Teacher Notes: Risky Genetics

Background Information

Can genetic testing predict who will get a particular disease? The answer depends on the disease, how it is inherited, and whether or not it is influenced by other factors. For every gene, we inherit one copy, known as an allele, from each parent. Alleles can come in different forms, and some are harmful enough to cause diseases.

Some diseases are simply caused by a defect in one gene. For example, a type of lung disease known as Alpha-1 Antitrypsin Deficiency is caused by a defective SERPINA1 gene. Normally, this gene codes for an enzyme called alpha-1 antitrypsin that protects the lungs against deterioration. In healthy people, two normal, dominant alleles produce plenty of the enzyme. But if these two are damaged, recessive alleles are inherited, then the person does not produce enough of the enzyme, and his or her lungs slowly deteriorate over a lifetime. If one copy of each type of allele is inherited (one normal-dominant and one damaged-recessive), then an intermediate amount of the enzyme is produced, which is usually enough to protect the lungs. However, if a person is a heavy smoker or works in a dust-filled factory, severe problems could start early. This is an example of when genetic testing cannot predict the severity of the disease or when it will strike, because environmental factors can have a powerful influence on human health.

Other genetically caused diseases are more complicated. A specific type of Alzheimer's disease, which causes mental deterioration, is strongly linked to the gene PSEN1. A person with a dominant disease allele will almost certainly get "early onset" Alzheimer's disease, which occurs before the age of 65, because a harmful protein builds up within the brain. However, Alzheimer's disease that develops later in life is still poorly understood. Scientists have discovered several genes involved, but details remain fuzzy.

In another example, two genes—BRCA1 and BRCA2—are strongly linked to breast and ovarian cancer. Dominant disease alleles for either gene lead to a fivefold increase in a woman's risk of the disease, and even increase cancer risk for men. However, not all women with the disease alleles will get breast cancer, and not all women with breast cancer have these specific alleles. What accounts for this variation? Many genes are involved in cancer, as are health and environmental factors such as smoking habits and toxic pollution. Scientists are still looking for answers.

People may find genetic testing valuable, depending on the specific diseases they are interested in and their motivations. For example, genetic testing for alpha-1 antitrypsin deficiency, or for breast cancer, could give a person important insights into his or her health, leading to more diligent screening and better prevention and treatment. However, testing for early-onset Alzheimer's disease could result in a person feeling despair over a condition for which there is currently no treatment or cure. Some people choose genetic testing for other reasons, such as for help in deciding whether to have children or to contribute to research focused on learning about a disease and developing cures.

Answer Key

Lesson Plan: Step 7

a. Did the recommendations differ among the patients?

- In some cases, students' recommendations will be strikingly similar, such as "make healthier choices." This highlights a limitation of genetic testing: testing can give us more information, but might not actually be able to help us in our lifetimes. In other cases, recommendations will differ. For example, a patient with a high risk of breast cancer will benefit from frequent mammograms, but for other patients, such action would be unnecessary.

b. In terms of subsequent generations, do children inherit the same disease risks their parents have?

- Sometimes. Each parent has a unique genetic makeup. Depending on whether parents carry dominant or recessive alleles and what combination a child receives, a child may or may not be at risk for a disease.

c. Did the Punnett square help predict what genotype the child got?

- A Punnett square only shows a child's theoretical probability of getting a particular combination of genes.

Lesson Plan: Check for Understanding

What are the pros and cons of discovering a person's genotype for a particular disease?

- Finding out makes great sense when there are therapies or lifestyle actions that can improve a person's quality of life. For diseases with no treatment, finding out can cause anxiety. Often, the decision to know or not know comes down to a person's temperament and approach to life.

Student Handout: Procedure

1. Disease Chart from Section 4 of the Patient Record on the Student Handout

	Brief description, including any prevention, treatment, or cures
Breast Cancer	• Cells in breast tissue divide uncontrollably and create tumors. • Prevention and treatment include: regular checkups to look for tumors, preventive surgery to remove breasts and ovaries, surgery to remove tumors, and chemo and radiation therapy.
Lung Disease (alpha 1 antitrypsin deficiency)	• An enzyme that protects lung tissue is not present, therefore lung tissue slowly degrades over a lifetime. • Prevention is impossible, but avoiding smoking and illnesses and getting infusions to restore enzymes can help slow disease progress. If disease is advanced, lung transplants can extend life.
Alzheimer's Disease	• Brain function deteriorates. • No prevention or significant treatment is available. Doctors recommend staying active, and drugs can help slow disease progress.

