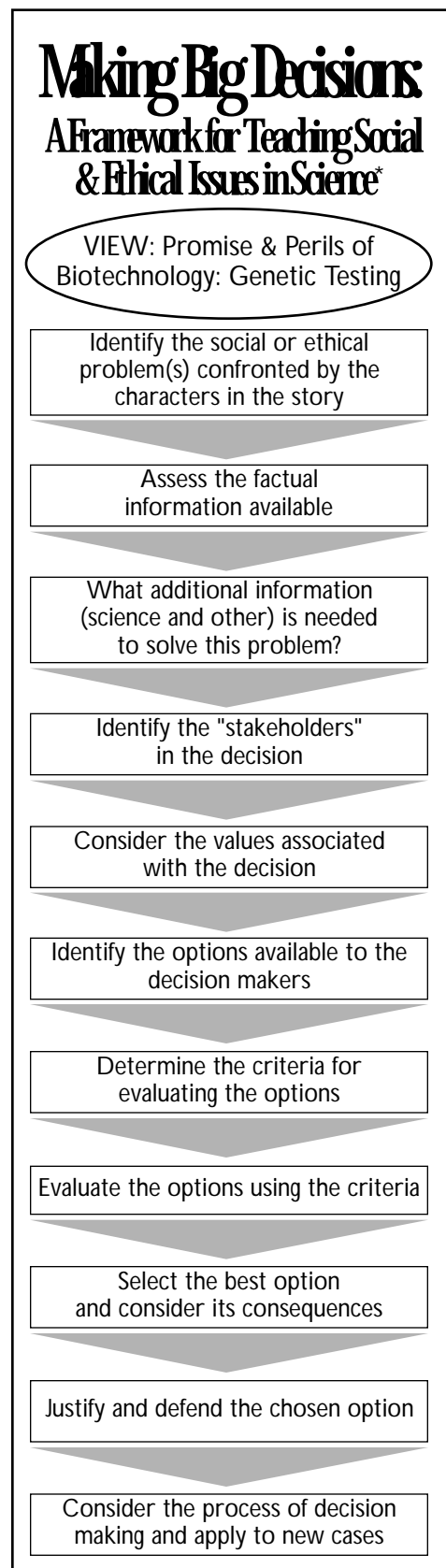
Before viewing the video:

1. Answer the following questions: What is genetic testing? Who needs genetic testing? Give some of the positive and negative reasons for undergoing genetic testing. After viewing the video, review your responses. Did any of your answers change? Explain.

After viewing the video:

2. In the video, Jennifer decides to be tested for Huntington disease. Would you have taken the test in the same circumstances? Why or why not? If you took the test, and discovered that you had inherited the gene for Huntington disease, what would you do with that information?
3. In the video, Lily Ann and Laura Sholer have been diagnosed as carriers for the gene that causes dangerously high levels of cholesterol, or familial hypercholesterolemia. Would you have taken the test for this disorder? Why or why not? If you took the test, and discovered that you had inherited the gene, what would you do with that information?

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ACTIVITY 1

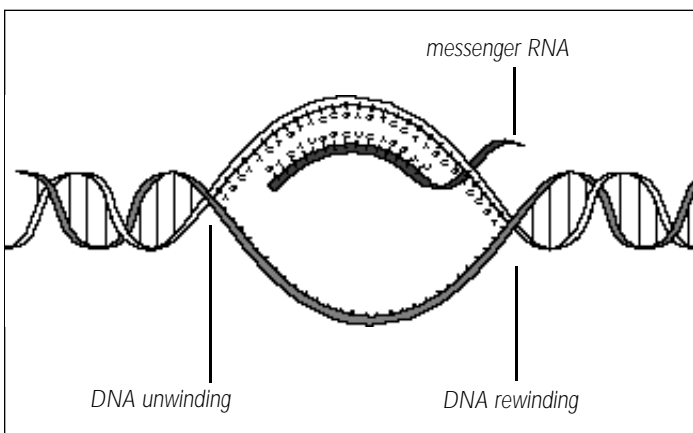
Objective

Students will model two ways in which genetic mutations can cause genetic disease.

Background Information

Genetic information is stored in a cell as deoxyribonucleic acid, or DNA, which are strands that are paired, as in the rungs of a ladder, and consists of pairs of four nucleotide bases—adenine (A), guanine (G), cytosine (C), and thymine (T). Genes within DNA can be hundreds or thousands of base pairs long, with each gene having a specific sequence of nucleotide bases. The DNA inherited by an organism directs the activities of each cell by specifying the synthesis of proteins from amino acids. The formation of proteins from the genetic information requires two main steps: transcription and translation.

During transcription, the double-stranded DNA partly unwinds. The individual strands act as a template for the creation of messenger RNA (mRNA). Messenger RNA is a single-stranded nucleic acid that contains the sugar ribose. It consists of four nucleotide bases—adenine (A), guanine (G), cytosine (C), and uracil (U). These bases follow the same base-pairing rules that govern DNA replication (where guanine pairs with cytosine, thymine pairs with adenine) except that uracil, rather than thymine, pairs with adenine. Information for the sequence of amino acids is contained in the mRNA in groups of three bases, known as

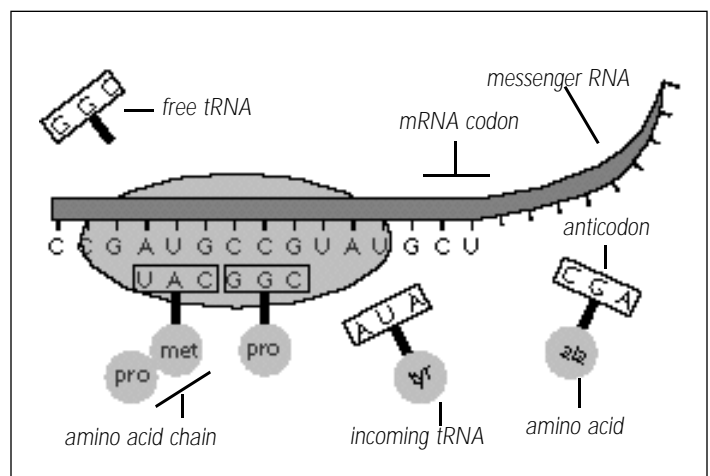


DNA is transcribed into messenger RNA.

codons. Once the mRNA strand has been formed, it moves to the ribosomes in the cytoplasm of the cell, where translation, or protein synthesis, takes place.

Translation involves another type of molecule known as transfer RNA (tRNA), which is an L-shaped structure that has three bases on one end (known as an anti-codon) and an amino acid attached to the other end. The ribosomes in the cell link the anticodon on the tRNA with the complementary codon on the mRNA. The amino acids on the tRNA detach from the tRNA and link together in the specified order to form the protein. The tRNA then moves away from the mRNA and is free to pick up another amino acid of the same type to add to another protein chain.

Many genetic disorders are due to mutations, or changes in the nucleotide sequence of DNA. There are two main types of mutations within a gene: base-pair substitutions and base-pair insertions or deletions. A base-pair substitution is the replacement of one nucleotide and its partner with another pair of nucleotides. This type of mutation may cause either no change in the protein; a small, insignificant change in the protein; or a major alteration. For example, people with sickle-cell anemia have an adenine-thymine pair instead of a thymine-adenine pair in their hemoglobin gene; this substitution results in a major change in the hemoglobin molecule. A base-pair insertion or deletion occurs when one or more nucleotide pairs are inserted or deleted in a gene. Usually insertion and deletion mutations cause more damage than the single-pair substitutions because they may



Translation of messenger RNA into protein.



drastically change the sequences of the codons downstream from the mutation.

Materials

For each group:

- Handouts 1 and 2, pages 16 and 17
- Scissors
- Paper
- Pen or pencil

Preparation

Duplicate Handouts 1 and 2 to distribute to students.

Instructions

1. Have students cut out the DNA sequence patterns from Handout 1 and put pieces together side-by-side to form the following single-strand sequence:

C T T T T A T A G T A G A T A C C A C A A A G G

Explain to students that they have just built a sequence for part of the gene that can cause cystic fibrosis.

2. Have the students cut out the mRNA and tRNA pieces from Handouts 1 and 2. Have them build a strand of mRNA by matching the ribonucleic bases to the complementary bases on the DNA strand.
3. Once students have created the mRNA strand, have them model translation using the tRNA pieces. Students should match the tRNA pieces to the corresponding codon on the mRNA strand. Tell them to use the amino acid chart on the bottom of Handout 2 to determine the amino acids that are carried by the tRNA. Students should record the sequence of amino acids on a separate piece of paper.

4. Next, explain that students will be making base-pair substitutions in the original DNA sequence. Have them change the nucleotide in the 15th position (from the left) of the original DNA sequence to cytosine. Have students make the appropriate changes in the mRNA and tRNA strands, and record the changes, if any, to the amino acid sequence. Then ask students to change the nucleotide in the 15th position to adenine. Once again have them record the corresponding change, if any, in the amino acid sequence.
5. Now tell students that they will be making a deletion in the original DNA sequence. Have them remove the nucleotides in the 13th, 14th, and 15th positions. Then have students move the nucleotide pieces to the left to close the gap that is created. Have them make the appropriate changes in the mRNA and tRNA strands, and record the changes, if any, to the amino acid sequence.

Discussion Questions

1. Does changing the sequence of nucleotides in the DNA strand always result in a different amino acid sequence? Why or why not?
2. If the thymine in the 15th position of the sequence is changed to cytosine, the person does not have cystic fibrosis. However, if the thymine in the 15th position is changed to adenine, the person does have cystic fibrosis. What are some reasons this might occur?
3. Suppose that in the original DNA strand the adenine in the 14th position were changed to cytosine. Do you think a person with the change would have cystic fibrosis? Why or why not?
4. What happened to the amino acid sequence when you deleted three bases from the original DNA strand?
5. What do you think would happen if a single nucleotide were added somewhere in the sequence. Explain your answer.

ACTIVITY 2

Objective

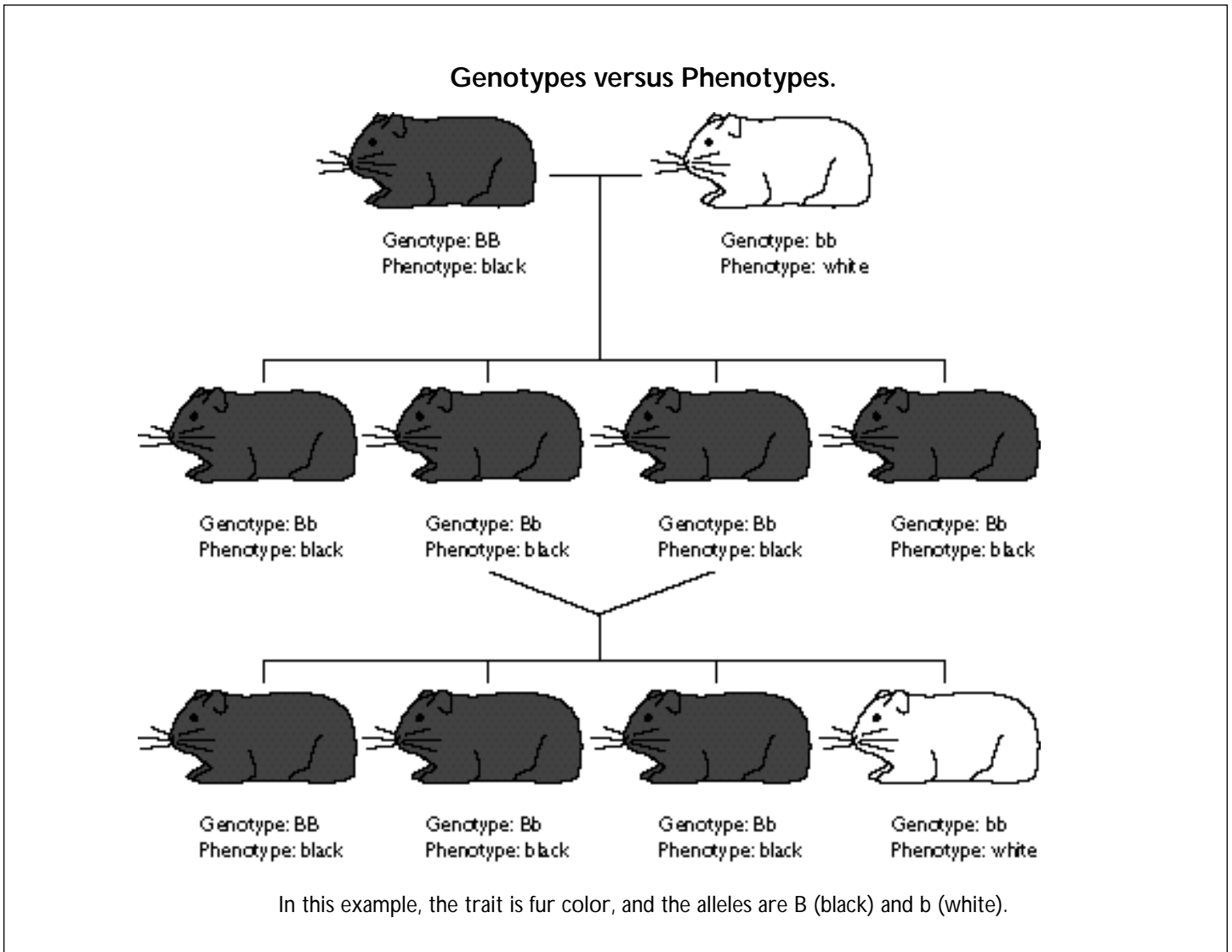
Students will model inheritance patterns in humans to compare the difference between genotypes and phenotypes.

