



FUTURELAB+

BIOMED


*Crowdsourcing Innovations
in Biotechnology*

Errors in Cell Replication

Developed in partnership with:
Discovery Education and Ignited

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This document is separated into two sections, For Teachers [T] and Student Resources [S], which can be printed independently.

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Cover Image

The image shows a cell that has been divided by mitosis.

Errors in Cell Replication

DRIVING QUESTION

How does a cell quality check and handle abnormalities?

OVERVIEW

Cell cycle regulation is necessary for healthy growth. Both internal and external factors regulate cell division and can cause mutations. Mutations may be inherited and passed down to subsequent generations from parents to offspring. They can also be acquired from environmental factors such as smoking and radiation. Some of these mutations can also generate evolutionary changes in species that promote species diversity, while others cause genetic disorders and disease. On occasion, some genetic variations can even provide positive outcomes in select environments.

In this lesson, students will investigate the classes and types of mutations and their effects on organisms. Students will also learn how manipulating a strand of DNA can cause variations in the corresponding mRNA chains and amino acid sequence. They will then learn how geneticists use math to calculate mutation frequency to better understand the disorders they cause.

ACTIVITY DURATION

Four class sessions
(45 minutes each)

ESSENTIAL QUESTIONS

What types of mutations can a cell have and how are they formed?

What types of disease can develop as a result of these mutations?

What is the connection between control of the cell cycle and cancer?

OBJECTIVES

Students will be able to:

Recognize various types of mutations and their effects.

Relate the role of mutations in the development of genetic disorders.

Describe some benefits of genetic variation and relate them to human evolution.

Develop a chart summarizing the different classes of mutations and the diseases that may result from them.

BACKGROUND INFORMATION

Mutations are changes in a sequence of DNA that may be as small as a change in a single nucleotide, or as large as wholesale deletions or insertions of sections of DNA. The vast majority of mutations occur in non-protein coding areas of DNA, sometimes known as “junk DNA”. Mutations that occur here have no positive or negative bearing on the health or evolution of an organism. On occasion, some genetic variations can provide positive outcomes in select environments. For instance, the heterozygous carriers of the mutation which is responsible for sickle-cell hemoglobin provide some protection against malaria in regions where the disease is prevalent and endemic, such as west and east Central Africa. In this region, homozygous dominant carriers of the mutation are more likely to die from malaria while homozygous recessive carriers are stricken by sickle cell anemia. In addition, research on mutations to the CCR5 gene has led to theories that it not only provides protection against HIV infection but also infection by *Yersinia pestis*, the bacterial cause of the pneumonic and bubonic plagues.

**Materials****Mutations K-W-L Chart****Mutation Type Effects****Difference vs Disease Capture Sheet****Cell Cycle and Cancer Lab****Find the Cancer Capture Sheet****Microscopes****Microscope Slides**

- *Lung Tissue, Normal*
- *Lung Tissue, Cancerous*
- *Ovarian Tissue, Normal*
- *Ovarian Tissue, Cancerous*
- *Stomach Tissue, Normal*
- *Stomach Tissue, Cancerous*

Marfan Syndrome Pedigree**Medical Specialty Report Form****Diagnosis of Richard's Disorder****Design Journal**

Pedagogical Framing

Instructional materials are designed to meet national education and industry standards to focus on in-demand skills needed across the full product development life cycle—from molecule to medicine—which will also expose students and educators to the breadth of education and career pathways across biotechnology.

Through this collection, educators are equipped with strategies to engage students from diverse racial, ethnic, and cultural groups, providing them with quality, equitable, and liberating educational experiences that validate and affirm student identity.

Units are designed to be problem-based and focus on workforce skill development to empower students with the knowledge and tools to be the change in reducing health disparities in communities.



SOCIAL-EMOTIONAL LEARNING

This lesson addresses genetic abnormalities. The research and discussion around this topic offers students an opportunity for growth of critical consciousness and continued social-awareness while learning. A growth mindset has a powerful positive effect on the natural abilities and qualities that students perceive in themselves.

CULTURALLY AND LINGUISTICALLY RESPONSIVE INSTRUCTION

This lesson employs culturally and linguistically responsive strategies in order to encourage learners from all backgrounds to engage in a format that is comfortable for them. Equitable practices allow students to safely discuss sensitive topics like health disparities and questions involving specific communities, while it centers students' learning in their personal experience.