2. Character Analysis

Answers will vary. For the Patient Record, check that students have:

- Correctly used the terms homozygous and heterozygous
  - o Two dominant alleles → homozygous dominant
  - o Two recessive alleles → homozygous recessive
  - o One dominant and one recessive → heterozygous
- Based the genetic risk of disease on the correct genotype
  - o BRCA2 → homozygous dominant and heterozygous genotypes will have high risk of disease
  - o SERPINA1 → only the homozygous recessive genotype will have high risk of disease
  - o PSEN1 → homozygous dominant and heterozygous genotypes will have high risk of disease

3. Medical Recommendations

Answers will vary, but check that students have correctly identified the appropriate actions for each disease and interpreted the role of lifestyle choices for each disease genotype:

- BRCA2 → High-risk patients should have regular checkups to look for tumors, and possibly consider having preventive surgery to remove breasts and ovaries. High-risk patients might want to encourage family members to be tested so that others can protect their health. Healthy living could slightly reduce risks, whereas unhealthy living could slightly increase risks.
- SERPINA1 → Homozygous recessive patients should take measures to protect their lung health, avoiding pollution, smoking, and contagious illnesses. Patients experiencing difficulty breathing can take medications and/or infusions. Family members might consider getting tested, particularly if they are having symptoms like difficulty breathing. Healthy living could reduce risks, whereas unhealthy living would definitely increase risks.
- PSEN1 → High-risk patients have few options except to be aware of the disease. Lifestyle choices do not influence risk. Family members might want to consider getting tested.

4. Punnett Squares and the Future Generation

Answers will vary, but be sure that students have used and interpreted Punnett squares correctly. For example, for the BRCA2 gene: If the parents' genotypes are homozygous dominant and heterozygous, then:

Punnett Square

	b	b
B	Bb	Bb
b	bb	bb

Probabilities

BB — 0%*
Bb — 50%*
bb — 50%

*genotypes potentially affected by breast cancer

5. Students should refer to their textbooks for how to construct a pedigree.

Student Handout: Questions

1. What is the difference between a Punnett square and a pedigree?
   - A Punnett square is a tool that shows a child's theoretical probability of getting a particular combination of genes. A pedigree shows the actual family history.
2. Can doctors predict who will get a particular disease based on a genotype for one gene alone? Why or why not?
   - Different diseases are inherited in different ways. Some diseases are based on a defect in one gene alone, and in that case, yes, doctors can predict who will be affected by the disease. But because many diseases are influenced by many genes and the relationships between all genes are unknown, the answer is usually no.
3. Do factors other than genes—food choices, environmental pollution, smoking habits—have the same effect on all people? If not, why not?
   - No. The influence of factors other than genes depends on each individual's genotype. In general, a healthy lifestyle is always a good idea. However, for most diseases, such as cancer or lung disease, whether or not disease strikes depends on a combination of both genetics and lifestyle.
4. List some of the advantages and disadvantages of genetic testing.
   - See answer below.
5. Do the advantages of genetic testing outweigh the disadvantages? Form an opinion and support your response with facts and examples.
   - Answers will vary but should be based on facts and examples. Advantages include: knowing about genetic-disease risks can encourage people to take measures to protect their health (frequent doctor visits) and reduce their other risk factors (stopping smoking or quitting a job in an unhealthy environment). For some diseases, such as lung disease, knowing the genotype can be very useful because specific treatments are available (such as enzyme infusions) that would not be used if the diagnosis were a different type of lung disease. Disadvantages include: genetic testing cannot predict the future; it can be expensive; and it could be used to discriminate against people. For diseases like early-onset Alzheimer's, knowing the genotype is not necessarily helpful and could be psychologically difficult to accept.

Rubric

Task	Excellent	Satisfactory	Needs Improvement
Completing genetic analysis and answering questions on the student handout	• Students use Web resources effectively to determine the genetic risks of disease and to answer questions. • Students can apply patient information to make recommendations.	• Student needs assistance answering questions. • Student interprets information from charts and diagrams.	• Students need assistance determining how specific genotypes relate to disease and are able to answer questions adequately. • Students have difficulty applying information to make recommendations.