Background Information

The traits or characteristics of an organism are determined by genes. The gene for a particular trait can have two or more different forms, which are called alleles. For every gene, a person has two alleles, one inherited from each parent. The combination of inherited alleles represents the genetic makeup, or genotype, of the organism. The way a

genotype is expressed in an organism is called its phenotype. For many traits the phenotype is a result of an interaction between the genotype and the environment.

For a specific trait, some alleles may be dominant while others may be recessive. The phenotype of a dominant allele is expressed regardless of what the other allele is, while the phenotype of a recessive allele is expressed only when both alleles are recessive. However, in some cases, one allele is not completely dominant over the other allele, and the resulting phenotype is a combination of each allele's phenotype. This is known as incomplete dominance. In addition, some traits are determined by a combination of several





genes, and the resulting phenotype is determined by the final combination of alleles of all the genes that govern a particular trait.

Geneticists symbolize alleles in various ways. Often uppercase letters are used to represent dominant alleles and lowercase letters are used to represent recessive alleles. An organism that has a pair of identical alleles for a trait is said to be homozygous for that trait. Organisms that are homozygous for a dominant trait are represented by all uppercase letters (i.e., GG), while those that are homozygous for a recessive trait are represented by all lowercase letters (i.e., gg). Organisms that have different alleles for a trait are said to be heterozygous for that trait, and are represented by a combination of uppercase and lowercase letters (i.e., Gg).

Materials

For each pair of students

- Handouts 3, 4, & 5, pages 18-20
- 2 coins
- Pencil

Preparation

Duplicate Handouts 3, 4, and 5 to distribute to pairs of students.

Instructions

1. Explain to students that they will be creating a hypothetical genetic profile of a “child” using the traits listed on Handout 3. (Note: you may want to point out that some of the skills listed on the handout and their pattern of inheritance are hypothetical, and not necessarily inherited.) One student in each pair will represent the mother of the child, while the other student will represent the father. For each gene listed, each student should flip his or her coin. Then each pair of students will record the results of their coin flips in the genotype column on Handout 4. Heads represents a dominant allele, while tails represents a recessive allele.

2. After students have recorded the genotype for each trait, have them use Handout 3 to determine the phenotype for each trait. Remind students that some of the phenotypes are determined using one gene, while other phenotypes are determined using a combination of genes.
3. Have students use the profile they created to answer the questions on Handout 5.

Discussion Questions

1. Discuss the answers to the questions on Handout 5. What were some of the reasons you decided that certain jobs were suitable for your child? What were some of the reasons you decided that certain jobs were unsuitable for your child?
2. If a person's genotype was not very well suited for a given career or task, what might he or she be able to do to overcome the limitation?
3. If a person's genotype indicated that he or she had a very high predisposition to alcoholism, does this mean he or she would become an alcoholic? Why or why not? Do you think the person's employer should be given this information? Why or why not?
4. How might having a genetic profile be helpful? How might it be a disadvantage? If a genetic profile is created, who should have access to the profile?
5. In the simulation you just completed, you simulated the creation of possible genotypes using hypothetical traits. How is a simulation useful in helping to understand certain biological events? What are some limitations of simulations?

ACTIVITY 3

Objective

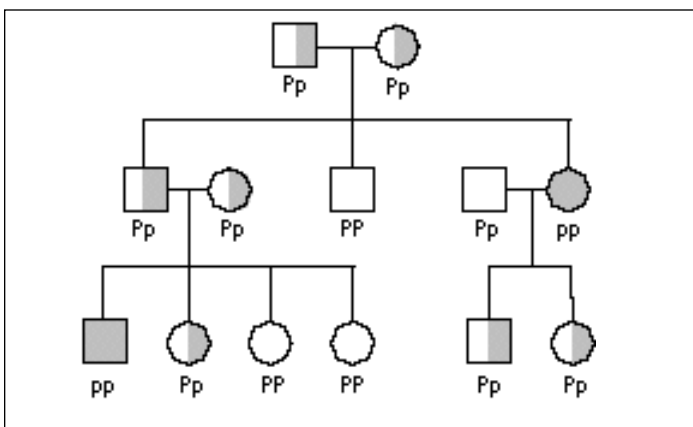
Students will develop pedigrees to trace the inheritance pattern of a genetic disease.

Background Information

A pedigree is a chart showing the genetic history of a particular trait within a family. Pedigrees can show the inheritance patterns of cosmetic traits such as hair texture and eye shape or of potentially life-threatening traits such as genetic disorders. These charts are also useful in predicting possible outcomes from future gene combinations.

By convention, circles in a pedigree represent females and squares represent males. A horizontal line between a circle and a square indicates a marriage or partnership; vertical lines indicate the children from the marriage or partnership. In this activity, a filled-in circle or square shows that the individual has both alleles for the trait. A half-filled-in circle or square indicates that the individual has one recessive allele for the trait.

A person who is heterozygous for a recessive genetic disorder is called a carrier. A carrier does not usually manifest symptoms of the disease, but may pass on the defective copy to his or her child. If a child of two carriers receives a recessive allele for the trait from each parent, he or she will express the disorder.



A pedigree showing the occurrence of a recessive trait in three generations of a family.

Geneticists can use pedigrees to help predict the probability of whether a child will express a given trait. One method of illustrating the possible gene combinations that may occur when two people reproduce is a chart called a Punnett square. In a Punnett square, the alleles from one parent are written across the top of the square, while the alleles from the other parent are written down the side of the square. All the different possible combinations of alleles are shown within the square.

Materials

For teacher preparation:

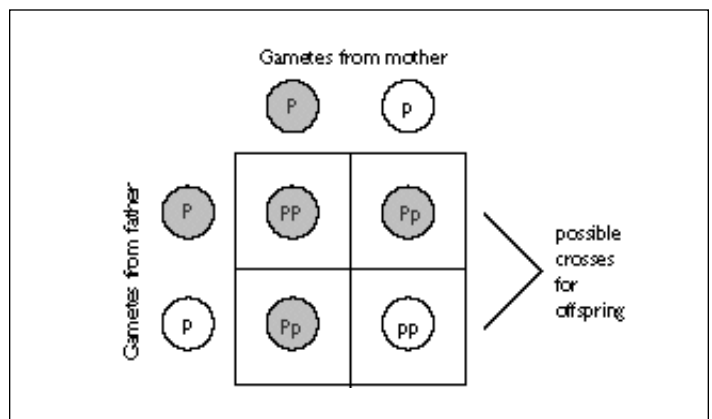
- Colored markers or crayons, in three colors
- 2 Popsicle sticks, tongue depressors, or strips of cardboard per student

For each pair of students:

- 2 copies of Handout 6, page 21
- Colored pencils, in three colors (preferably in the same colors as the markers)
- Pencil

Preparation

Duplicate Handout 6 to distribute to students. The Popsicle sticks or tongue depressors will represent chromosomes. Indicate three "genes" on each "chromosome" by drawing lines with the markers or crayons. Use a different color marker or crayon for each type of gene, and use thick lines



A Punnett Square that shows the possible crosses between two parents with the alleles Pp. Here, white indicates the recessive trait.



for dominant alleles and thin lines for recessive alleles. Vary the frequency of dominant and recessive alleles for each gene. For example, for the first gene, mark 80% of the sticks with a thin line and 20% of the sticks with a thick line. For the second gene, use a 50/50 ratio, and for the third gene, use a 20/80 ratio. Be sure to put the lines for each gene at the same location on each stick to help convey the idea that they represent alleles on a chromosome. Finally, assign the color that will represent the gene for phenylketonuria (PKU), an inherited disease caused by a recessive allele, which affects one out of 10,000 babies.

Instructions

1. Divide the class into pairs. Give each student two sticks and the Handouts. Explain that each pair of sticks represents the possible genetic material that can be donated from one parent, and that each line on the stick represents a different gene from that parent. Explain that for this activity they will be investigating the inheritance patterns of PKU. Tell students which color represents the gene for PKU.
2. Have each pair of students decide which pair of sticks represents the mother's genetic material and which represents the father's genetic material. Ask them to locate the PKU alleles on their trait sticks. Then have students determine the PKU genotypes for the parents and record the information in the "Parent" position of the pedigree. Ask them to use the colored pencils to indicate the phenotype of each parent on the form.
3. Have students use the Punnett square at the bottom of the handout to show all the possible genotypes for the children. Then have them record both the genotype and phenotype for each child in the "Children" positions on the pedigree.
4. Next have each pair of students join with another pair. Ask them to randomly select one child from each pair's pedigree to use as parents for the next generation. Have them record the new parents' genotypes and phenotypes in the "Parents" positions on the second handout.
5. Using the new parents, have students once again show the possible crosses for the second generation of children. Have them trace the transmission of PKU throughout the families.

Discussion Questions

1. Examine the Punnett square for the original parents. What was the probability for each birth that these parents would have a child with PKU? What was the probability for each birth that the child would be a carrier? How can you tell?
2. How many family members (including the parents, first generation of children, and second generation of children) actually had PKU? How many were carriers? Are these numbers the same as the probabilities? Why or why not?
3. Suppose you knew there was a history of PKU in your family. What are some of the advantages of creating a pedigree? What are the limitations of using a pedigree? Would you want to have the pedigree made? Why or why not?
4. If you knew you were a carrier for PKU, that is, you had one recessive gene for the trait, how would you feel about marrying a person who is also a carrier for the trait? Would you want to have children with the person? Explain your answer.
5. Would you want to know if the person you plan to marry is a carrier for PKU? Should this person be required to tell you? Give reasons for your answers.

Extensions

1. Repeat the activity using the second set of colored lines to represent genes for a dominant genetic trait. Point out that someone who is heterozygous (or has one copy of a dominant gene) for a dominant disorder will have the disorder.
2. Have students use the sticks to investigate the concept of independent assortment. Choose two colors on the sticks to represent two genes for the crosses. Then repeat the activity, having students create new pedigrees and Punnett squares.

ACTIVITY 4

Objective

Students will investigate the impact of carrier screening and prenatal testing.

Background Information

Genetic disorders affect large numbers of people from all racial and cultural groups. Preventive approaches to these disorders are becoming more feasible as scientists gain an understanding of genes and of the causes of genetic disorders. In some cases, the risk that a particular genetic disorder will occur can be assessed before a child is conceived or in the early stages of pregnancy. In other cases, newborns can be screened for a disorder so that appropriate treatment can be started before the condition becomes fatal.

One key to assessing genetic risk for having a child with a particular disorder is carrier testing. This type of testing determines whether the prospective parents are carriers of the gene for the trait. If both the parents are identified as carriers, then there is a 25% chance with each pregnancy that the child will inherit the disease. Carrier testing can also be conducted for X-linked disorders.

One form of prenatal testing involves collecting a sample of fetal cells from the amniotic fluid surrounding the fetus, and testing the fetal DNA to determine if there are chromosomal or special genetic abnormalities. Some types of prenatal diagnosis techniques can be performed as early as nine weeks into the pregnancy. A newer test, known as preimplantation diagnosis, can be performed before in-vitro fertilized cells are implanted in the womb. Prenatal tests are available for hundreds of conditions ranging from mental retardation to late-onset disorders that cause serious mental and physical deterioration in middle age. In about one percent of the cases, prenatal testing may cause complications such as maternal bleeding or fetal death.

Some genetic diseases can be detected at birth by biochemical tests. This type of testing is referred to as newborn screening. Newborn tests are particularly important if the disorder can be treated with interventional therapy.

Materials

For teacher preparation:

- Small head of red cabbage
- Cooking pot
- Distilled water
- Strainer
- 2 Bowls
- Red & blue food dyes
- White paper coffee filters
- Scissors

For each pair of students

- White vinegar
- Paper cup
- Paper
- Pencil
- Cystic fibrosis information (page 24)

Preparation

1. Before class, prepare red cabbage indicator strips. Tear or cut the cabbage leaves into small pieces and place them in a cooking pot filled with distilled water. Boil for five minutes, then allow to cool to room temperature. Pour the cooled cabbage extract through the strainer into a bowl. Soak coffee filters in the solution, and allow them to dry. Cut the dry filters into 1 x 1/2-inch strips and store them in a closed container.
2. Also prepare control indicator strips. Mix red and blue food coloring with distilled water to produce a dye the same color as the red cabbage solution. Soak coffee filters in the solution and allow them to dry. Cut the filters into 1 x 1/2 inch strips and store in a closed container.

Instructions

1. Have students read the information on cystic fibrosis, then discuss the information with the class. Ask students to think about how they might feel if they knew there was a chance that they could have a child with the disorder.



2. Divide the class into groups of two. Explain that each group represents a pair of potential parents. Explain to students that they will have the opportunity to test to see if they “carry” the gene for cystic fibrosis. Have each “parental” unit discuss how they feel about being tested. How would they react if they knew they were carriers for cystic fibrosis? Would they want to have children? Why or why not? Ask students to write a brief description of their position.
 3. Mix the red-cabbage indicator strips and control indicator strips together, then hand out one indicator strip to each student. Also have students place a small amount (a tablespoon or so) of vinegar in a paper cup. Explain that the strip represents a blood sample taken from the student. If the student is a carrier for the cystic fibrosis gene, the strip will turn pink when dipped in the vinegar. If the student is not a carrier for the gene, the strip will not change color.
 4. Have students put a drop of vinegar onto their indicator strips and record the results. Then ask each “couple” to determine the chances of having a child with cystic fibrosis. Have students discuss how they feel about the results of the test.
 5. Next, ask students in each pair to imagine that they are a couple expecting their first baby. This time provide each pair with a single strip of indicator paper. Explain that this strip represents the genetic makeup of the couple’s “fetus.” If the strip turns pink, the fetus has cystic fibrosis. Once again have each couple write a brief description about how they feel about the testing and the results.
4. What is the relationship between genetic testing for a disorder and curing the disorder? Would the availability of a cure for a disorder affect your desire to be tested? Explain your answer.
 5. Suppose that scientists knew the function of every human gene and were able to test for each trait. For what genetic characteristics, if any, would you want to test an embryo? Which characteristics, if any, might make you decide not to have children or to terminate a pregnancy? Why?

Extensions

Discussion Questions

1. Do you think carrier testing is a good idea? Why or why not? Do you think prenatal testing is a good idea? Why or why not?
 2. Should genetic screening for lethal diseases be mandatory? Why or why not?
 3. How would you feel if you knew there were genetic tests for traits, such as stature, physical appearance, or mental ability? Would you take such a test? Why or why not? Who should determine which traits are “desirable” and which are “undesirable?”
1. Divide the class into groups and supply each group with the Genetic Disorder Profiles and Organizations pages (pages 24-27). Ask the groups to read the profiles. Then ask them to make a list showing the disorders for which they would consider being tested and the disorders for which they would consider testing a fetus or newborn. Have groups present their lists and discuss the reasons for their choices.
 2. Divide the class into groups and have each group choose one of the disorders listed in the Genetic Disorder Profiles and Organizations (pages 24-27). Then have them research news articles and other sources for further information about the disorder. (You may want them to contact one of the organizations listed for more information.) Ask the groups to write two editorials—one presenting the pros of testing for the disorder and another presenting the cons. Have students share their editorials with the class, and discuss their positions.
 3. Have teams of students explore the potential implications of genetic testing by having them research different tests currently used to detect latent or hidden conditions. Ask students to make a brief oral presentation of their findings.

ACTIVITY 5

Objective

Students will role play to explore some of the dilemmas associated with genetic testing for late-onset disorders.

Background Information

Some diseases, such as Huntington disease and familial Alzheimer disease, may become apparent primarily in middle age or later. Both Huntington and familial Alzheimer are caused by dominant genes, so that only one dominant gene is needed to produce the disorder. Therefore, an individual with an affected parent has a fifty-fifty chance of inheriting the disorder.

Unfortunately, because both Huntington disease and familial Alzheimer are late-onset disorders, an affected individual may already have had children before developing any symptoms. Presymptomatic, or predictive, tests can clarify an individual's risk for these diseases. Some of these tests involve indirect DNA testing, which involves looking at DNA sequences physically near — but not part of — the gene. This line of testing requires testing both an affected family member and other relatives in order to diagnose the disease in a person at risk. Other tests use direct DNA testing, which involves a direct examination of the relevant gene in a search for mutations in that gene. Only individuals at risk are tested by this method. However, these diseases are currently untreatable, and individuals at risk may decide that they would rather not know if they or other family members are destined to suffer through the mental and physical deterioration these diseases cause. In addition, people with these types of degenerative diseases may be denied insurance, have difficulties obtaining employment, and are ineligible to adopt children.

Materials

For each group:

- Handout 7, page 22
- Pencil
- Paper

Preparation

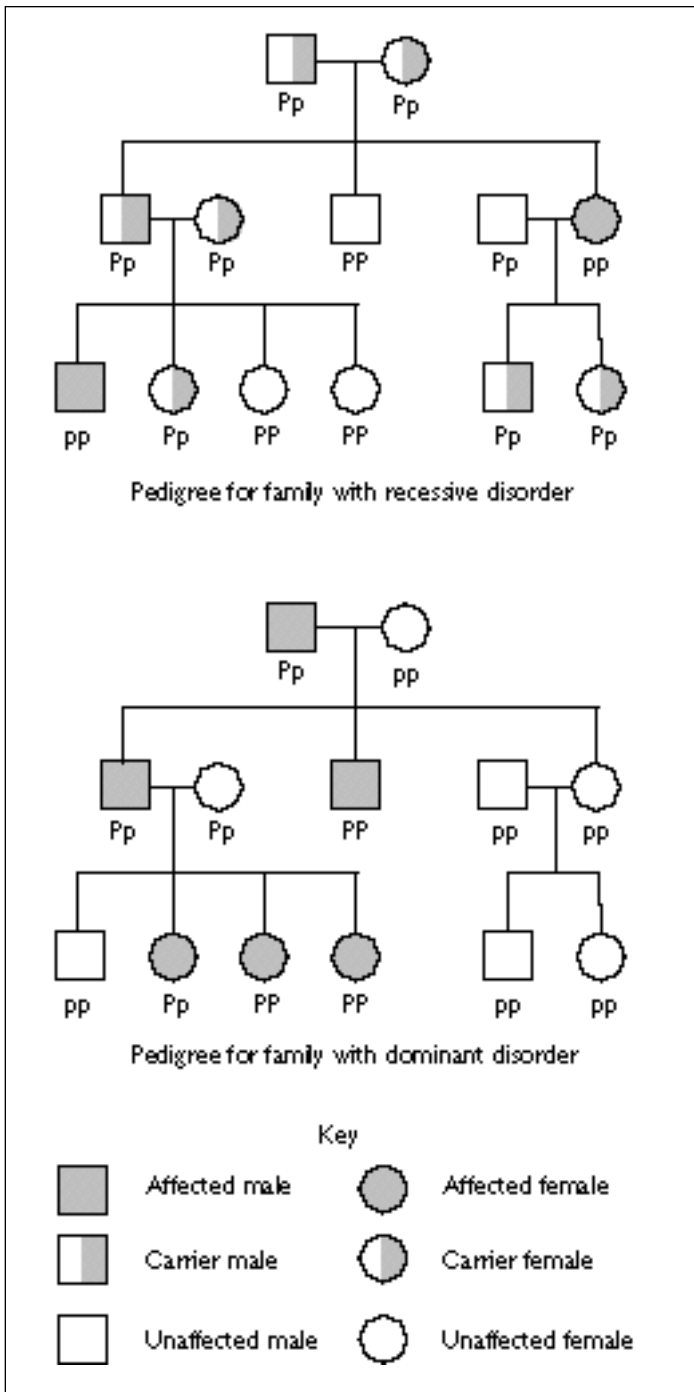
Duplicate Handout 7 to distribute to students.

Instructions

1. Divide the class into groups of four to six. Explain that each student should choose one of the roles listed at the top of the case study handout. If needed, explain the responsibilities of a genetic counselor, which include being a sensitive, knowledgeable, and supportive listener; explaining the nature of the genetic condition, including its background, inheritance patterns, and possible treatments; and helping people understand the options available to them.
2. Ask the students to read carefully through the scenarios on the handout. Have them answer the question beneath each scenario based on how they think that person would respond.
3. If time permits, have students choose another role and discuss the consequences of the scenarios from the new viewpoint.

Discussion Questions

1. What can genetic testing for a late-onset disease tell you? What can it not tell you?
2. What are the potential advantages of knowing that you carry or are at risk for a genetic disorder? What are some of the disadvantages?



Comparison of the inheritance pattern of recessive and dominant disorders in a family.

3. Would you want to be tested for a late-onset disorder? Why or why not?
4. If you knew that your employer would have access to the information, would you decide to test for a late-onset disease? Why or why not? Who do you think should have access to this information?

Extensions

1. Have students contact local hospitals and public health facilities to create a list of local genetic counseling resources. Have students interview a genetic counselor to find out how the counselor helps people make decisions and what ethical dilemmas the job presents. Before the interview, students should brainstorm a list of questions to ask during the interview.
2. Ask each student to write a letter as though he or she were someone seeking advice about some aspect of genetic testing. For example, students might pretend they are individuals who are being pressured into testing by close relatives; individuals who are trying to decide whether or not to test their fetus; or individuals who are trying to determine the risks and benefits of a particular test.

After students have written their letters, ask them to exchange letters with someone else in the class. Have them write a response to the letter they are given. Discuss the letters and the responses with the class.

3. Draw the pedigrees shown on the left on a blackboard or piece of paper. Ask students to examine the pedigrees and note any patterns they see. Ask them to imagine that they have been given a pedigree showing the affected and non-affected individuals in a family. Have them discuss how they might determine whether the trait was dominant or recessive.

ACTIVITY 6

Objective

Students will assess the risks and benefits of different gene therapies.

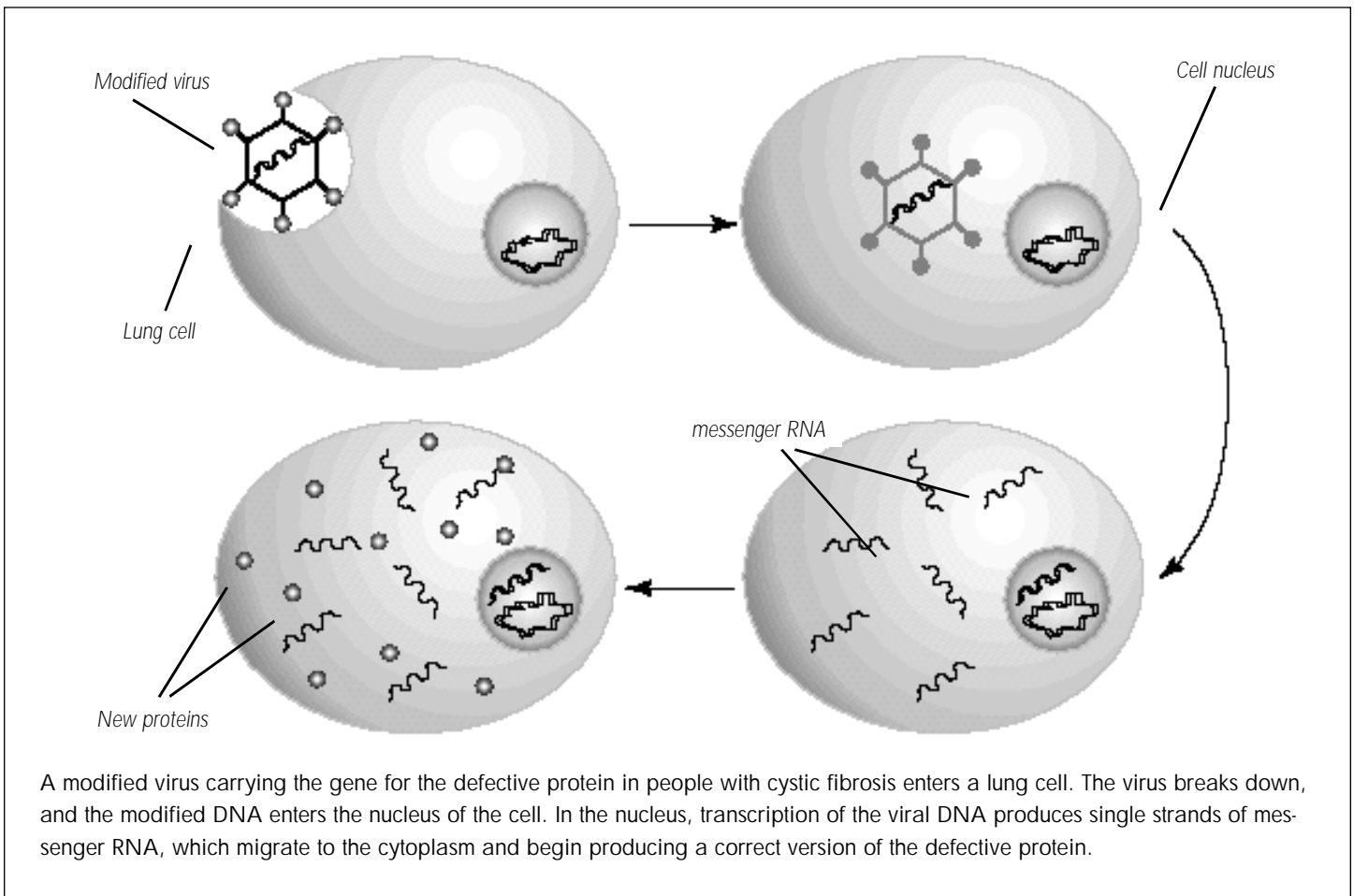
Background Information

Gene therapy involves the insertion of new genetic material into cells in a patient's body. By inserting manipulated DNA directly into the body, doctors can correct or enhance a particular cellular function, such as enzyme production; increase the vulnerability of diseased cells; or, in some cases, block the operation of particular cells or cell functions.

Developing specific therapies requires several steps. First, researchers must determine the gene or genes that cause or affect the disorder. Next, they must decide on the best approach for solving the problem and determine how to

modify DNA sequences to carry out that solution. And then researchers must find safe, efficient vehicles—called vectors—to carry the modified DNA to targeted cells. There are several vectors already in use, including chemical solutions, synthetic fat molecules, and viruses that have been modified so that they are harmless.

In each step of the process there is some degree of difficulty and risk. It is not always clear how modifying one gene may affect other genes in the DNA sequence, and if more than one gene needs to be modified, the chances of other genes being affected goes up. It is also possible that the integration of viral DNA into a cell's genome might accidentally activate genes that can trigger the growth of cancer. And it is difficult to target the correct cells to modify. For example, the cells responsible for producing mucous in cystic fibrosis patients are located in the patients' lungs. There is no easy way to remove and insert cells directly into the lungs, so current experimental procedures involve





using a tube that drips a solution containing modified cells into the lungs. Doctors hope that enough cells will be reached by this process to effect a change.

In addition, there are many ethical issues involved in gene therapy. For example, some of the current questions being debated include: Which diseases should be targeted? How will the genetic manipulation be regulated? How much money should be spent on developing gene therapies for disorders for which alternative therapies already exist? Should genetic manipulation be used to eliminate defective genes from egg or sperm cells? Will genetic manipulation be used to “improve” the human species by selectively controlling for certain traits? Who should make these decisions?

Materials

For each pair of students

- Handout 8, page 23
- Paper
- Pencil

Preparation

Duplicate Handout 8 to distribute to pairs of students.

Instructions

1. Divide the class into groups of four to six. Explain that each group represents a committee that oversees the development of new gene therapies. The committee decides which projects should be given money for research and development of a therapy. However, funds are limited, and only one new project can be funded.
2. Ask the students to carefully read through the project summaries on the handout. Then ask each student to do a risk/benefit analysis for the projects to describe the issue and record information upon which to base his or her decisions. Explain that their risk/benefit analyses should contain the following five parts:
 - At least five facts about the proposed therapies
 - At least five opinions about the proposed therapies

- At least five risks involved in developing the therapies
- At least five benefits involved in developing the therapies
- A decision statement that includes a rationale based on the risks and benefits involved.

If necessary, you may want to help students get started by asking questions such as: How many people does the therapy affect? Are there specific ethnic groups that the therapy affects? Is the disorder fatal or debilitating? Does the therapy require modifying a single gene or more than one gene? Will modifying the genes cause unintended changes? Will the changes produced by the modified genes be inheritable? Are alternative treatments available for the disorder? If so, how effective are they?

3. Once students have completed their risk/benefit analyses, have each group use the information to decide which project should be funded. Then have the groups present their decisions, along with their rationales, to the class. They should also indicate any additional information they might need to make a better decision.

Discussion Questions

1. Which factors were most important to you in deciding which gene therapy project to fund? Which factors were least important? Why? Did all the members of your group agree on which project to fund? If not, what factors helped your group reach the final decision?
2. Suppose there were a fourth project that involved developing a gene therapy to “change” skin color. Do you think such a project should be funded? Why or why not? What other information might you want to have about the project before you decide?
3. Suppose it were possible to eliminate genes from egg or sperm cells that make us vulnerable to disease or aging. What are some of the consequences of changing the egg or sperm cells? Under what conditions do you think this practice should be allowed? Give reasons for your answers.



DNA patterns

T	T	T	T	T	T	T	T	T	T
T	T	T	C	C	C	C	C	C	
G	G	G	G	A	A	A	A	A	A
A	A	A	A						

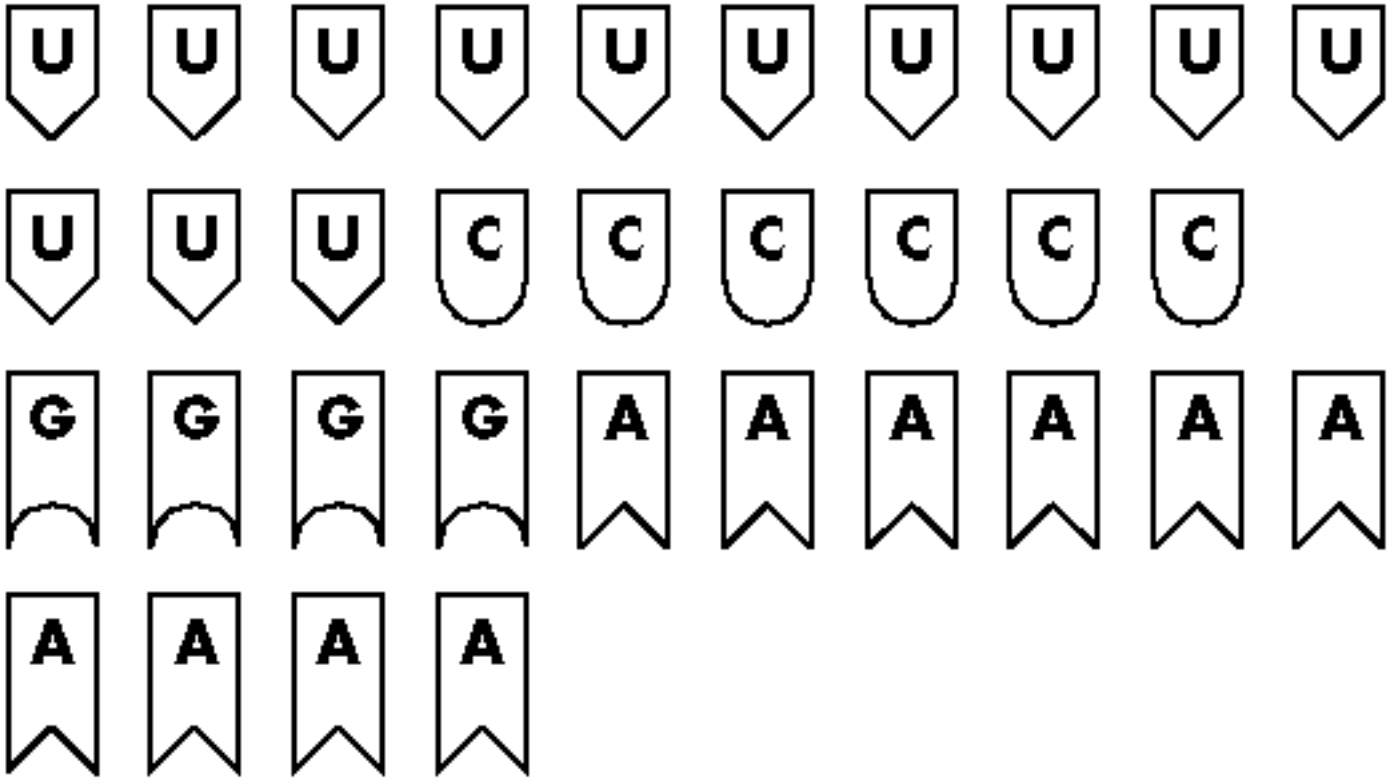
Messenger RNA patterns

						A	A	A	A
A	A	A	A	A	A	G	G	G	G
	C	C	C	C	C	C	U	U	U
U	U	U	U	U	U	U	U	U	U

tRNA and Amino Acid Codes

ACTIVITY 1, page 4

Transfer RNA patterns



mRNA Codons and Corresponding Amino Acids

First Nucleotide	Second Nucleotide			
	U	C	A	G
U	UUU phenylalanine UUC UUA leucine UUG	UCU serine UCC UCA UCG	UAU tyrosine UAC UAA stop UAG	UGU cysteine UGC UGA } stop UGG } tryptophan
C	CUU leucine CUC CUA CUG	CCU proline CCC CCA CCG	CAU histidine CAC CAA glutamine CAG	CGU arginine CGC CGA CGG
A	AUU isoleucine AUC AUA AUG } methionine /start	ACU threonine ACC ACA ACG	AAU asparagine AAC AAA lysine AAG	AGU serine AGC AGA arginine AGG
G	GUU valine GUC GUA GUG	GCU alanine GCC GCA GCG	GAU aspartic acid GAC GAA glutamic acid GAG	GGU glycine GGC GGA GGG



Genetic Trait Chart

ACTIVITY 2 page 6

Use the following traits to determine the genotype and phenotypes of your child.

Trait/Gene(s)	Alleles	
Finger Length Finger Length (F or f)	F = normal fingers	f = long fingers
Height* Height 1 (H ₁ or h ₁) Height 2 (H ₂ or h ₂)	H ₁ H ₁ H ₂ H ₂ = very short H ₁ H ₁ H ₂ h ₂ = somewhat short H ₁ H ₁ h ₂ h ₂ = average	H ₁ h ₁ h ₂ h ₂ = somewhat tall h ₁ h ₁ h ₂ h ₂ = very tall
Communication Skills* Communication Skills (T or t)	T = talkative	t = quiet
Math Ability* Math 1 (M ₁ or m ₁) Math 2 (M ₂ or m ₂)	M ₁ M ₁ M ₂ M ₂ or M ₁ M ₁ M ₂ m ₂ = high M ₁ M ₁ m ₂ m ₂ = average	M ₁ m ₁ m ₂ m ₂ or m ₁ m ₁ m ₂ m ₂ = low
Hypercholesterolemia* Hypercholesterolemia 1 (C ₁ or c ₁) Hypercholesterolemia 2 (C ₂ or c ₂)	C ₁ C ₁ C ₂ C ₂ or C ₁ C ₁ C ₂ c ₂ = very likely C ₁ C ₁ c ₂ c ₂ = likely	C ₁ c ₁ C ₂ C ₂ or c ₁ c ₁ C ₂ C ₂ = not very likely
Stamina* Stamina (S or s)	S = high	s = low
Hair Type Hair Type (K or k)	K = curly	k = straight
Alcoholism* Alcoholism 1 (D ₁ or d ₁) Alcoholism 2 (D ₂ or d ₂) Alcoholism 3 (D ₃ or d ₃)	D ₁ D ₁ D ₂ D ₂ D ₃ D ₃ = extremely likely D ₁ D ₁ D ₂ D ₂ D ₃ d ₃ = very likely D ₁ D ₁ D ₂ D ₂ d ₃ d ₃ = likely D ₁ D ₁ D ₂ d ₂ d ₃ d ₃ = somewhat likely	D ₁ D ₁ d ₂ d ₂ d ₃ d ₃ = not very likely D ₁ d ₁ d ₂ d ₂ d ₃ d ₃ = unlikely d ₁ d ₁ d ₂ d ₂ d ₃ d ₃ = very unlikely
Vision Vision (V or v)	V = near sighted	v = normal vision
Dimples Dimples (I or i)	I = dimples	i = no dimples

* Note that these traits may also be affected by the child's environment

Genotype and Phenotype Record Sheet

ACTIVITY 2 page 6

1. Flip two coins to determine the genotype for each gene listed on Handout 3. Heads represents a dominant allele, tails represents a recessive allele. Record the results in the Genotype column.
2. Use Handout 3 to determine the phenotype for each trait. Record the results in the Phenotype column.

Gene	Genotype	Phenotype
Finger Length		
Height 1 (w/ Height 2)*		
Communication Skills*		
Math Ability 1 (w/ Math Ability 2)*		
Hypercholesterolemia 1 (w/ Hypercholesterolemia 2)*		
Hypercholesterolemia 2 (w/ Hypercholesterolemia 1)*		
Stamina*		
Hair Type		
Math Ability 2 (w/ Math Ability 1)*		
Alcoholism 1 (w/ Alcoholism 2 and 3)*		
Alcoholism 2 (w/ Alcoholism 1 and 3)*		
Vision		
Height 2 (w/ Height 1)*		
Dimples		
Alcoholism 3 (w/ Alcoholism 1 and 2)*		

* Note that these traits may also be affected by the child's environment



Genetic Profile Worksheet

ACTIVITY 2 page 6

Use the genetic profile of your "child" to help you answer the following questions.

1. What experiences in your child's life will influence his or her development? How will these experiences interact with the child's inherited traits?
2. Which, if any, of the following careers do you think would be particularly suitable for your child? Explain your answer.

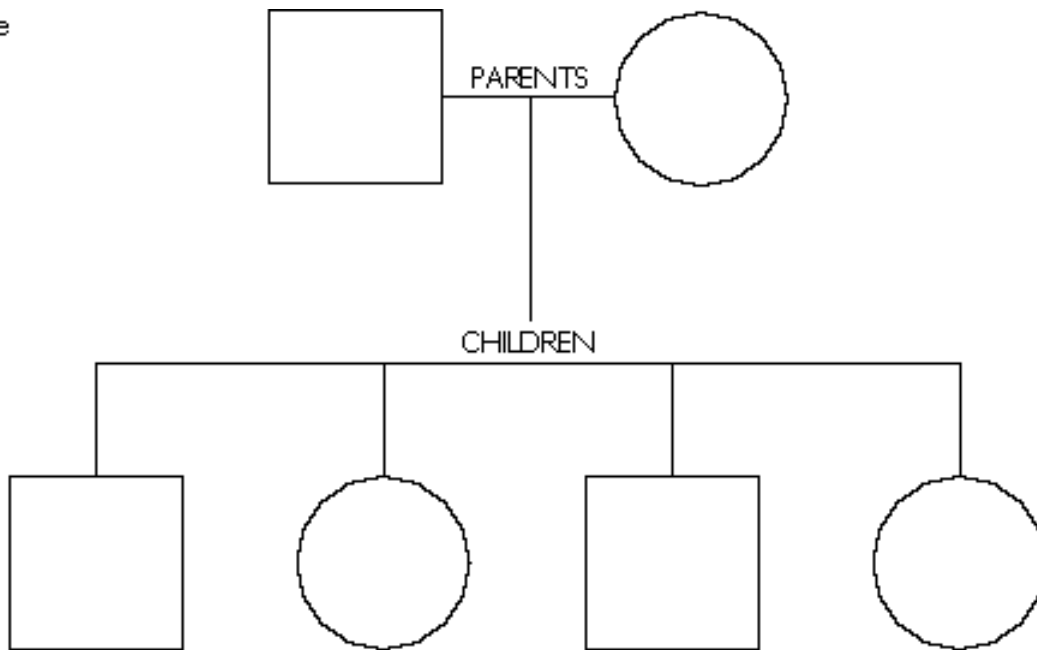
pilot	model	teacher	scientist	artist	accountant
athlete	plumber	musician	counselor	bartender	housekeeper
3. Which, if any, of the careers do you think would be particularly unsuitable for your child? Explain your answer.
4. What factors other than your child's genetic profile determine how successful the child will be in his or her career? Explain your answer.
5. Suppose your child has a high number of dominant alleles for math ability. Does this mean your child will be a genius at math? Why or why not? What if your child has a low number of dominant alleles for math? Does this mean your child will never be able to add? Why or why not?
6. Who should have access to a genetic profile? Give reasons for your answer.

Pedigree and Punnett Square Worksheet

ACTIVITY 3 page 8

1. Write the genotypes of the parents in the Parents positions of the pedigree. Use the appropriate color to indicate the phenotypes of the parents.
2. Use the Punnett Square to show all possible combinations of the parent alleles. Then write each combination in one of the Children positions on the pedigree. Use the appropriate color to indicate the phenotypes of the children.

Pedigree



Punnett Square

ALLELES FROM MOTHER

ALLELES FROM FATHER



Genetic Testing Worksheet

ACTIVITY 5 page 12

Choose one of the roles below. Then answer the questions following each scenario based on how you think that person would respond.

The Roles

Father
Mother
Son, age 21
Daughter, age 25
Genetic Counselor
Employer

The Scenarios

Scenario 1

The mother has a family history of Huntington disease (HD), but has not been tested. The father does not carry the HD gene. The son wants to be tested, but the daughter does not. What advice would you give the son, daughter, and mother? Why?

Scenario 2

The father is in the early stages of Huntington disease. The mother does not carry the HD gene. The son has interviewed for a job, but the employer wants to have the son tested for the HD gene as a condition of employment. What advice would you give the son about taking the test? Why?

Scenario 3

Both the mother and father have a family history of HD, but neither has been tested for the gene. The daughter is considering having children, but can't decide whether to take the test or not. What advice would you give her? Why?

Scenario 4

The mother is in the early stages of Huntington disease. The father does not carry the HD gene. The daughter is pregnant with her first child. She has decided to test the fetus for the HD gene. What advice would you give the daughter if the fetus tests positive? What advice would you give her if the fetus tests negative? Why?

Scenario 5

The father has a family history of Huntington disease but does not yet show any symptoms. The mother does not carry the HD gene. Both the parents want their children to be tested, but the son and daughter have not yet decided what to do. What advice would you give the family? Why?

Gene Therapy Project Summaries**ACTIVITY 6 page 14**

You are part of a committee that oversees the development of new genetic therapies—treatments for disorders that involve the use of manipulated DNA. You have received several proposals for new therapies; however, there is only enough money to fund the development of one treatment. Carefully read through the proposal summaries below. Then do a risk/benefit analysis to help you decide which proposal, if any, should be the one that is funded.

1. Severe combined immune deficiency (SCID) is an extremely rare and life-threatening disease that affects approximately 25 children a year. Many children with this disease lack an enzyme, called adenosine deaminase (ADA), which is critically needed by cells of the immune system, which fights disease and infections. Without the ADA enzyme the person's immune system does not develop. He or she is defenseless against even the most harmless viruses, bacteria, and fungi. A new therapy is being developed that involves removing white blood cells from an afflicted child, modifying a single gene in the cell DNA, and then transferring the modified DNA back into the blood. The modified DNA allows the body to produce the ADA enzyme. The modification only affects a specific DNA sequence, and the changed cells can be accurately reinserted into the body. In addition, the modified cells have a fixed lifetime, and are not inheritable. Repeated applications of the therapy will be needed every few months. Alternate treatments include lifetime care inside a germ-free environment, and bone marrow transplant, which requires a genetically compatible donor.
2. Sickle cell anemia is a blood disorder in which the red blood cells lose their round shape and collapse into sickle shapes. The sickle-shaped cells cannot carry oxygen to the body cells as normal blood cells do. In addition, the sickle cells tend to clog up small blood vessels, causing reduced circulation and severe pain that can last weeks or months. Damage may also result to major organs such as the heart, lungs, and brain. The disease affects approximately 1 out of every 500 African Americans, though the severity of the disease varies. A new therapy is being developed that involves removing cells from the bone marrow of an afflicted person, modifying a single gene in the cell DNA, and then transferring the modified DNA back into the bone marrow. The modified gene allows the body to produce normal hemoglobin, which is needed to prevent the red blood cells from collapsing. The modification affects only a specific DNA sequence, and the modified genes have a fixed lifetime and are not inheritable. However, it may be difficult to insert the modified cells into the stem cells where they are needed. Repeated applications of the therapy will be needed every few months. Alternate treatments for severe cases of the disease include frequent blood transfusions to relieve the symptoms, and bone marrow transplant, which requires a compatible donor. Treatments for less severe cases include increased attention to diet and nutrition.
3. Type 1 diabetes mellitus affects approximately 1 out of every 500 people, particularly those of northern European descent. The disease occurs when the pancreas stops producing insulin. Without insulin, the body is unable to metabolize, or use, food correctly. The symptoms of the disease include excessive thirst, weight loss, abdominal pain, tiredness, and increased likelihood of infection. A new therapy is being developed that involves modifying the genes that produce insulin so that they produce insulin when the concentration of sugar in the blood is high and do not produce insulin when the concentration of sugar in the blood is low. This requires modifying several genes, and may affect other DNA sequences near each gene. However, the modified cells will have a fixed lifetime and will not be inheritable. Repeated applications of the therapy will be needed every few months. Alternative treatments include daily shots of insulin.



GENETIC DISORDER PROFILES AND ORGANIZATIONS

Adenosine Deaminase Deficiency (ADA)

Affects: 1 out of 100,000

Type of trait: autosomal recessive

Chromosome on which gene is located: 20

Test applications: prenatal, carrier

Children with this disease have a defective immune system, and are susceptible to all types of infections. Gene therapy is being tested as a potential cure.

Cystic Fibrosis

Affects: 1 out of 2,500 Caucasians; 1 out of 90,000 African Americans

Type of trait: autosomal recessive

Chromosome on which gene is located: 7

Test applications: carrier, prenatal, newborn

Cystic fibrosis results in the secretion of a thick mucous in the lungs that blocks the flow of air. The disorder also causes digestive problems, salty-tasting skin, and susceptibility to respiratory tract infections. Cystic fibrosis is progressive and requires extensive medical treatment with antibiotics and digestive enzymes. It also requires daily respiratory therapy. Left untreated, most children will die by the time they are four or five. A special diet, daily doses of antibiotics to prevent infection, and other treatments can extend life expectancy to adolescence or later. About 40% of people with cystic fibrosis live to the age of 30.

Resource Organization:

National Cystic Fibrosis Foundation
6931 Arlington Road
Bethesda, MD 20814
800/344-4823 or 301/951-4422

Diabetes Mellitus Type I

Affects: 1 out of 300

Type of trait: polygenic

Chromosome on which gene is located: 6 and others

Test applications: presymptomatic

Type I diabetes mellitus results from destruction of the cells in the pancreas that make the hormone insulin. The loss of the insulin causes uncontrolled breakdown

of tissues and elevated blood sugar levels, progressing rapidly to death unless treated with insulin. Lifelong treatment with insulin is necessary. Because more than one gene along with environmental factors contributes to development of the disease, only 3-6% of children of parents with type I diabetes develop the disease.

Resource Organization:

National Diabetes Information Clearinghouse
1 Information Way
Bethesda, MD 20892-3560
301/654-3327

Down Syndrome (Trisomy 21)

Affects: 1 out of 800

Type of trait: extra chromosome (trisomy)

Chromosome on which gene is located: extra 21

Test applications: prenatal

People with Down syndrome have distinctive features, including a depressed nose bridge, a round face, and up-slanted eyes. There is also some degree of mental retardation. Early deaths in Down syndrome are sometimes due to leukemia, infection, or heart disease. Lifetime care is usually required.

Resource Organizations:

Association for Children with Down Syndrome
2616 Martin Avenue
Bellmore, NY 11710
516-221-4700

National Down Syndrome Society
666 Broadway Avenue
New York, NY 10012
800-221-4602

Duchenne Muscular Dystrophy

Affects: 1 out of 4,000 males

Type of trait: X-linked recessive

Chromosome on which gene is located: X

Test applications: carrier, prenatal, confirmatory

This disease predominately affects males. Symptoms, which include weakening of the leg and pelvic muscles, first appear around the age of 3 or 4. The muscles

continue to degenerate over time. Death, usually due to respiratory failure, often occurs in the twenties and thirties.

Resource Organization:

Muscular Dystrophy Association
3300 East Sunrise Drive
Tucson, AZ 85718
520/529-2000

Familial Alzheimer Disease

Affects: 1 out of 2-4 million adults

Type of trait: autosomal dominant

Chromosomes on which gene is located: 1, 14, 21

Test applications: presymptomatic, confirmatory

Symptoms of this disease begin to appear when a person is in his or her late 30s to 40s. They include loss of memory, intellectual deterioration, disorientation, apathy, and abnormal speech and movements. No cure exists.

Resource Organization:

Alzheimer's Disease and Related Disorders Association
919 N. Michigan Avenue, Suite 1000
Chicago, IL 60611
800-272-3900 or 312/335-8700

Fragile X

Affects: 1 out of 2,000 males; 1 out of 3,000 females

Type of trait: X-linked recessive

Chromosome on which gene is located: X

Test applications: carrier, prenatal, confirmatory

Fragile X Syndrome is the most common inherited cause of mental retardation. Other symptoms include learning disabilities, speech and language problems, and a loose-jointed walk. There is currently no cure for the disease.

Resource Organization:

National Fragile X Foundation
1441 York
Denver, CO 80206
800-688-8765 or 303/333-6155

Familial Hypercholesterolemia

Affects: 1 out of 500 (heterozygous); 1 out of 1 million (homozygous)

Type of trait: autosomal semidominant

Chromosome on which gene is located: 19

Test applications: newborn, confirmatory

People with familial hypercholesterolemia have high levels of cholesterol in their blood from birth. The cholesterol can gradually build up in artery walls, causing narrowing of the arteries. This process is known as atherosclerosis. Without treatment, a heart attack can result as early as age 25, although the average is in the forties for men and fifties for women. Usually no other symptoms are present, but some affected people develop cholesterol deposits in their tendons, which can become painful. With the proper combination of cholesterol-lowering medication, diet, exercise, and avoidance of cigarette smoke, most people with familial hypercholesterolemia can live normal lives and may never have a heart attack.

Galactosemia

Affects: 1 out of 80,000

Type of trait: autosomal recessive

Chromosome on which gene is located: 9

Test applications: carrier, prenatal, newborn

A person with galactosemia is intolerant to galactose, which is primarily found in milk and milk products. If left untreated, disease can cause liver failure, infection, cataracts, and mental retardation. No cure is available, but early treatment and life-long dietary restrictions prevent serious symptoms.

Hemophilia A

Affects: 1 out of 20,000 males, some carrier females

Type of trait: X-linked recessive

Chromosome on which gene is located: X

Test applications: carrier, prenatal, confirmatory

A person with this disorder is unable to produce the clotting material needed to stop bleeding. The person bleeds easily and may bleed to death even from small cuts. There is currently no cure, but symptoms of



GENETIC DISORDER PROFILES AND ORGANIZATIONS

hemophilia can be treated effectively with a supplemental clotting factor to slow down excessive bleeding.

Resource Organization:

National Hemophilia Foundation
110 Greene Street, Suite 303
New York, NY 10012
800/424-2634 or 212/219-8180

Huntington Disease

Affects: 1 out of 20,000 adults

Type of trait: autosomal dominant

Chromosome on which gene is located: 4

Test applications: prenatal, presymptomatic, confirmatory

This disorder of the central nervous system may first appear in adults between the ages of 20 and 70, but most frequently appears in the forties and fifties. A person with Huntington disease has involuntary jerky or writhing movements. Other changes include dementia, personality changes, depression, anger, and memory loss. In the final stages, the person usually enters an almost vegetative state. The disease is fatal and currently incurable.

Resource Organization:

Huntington Disease Society of America
140 West 22nd Street, 6th Floor
New York, NY 10011-2420
800/345-4372 or 212/242-1968

Phenylketonuria (PKU)

Affects: 1 out of 10,000

Type of trait: autosomal recessive

Chromosome on which gene is located: 12

Test applications: carrier, prenatal, newborn

People with PKU cannot completely metabolize foods

that contain the amino acid phenylalanine. Over time, the partially metabolized phenylalanine builds up in the blood and damages brain cells. Without early detection and treatment, individuals with PKU generally suffer from severe mental retardation as well as behavior disorders, seizures, and decreased pigmentation. There is currently no cure, but lifelong dietary precautions can prevent mental retardation and other symptoms.

Resource Organization:

Children's PKU Network
1520 State Street, Suite 240
San Diego, CA 92101
619/233-3202

Sickle-cell anemia

Affects: 1 out of 500 African Americans

Type of trait: autosomal recessive

Chromosome on which gene is located: 11

Test applications: carrier, newborn, prenatal

Sickle-cell anemia is a serious disorder in which the red blood cells lose their round, slightly disk shaped appearance and collapse into sickle shapes which cannot carry oxygen to the body cells. The flattened cells also tend to block and clog capillaries, causing reduced circulation and severe pain. People who have the disease may have shortened life expectancies.

Resource Organization:

Sickle-Cell Disease Association of America, Inc.
200 Corporate Pointe, Suite 495
Culver City, CA 90230-7633
800-421-8453 or 310/216-6363

Tay-Sachs Disease

Affects: 1 out of 3,600 Ashkenazi Jews

Type of trait: autosomal recessive

Chromosome on which gene is located: 15

Test applications: carrier, prenatal, confirmatory

The brain cells in people with Tay-Sachs are unable to metabolize a particular type of lipid. As lipids accumulate in the brain, brain cells gradually cease to function normally. This results in nervous system degeneration, uncontrollable convulsions, and total loss of sensory input. Children with Tay-Sachs usually die by the age of four.

Resource Organization:

National Tay-Sachs and Allied Diseases Association
92 Washington Avenue
Cedarhurst, New York 11516
516-569-4300

Thalassemia

Affects: 1 out of 2,500 of Mediterranean and Chinese/Southeast Asian ancestry

Type of trait: autosomal recessive

Chromosomes on which gene is located: 11 & 16

Test applications: carrier, prenatal, confirmatory

Children with this disorder are born normal, but become anemic between the ages of 3-18 months. The children become pale, do not sleep well, have decreased appetite, and fail to thrive. Current treatment includes frequent blood transfusions. If not treated, children with this disorder may die from anemia between the ages of 1 and 8.

Resource Organization:

Cooley's Anemia Foundation
129-09 26th Avenue, Suite 203
Flushing, New York 11354
800-522-7222 or 718/321-2873

General Genetic Disorder Resource Organizations

The following organizations provide a variety of services and activities, including support groups, educational materials, and general information.

March of Dimes Birth Defects Foundation
1275 Mamaroneck Avenue
New York, New York 10605
914-428-7100

National Center for Human Genome Research,
Office of Communications
National Institutes of Health
Building 31, Room 4B09
31 Center Drive
Bethesda, MD 20892
301/402-0911

National Network to Prevent Birth Defects
701 E Street, S.E.
Washington, DC 20003
202-543-5450

For information on careers in genetic counseling:

National Society of Genetic Counselors, Inc.
233 Canterbury Drive
Wallingford, PA 19086
610/872-7608



REFERENCES

Level indicators:

- 1 = suitable for general public
- 2 = suitable for high school students
- 3 = useful for faculty
- 4 = useful for advanced faculty

GENERAL READING

Andrews, Lori B., et al., eds. *Assessing Genetic Risks: Implications for Health and Social Policy*. Washington, DC: National Academy Press, 1994. This report by the Committee on Assessing Genetic Risks addresses the many phases of genetic testing and its impact on patients, providers, and laboratories. (1)

Bains, William. *Genetic Engineering for Almost Everybody*. New York, NY: Viking Penguin, 1990. Provides accessible information about the development of genetics, molecular biology, and decoding DNA. (1)

Balkwill, Fran. *Amazing Schemes Within Your Genes*. Cold Spring Harbor, NY: Cold Spring Harbor Laboratory Press, 1993.

—————. *Cells Are Us*. Cold Spring Harbor, NY: Cold Spring Harbor Laboratory Press, 1990.

—————. *Cell Wars*. Cold Spring Harbor, NY: Cold Spring Harbor Laboratory Press, 1990.

—————. *DNA is Here to Stay*. Cold Spring Harbor, NY: Cold Spring Harbor Laboratory Press, 1992.

Cartoon illustrations in all four books support explanations of scientific concepts; suitable for reading aloud to students, as well as for students' use. (1, 2)

Beardsley, Tim. "Vital Data." *Scientific American* March 1996; 274:3. As the Human Genome Project is producing vol-

umes of information about our hidden susceptibilities to disease, it is challenging us with many difficult and thorny societal issues. An accessible article that covers everything from sequencing to genotype to who should know to who benefits financially.

Bishop, Jerry E., and Michael Waldholz. *Genome: The Story of the Most Astonishing Scientific Adventure of Our Time—The Attempt to Map All the Genes in the Human Body*. New York, NY: Simon and Schuster, 1990. Highlights major events leading up to our present state of genetic exploration and biotechnology. Includes examples of personal challenge and achievement as well as a good feeling for the personal and professional challenges involved in scientific research. (1)

Cavalieri, Liebe F. *The Double-edged Helix: Science in the Real World*. New York, NY: Columbia University Press, 1981. A biochemist's critical view of the long-range consequences of recombinant DNA technology, and, more generally, of what he sees as the growing subservience of science to technology. (1)

Cook-Deegan, Robert. *The Gene Wars: Science, Politics, and the Human Genome*. New York, NY: W.W. Norton, 1994. A firsthand look at the politics and science behind the Human Genome project. (1)

Davis, Bernard D., ed. *The Genetic Revolution: Scientific Prospects and Public Perceptions*. Baltimore, MD: Johns Hopkins University Press, 1991. This collection of essays examines molecular genetics, the practical applications of biotechnology, its legal implications, benefits, and harmful consequences. (1)

Duster, Troy. *Backdoor to Eugenics*. New York, NY: Routledge, 1990. This book focuses on ethical and social issues. (1-4)

Edey, Maitland A. and Donald C. Johanson. *Blueprints: Solving the Mystery of Evolution*. New York, NY: Viking Penguin, 1990. An introduction to evolution and genetics for the general public. (1)

Gonick, Larry, and Mark Wheelis. *The Cartoon Guide to Genetics*. rev. ed. New York, NY: HarperCollins Perennial, 1991. Cartoons for all ages. Some illustrations are helpful for class explanations of concepts. (1-3)

Goodfield, June. *Playing God*. New York, NY: Random House, 1977. A look at both the people and ethical issues involved in the early days of genetic engineering. (1)

Grobstein, Clifford. *A Double Image of the Double Helix: The Recombinant-DNA Debate*. New York, NY: W.H. Freeman, 1979. Recounts the background and significance of the controversy over recombinant DNA research. Illustrates the scientific and social issues generated and how they were addressed early in the history of recombinant DNA. (1-4)

Hall, Stephen S. *Invisible Frontiers: The Race to Synthesize a Human Gene*. Redmond, WA: Microsoft Press, 1988. An inside view for the average reader on the science, politics, and pitfalls of the race to clone the gene for insulin. This well-researched account describes molecular biology in action, scientific competition, the development of NIH's recombinant DNA committee, and the birth of the first biotechnology company, Genentech, Inc. (1)

Herskowitz, Joel, and Ira Herskowitz. *Double Talking Helix Blues*. Cold Spring Harbor, NY: Cold Spring Harbor Laboratory Press, 1993. This tape-book package, illustrated by Judy Cuddihy, provides a unique way of learning about DNA and genes and how they work.

Interesting and fun for young people and adults who are curious about how they and their relatives became the unique individuals they are. (1, 2)

Hubbard, Ruth, and Elijah Wald.

Exploding the Gene Myth: How Genetic Information is Produced and Manipulated by Scientists, Physicians, Employers, Insurance Companies, Educators, and Law Enforcers. Boston, MA: Beacon Press, 1993. A compelling look at the possibilities, prophecies, and propaganda of genetic research and the Human Genome Project. (1)

Judson, Horace F. *The Eighth Day of Creation: The Makers of the Revolution in Biology.* New York, NY: Simon & Schuster, 1979. A science writer's comprehensive and accessible history of the research leading to the elucidation of the structure of DNA, the deciphering of the genetic code, and the structure and function of proteins. (1-4)

Keller, Evelyn F. *A Feeling for the Organism: The Life and Work of Barbara McClintock.* New York, NY: W.H. Freeman and Company, 1983. Highly readable and enjoyable biography of Nobel Prize winner Barbara McClintock, whose work in genetics was not appreciated — or even understood — for thirty years. (1-3)

Kevles, Daniel J., and Leroy Hood, eds. *The Code of Codes: Scientific and Social Issues in the Human Genome Project.* Cambridge, MA: Harvard University Press, 1992. An anthology of essays on the potential scientific and medical triumphs and social and ethical implications of the Human Genome Project. (2, 3)

Lappe, Marc. *Broken Code: The Exploitation of DNA.* San Francisco, CA: Sierra Club Books, 1984. An exploration, by a public health expert, of the social and

ethical implications of recombinant DNA research. (1-4)

Levine, Joseph, and David

Suzuki. *The Secret of Life: Redesigning the Living World.* Boston, MA: WGBH Educational Foundation, 1993. In this companion book to the PBS series of the same name, the authors expound upon the most important areas of the growing field of molecular biology. (1)

Los Alamos National

Laboratory. "The Human Genome Project." *Los Alamos Science*, vol. 20, 1992. This is a nicely illustrated overview of The Human Genome Project from the perspective of Los Alamos National Laboratory. It provides an excellent review of genetics and molecular genetics as well as a very thorough overview of genome mapping. The typography and illustrations make this accessible to high school students. (1-3).

Marion, Robert. *Was George Washington Really the Father of Our Country?.* Reading, MA: Addison-Wesley, 1994. In this entertaining book, the author examines how the course of world history may have been affected by the genetic background of world leaders such as George Washington, King George III, Abraham Lincoln, and Napoleon. (1-4)

McCarty, Maclyn. *The Transforming Principle: Discovering that Genes are Made of DNA.* New York, NY: W.W. Norton, 1985. An engaging description of the crucial experiments that established DNA as the genetic material. (1)

National Institutes of Health.

Genetic Information and Health Insurance: Report of the Task Force on Genetic Information and Insurance. National Center for Human Genome Research, National Institutes of Health, May 10, 1993. This

report assesses the potential impact of new advances in human genetics on the current system of health care coverage, and makes recommendations for managing that impact within a reformed health care system. (1, 3)

Neubauer, Peter B. *Nature's Thumbprint: The New Genetics of Personality.* Reading, MA: Addison-Wesley, 1990. A look at the nature-nurture-behavior-personality controversy. (1-3)

Recombinant DNA: Readings from Scientific American. New York, NY: W.H. Freeman, 1978. Thirteen articles from *Scientific American* that describe major scientific discoveries basic to recombinant DNA. Includes the 1975 article by Stanley Cohen describing how recombinant molecules were first produced. Includes bibliography. (3, 4)

Robinson, Arthur, and Mary

Linden. *Clinical Genetics Handbook, 2nd ed.* Cambridge, MA: Blackwell Scientific Publications, 1993. A useful reference on clinical genetics and genetic counseling. (3-4)

Shapiro, Robert. *The Human Blueprint: The Race to Unlock the Secrets of Our Genetic Code.* New York, NY: Bantam Books, 1992. A "reader-friendly" account by a professor of chemistry of the historical background, scope, and social meaning of the Human Genome Project. (1)

Strachan, T. *The Human Genome.* 1st ed. Oxford, UK: BIOS Scientific Publishers, 1992. A brief description of the genome project and the science surrounding it. (3)

Suzuki, David, and Peter

Knudtson. *Genethics: The Clash Between the New Genetics and Human Values.* Cambridge, MA: Harvard University Press, 1989. (1-4)



REFERENCES

Watson, James D. *The Double Helix*. New York, NY: Penguin Books, 1969. A popular and highly personal account of the science and personalities involved in the discovery of the structure of DNA. (1-3)

Watson, James D., and Francis H.C. Crick. "Molecular Structure of Nucleic Acids: A Structure of Deoxyribose Nucleic Acid." *Nature*, vol. 171, 1953. This is the article that set the foundation for all of molecular genetics. Probably the single most important page in the history of biology. (2-4)

Watson, James D., and John Tooze. *The DNA Story: A Documentary History of Gene Cloning*. New York, NY: W.H. Freeman, 1981. A history of gene cloning told through scientific papers, correspondence, newspaper articles, cartoons, and so on. (1-3)

Watson, James D., et al. *Recombinant DNA*. 2nd ed. New York, NY: Scientific American Books, 1992. Highly readable, accessible book, covering everything from the very basics of molecular biology to the latest, ground-breaking applications of recombinant DNA technology. An excellent resource for the teacher with some molecular biology background as well as the advanced student. (2-4)

Wills, Christopher. *Exons, Introns and Talking Genes: The Science Behind the Human Genome Project*. New York, NY: Basic Books, 1991. A scientist's view of the human genome project. Includes stories about the scientists involved in the project, the biomedical breakthroughs, and the implications of decoding the genome. (2)

Wexler, Alice. *Mapping Fate*. New York, NY: Time Books Random House, 1995. The author recounts the impact that Huntington disease, a devastating genetic disorder, has had on her family, and links

the story with the social movements of the 1950s and 1960s. Includes a clear, understandable explanation of classic and molecular genetics. (2)

TEXTBOOKS AND LAB MANUALS

Alberts, Bruce, et al. *Molecular Biology of the Cell*. 3rd ed. New York, NY: Garland, 1994. A veritable encyclopedia of molecular biology and cell biology. (3-4)

Berg, Paul and Maxine Singer. *Dealing With Genes: The Language of Heredity*. Mill Valley, CA: University Science Books, 1992. A thorough, advanced textbook intended for non-science majors. (2-3)

Corcos, Alain F, and Floyd V. Monighan. *Gregor Mendel's Experiments on Plant Hybrids: A Guided Study*. New Brunswick, NJ: Rutgers University Press, 1993. The text guides students through Mendel's classic experiments, and includes excerpts from Mendel's original text, explanatory note, and biographical material. (1-3)

Griffiths, Anthony J.F., et al. *Introduction to Genetic Analysis*. 5th ed. New York, NY: W.H. Freeman Company, 1993. General genetics textbook. (3)

Micklos, D., and Greg Freyer. *DNA Science: A First Course in Recombinant DNA Technology*. Cold Spring Harbor, NY: Cold Spring Harbor Laboratory Press, 1990. The very basics in recombinant DNA/molecular biology for the beginner; also suitable for the high school classroom as a teacher's guide. (3)

Singer, Maxine, and Paul Berg. *Genes & Genomes*. Mill Valley, CA: University Science Books, 1991. Thorough and comprehensive advanced college text. (4)

Watson, J. D., et al. *Molecular Biology of the Gene*. 4th ed. Redwood City, CA: Benjamin/Cummings, 1987. The source on molecular genetics. Superb, readable, comprehensive textbook of molecular biology. (4)

TEACHER RESOURCES

American Association for the Advancement of Science. *Project 2061: Benchmarks for Science Literacy*. New York, NY: Oxford University Press, 1993. Project 2061 has been working since 1985 to produce a set of tools that will help reform education in science, mathematics, and technology—including both the design of local curriculum and the educational system in which curriculum unfolds. (3)

Biological Sciences Curriculum Study. *Basic Genetics: A Human Approach*. Dubuque, IA: Kendall Hunt Publishing Company, 1991. A student text that includes stories, articles, and editorials about genetic disorders. Excellent for use in teaching basic genetic principles through applications of human genetics. (3)

—————. *Mapping and Sequencing The Human Genome: Science, Ethics and Public Policy*. Colorado Springs, CO: BSCS and American Medical Association, 1992. Addresses ethical issues and explains the Human Genome Project. (3)

—————. *Developing Biological Literacy: A Guide to Developing Secondary and Post-secondary Biology Curricula*. Colorado Springs, CO: BSCS, 1993. Useful guide for changing biology curricula and integration of the various topics and ideas covered in the "Winding your way through DNA" symposium into biology courses. (3)

Dawson, Douglas, Stacey Hill, and Jill Rulfs, eds. *Biotechnology: The Technology of Life*. Worcester, MA:

Massachusetts Biotechnology Research Institute, 1992. A resource book of lesson plans and activities for K-12 teachers, developed by the Massachusetts Biotechnology Research Institute in collaboration with the Worcester Polytechnic Institute and The New England Science Center. (3)

Jennings, Bruce, et al. *New Choices, New Responsibilities: Ethical Issues In the Life Sciences*. Briarcliffe Manor, NY: The Hastings Center, 1990. A teaching resource on bioethics of high school biology courses. (3)

Kieffer, George H. *Biotechnology, Genetic Engineering and Society*. Monograph Series: III. National Association of Biology Teachers, 1987. This monograph provides a very accessible background to topics listed in its title. (3,4)

National Association of Biology Teachers and North Carolina Biotechnology Center. *A Sourcebook of Biotechnology Activities*. Reston, VA: National Association of Biology Teachers, 1990. (3)

National Research Council. *High School Biology Today and Tomorrow*. Washington, DC: National Academy Press, 1989. Includes a collection of articles about current issues in biology education. (1, 3)

—————. *Mapping and Sequencing the Human Genome*. Washington, DC: National Academy Press, 1992. (2-3)

—————. *National Science Education Standards: An Enhanced Sampler*. Washington, DC: National Research Council. February 1993. A working paper of the National Committee on Science Education Standards and Assessment. (1, 3)

—————. *National Science Standards*. Washington, DC: National Academy Press, 1995. These voluntary guidelines are designed to ensure that all students graduate with the science knowledge and intellectual abilities they will need to make effective decisions in their everyday lives, participate in civic and cultural affairs, and become economically productive. (1, 3)

—————. *Reforms in Science Education, K-12*. School of Education Review: Special Issue. San Francisco, CA: San Francisco State University, Spring 1993. Includes a number of useful articles on incorporating biotechnology in the curriculum. (3-4)

Speaker, Susan L., and M. Susan Lindee, with Elizabeth Hanson. *A Guide to the Human Genome Project: Technologies, People, and Institutions*. Philadelphia, PA: Chemical Heritage Foundation, 1993. A publication of the Biomolecular Sciences Initiative of the Beckman Center for the History of Chemistry. (3-4)

Woodrow Wilson 1992 Biology Institute. *Bioethics*. Princeton, NJ: Woodrow Wilson National Fellowship Foundation, 1992. A series of activities produced by biology teachers attending the 1992 Woodrow Wilson National Fellowship Summer Institute. (3)

MOVIES & VIDEOS

Mastervision, Inc. *Building Blocks of Life*. New York, NY: Mastervision, Inc. Examines the booming science and industry of genetics and how the "building blocks of life" have become the basis of genetic engineering. (2,3)

University of California San Francisco. *Winding your way through DNA Symposium*. Cold Spring Harbor, NY: Cold Spring Harbor Laboratory Press,

1992. Designed to educate the public and to encourage a dialogue about the scientific possibilities and social puzzles of recombinant DNA technology. This unique adventure in public education brought together some of the major figures in the development of the science and technology. (1-4)*

—————. *Winding your way through DNA: On Becoming a Scientist*. Santa Monica, CA: Pyramid Media, 1995. This fast-paced MTV-style video is designed to dispel some of the misconceptions about scientists and science. Three graduate students and a lab manager touch on several topics that include problem solving and dealing with setbacks; how science contributes to and affects people's lives; how dedication and flexibility work hand in hand to balance work and leisure; managing a career and family; and more. (1-4)*

—————. *Winding your way through DNA: Stories from the Scientists*. Santa Monica, CA: Pyramid Media, 1994. This documentary tells the story of two of the most famous partnerships in biology—those between Francis Crick and James Watson, who discovered the structure of DNA, and between Herbert Boyer and Stanley Cohen, who pioneered the recombinant DNA techniques that revolutionized modern science. This 30-minute videotape weaves together interviews, animation, re-enactments, and historical footage to illustrate the participants' scientific achievements, personalities, and individual struggles with the challenge of discovery. (1-4)*

WGBH. *The Secret of Life*. Boston, MA: WGBH, 1993. This eight-part series gives an in-depth look at the scientific revolution involving DNA and its impact on our daily lives. (1-4)

*Contact Pyramid Media directly for broadcast rights



GLOSSARY



allele One of two or more alternative forms of a gene that exist at a specific gene location on a chromosome.

amino acid The basic chemical subunit of proteins. There are 20 common amino acids.

autosomal traits Traits carried on the chromosomes other than the sex chromosomes (X and Y).

base One of five compounds—adenine, guanine, cytosine, thymine, and uracil—that form the genetic code in DNA and RNA.

chromosomes Long threadlike structures made of DNA and protein that are the gene-bearing structures of eukaryotic cells.

codon A three-nucleotide sequence that codes for a specific amino acid stop or start signal in protein synthesis.

deoxyribonucleic acid (DNA) A double-stranded, helical nucleic acid molecule that is the carrier of genetic information.

DNA replication The copying of a DNA molecule.

DNA sequencing The process of deciphering the precise order of nucleotide bases in a DNA molecule.

dominant trait A characteristic determined by an allele that is expressed over any other alleles for a given trait.

enzymes A class of proteins that acts as catalysts, chemical agents that change the rate of a reaction without being consumed by the reaction.

gel electrophoresis The separation and identification of molecules based on their movement through an electrically charged field.

gene A discrete unit of hereditary information that consists of DNA and is located on the chromosomes.

gene cloning The process of synthesizing multiple copies of a particular DNA sequence using a bacteria cell or another organism as a host.

genetic code The set of sixty-four codons corresponding to each amino acid.

genetic engineering The technique of altering the genetic makeup of cells or organisms by deliberately inserting, removing, or altering individual genes.

gene expression The process in which a cell produces the protein encoded by a particular gene.

gene therapy A method of treating diseases that involves inserting new genetic material into a patient's cells.

genetics The study of how traits pass from parents to children and the molecular basis of those traits.

genome The entire set of genetic instructions for a given organism.

heterozygous Having two different alleles for a given gene.

homozygous Having two identical alleles for a given gene.

messenger RNA (mRNA) A type of RNA that relays the genetic information from the DNA in the nucleus to ribosomes in the cytoplasm.

nucleotide A chemical subunit composed of a five-carbon sugar, bonded to a phosphate group and nitrogenous base, which makes up DNA and RNA.

protein A molecule chain containing amino acid subunits linked together in a specific sequence.

recessive trait A characteristic determined by an allele that requires the presence of two identical alleles to be expressed.

recombinant DNA (rDNA) A DNA sequence produced by artificially joining pieces of DNA from different organisms.

restriction enzyme An enzyme that cuts DNA molecules at a specific base sequence.

ribonucleic acid (RNA) A single-stranded nucleic acid molecule involved in protein synthesis. The structure of RNA is determined by DNA.

ribosome A structure within cells that manufactures proteins by linking together amino acids according to the coded sequence on a strand of messenger RNA.

transcription The process of converting genetic instructions coded in a segment of DNA into messenger RNA.

transfer RNA (tRNA) A type of RNA that carries amino acids to ribosomes for the purpose of constructing a protein.

translation The conversion of genetic information coded in a segment of mRNA into a sequence of amino acids.

X-linked trait A trait that is passed on from mother to child or father to daughter on the X chromosome.



Full Committee

Chair Elizabeth H. Blackburn, PhD, Professor and Chair,
Department of Microbiology & Immunology,
School of Medicine, University of California San Francisco.

Project Director & Executive Producer Valli T. McDougle

Assistant Project Director Katherine Riordan

Carmen Arbona, Multimedia Instructional Designer, MouseWorks
Margaret Ransom Clark, PhD, Professor Emeritus of Laboratory
Medicine, and Director, UCSF Science and Health Education
Partnership, UC San Francisco

Lane H. Conn, Education Coordinator, Human Genome Education
Program, Stanford University School of Medicine

Susan Connell, JD, Consultant in Bioethics, San Francisco State University
Michael A. Goldman, PhD, Professor of Biology, San Francisco State University
Marian Gonzalez, Science Teacher, Lowell High School, San Francisco, CA
Geri Horsma, Science Teacher, Henry M. Gunn High School, Palo Alto, CA

Sally Hughes, PhD, Science Historian, Regional Oral History Office, The
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Sciences, UC San Francisco

Kathy Liu, Science Teacher, Westmoor High School, Daly City, CA
Glynis T. McCray, Research Associate, Genentech, Inc.

Carol Morita, Science Education Liaison, Genentech, Inc.
Andrew W. Murray, PhD, Associate Professor of Physiology,
UC San Francisco

Susan Spath, PhD Candidate, Department of History, UC Berkeley
Clayton Squire, Science Teacher, University High School,
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Nancy Stevens, Science Teacher, Terra Linda High School,
San Rafael, CA

VivianLee Ward, Science Teacher, Sequoia High School, Redwood City,
CA, and Teacher Coordinator, Access Excellence, Genentech, Inc.
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of Genetics, Stanford University School of Medicine
Michael Patrick, PhD, Department of Genetics, University of Wisconsin
Rudi Schmid, MD, PhD, International Relations, School of Medicine, UC
San Francisco

Video and Teacher's Guide

Project Director & Executive Producer Valli T. McDougle

Assistant Project Director Katherine Riordan

Teacher's Guide Writer, Designer, & Illustrator Margy
Kuntz

Teacher's Guide Production Daniel Rowe and Bill Roarty,
University Publications, UC San Francisco

Print & Video Logo Bud Peen

Production Company Zamacona Productions

Executive Producer Frank Zamacona

Producer/Director Robert Hone

Coordinating Producer Greg Swartz

Editor Blair Gershkow

Assistant Producer Dawn Sanchez

Production Assistant Colleen Burke-Hill

Video Graphics Redhill Studios

Opening Animation Video Arts, Inc.

Music Judy Munsen

Facilities provided by First Camera Video
Robert Berke Sound
Telesis Productions
Video Arts, Inc.
Red Hill Studios
Studio Nine

Promise & Perils of Biotechnology: Genetic Testing

In *Promise & Perils of Biotechnology: Genetic Testing* students learn about inherited disorders, their prevalence in society, and the benefits and drawbacks of genetic testing. As advances in biotechnology allow doctors to use genetic testing to identify more genetic conditions, the information not only helps expectant couples learn the health of their developing fetuses, but also confirms the presence of genetic conditions in children and adults. These findings pose ethical, legal and social dilemmas about how that information should be used.

This moving documentary profiles a young woman, with a family history of Huntington disease — a disease with no known cure — who decides to be tested. Also profiled is a mother and her young daughter who have changed their lifestyles to counteract their genetic odds in dealing with dangerously high cholesterol levels, known as familial hypercholesterolemia. The video captures people as they struggle with the realities of their conditions and focuses on diseases that do not segregate to one ethnic or cultural group, while not excluding others that do.

Comments on *Promise & Perils of Biotechnology: Genetic Testing*:

From students

- "...the most powerful [part] was telling about how genetic research will impact everyone in one way or another."
- "We've watched a thousand videos, but this one was real — I like it."
- "...explained things in a simple way."
- "...the film was great...understandable. I was able to pinpoint some of the things I've worked with in my class."
- "...the film was put into a story rather than a plain lecture...made it more interesting."
- "The people connected in finding out the genes of Laura and her daughter and Jennifer were caring and that's a reflection on the film."

From teachers (video)

- "Ethics are left out of most textbooks; this helps fill the gap."
- "It had the kids hooked...haven't been able to 'hook' them until now."
- "...a good addition to biology and biotechnology courses."
- "...brought out the personal side of science through ethical issues that students need to think about."
- "It was a very motivating film; [students] want to know more about genetics now."

From teachers (teacher's guide)

- "I love it. It's teacher-friendly and the materials it suggests are down-to-earth and realistic for today's budgets."
- "They should have these for all videos...it's a great aid for teaching the subject matter."

**Winding
your
way
through
DNA**



Produced by the
University of California
San Francisco

Promise & Perils of Biotechnology Genetic Testing

Teacher's Guide

**Developed by teachers
for teachers and students**

Distributed by



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