ADVANCING INCLUSIVE RESEARCH

Some communities are hesitant to engage in clinical research, due to mistreatment, health disparities, limited access to health care and low health literacy. In this lesson, students discuss the stigma around genetic mutations and engage in conversations around the disability rights movement. They discuss the role of genetic research in correcting genetic mutations that result in disabilities, and consider whether the presence of these mutations develops a richer and more diverse human experience.

COMPUTATIONAL THINKING PRACTICES

Computational thinking involves utilizing practices from computer science to solve real-world problems. In this lesson, students focus on genetic mutations and the processes of cell replication. As they do this, they gain experience with five different computational thinking strategies: developing algorithms, finding patterns, decomposing problems, collecting data, and analyzing data. Students develop an algorithm that outlines how DNA instructions are translated to protein outputs. They put the computational thinking strategy of finding patterns to work as they translate "secret messages" hidden in mRNA sequences. Students then decompose the process of mitosis into component phases and collect and analyze data on mitotic indexes. Students also identify patterns in genetic disease and use them to identify symptoms and predict outcomes in the case of a patient with Marfan's syndrome.

CONNECTION TO THE PRODUCT LIFE CYCLE

CRISPR is a gene editing technology with vast implications. Gene editing technology is in the **manufacturing** phase of the product life cycle, where it is being used in treatments like the Covid-19 vaccines.

Have you ever wondered...

How even the smallest mutations can cause the most devastating diseases?

Mutations that involve even one DNA base-pair can cause serious disorders through the possible alteration of one or more proteins that play an important role in the body's development and function.

How do some cells become "immortal"?

Every cell in our body is supposed to eventually get old and die. When a cell's telomeres, which are sequences of DNA that protect the chromosome, become too short to provide that protection, the cell eventually dies. However, if the telomeres do not shorten and continue to grow longer, the cell survives past its normal life expectancy and becomes immortal. It is these immortal cells that cause the advent of cancer.

Can mutations be passed from one generation to the next?

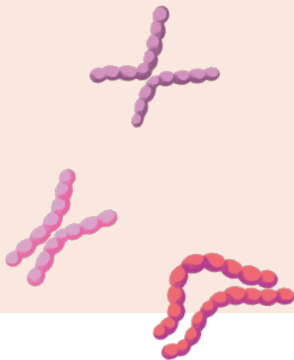
"Hereditary mutations," also known as germline mutations, are inherited from a parent due to their presence in the parent's sperm or egg cells. As a result, the mutated DNA is present in the fertilized egg and therefore, in a majority of the cells in the body. However, "acquired mutations" are caused by external factors, such as the environment. Because these mutations affect somatic cells, they cannot be passed to the offspring.

MAKE CONNECTIONS!

How does this connect to the larger storyline?

Genetic diseases are often the result of errors in cell replication.

The development of wearable technology that can collect information via digital biomarkers, act as indicators for the presence and severity of potential genetic diseases. As a result, wearable technology can be crucial in helping diagnose, manage, and treat these diseases.



How does this connect to careers?

Genetic counselors work in a variety of healthcare, medical, and research settings. They provide services to patients and families by assisting in understanding potential risks of genetic disorders in family planning and making decisions regarding treatment options.

They often work with doctors such as obstetricians and oncologists as well as research scientists and geneticists.

How does this connect to our world?

Genetic diseases have impacted humans globally for millennia. Learning how these diseases develop and are passed on through generations is the first step in developing treatments and possible cures for them.

Recent advances in science and technology have helped people with genetic diseases live longer and healthier lives.

Day 1

LEARNING OUTCOMES

Students will be able to:

Investigate errors in cell replication.

Translate mRNA sequences into amino acids.



COMPUTATIONAL THINKING IN ACTION

We can think of DNA as the instruction manual that tells our bodies how to make proteins. In this way, DNA is like the algorithms computer scientists write that tell computers how to perform tasks. In this activity, students are gaining hands-on experience with the computational thinking strategy of developing algorithms by creating a list of steps detailing the path from DNA instructions to protein output.

Procedure

Whole Group (15 minutes)

- 1 Distribute to students the [Mutations K-W-L Chart](#). Students should complete the K and W columns of the capture sheet.
- 2 Introduce the concept of mutations by using the CLR Participation Protocol: [Whip Around](#). In this activity, students name some of their favorite comic superheroes and describe specific mutations they possess to give them their powers. During this discussion, ask students if they know if their chosen superhero's mutation was hereditary or acquired. (Examples: Some were born with their mutations while others acquired their mutations.)
- 3 Next, the class will be introduced to mutations by watching [Mutations](#), a SciToons video.

Teacher Note > [SciToons YouTube Channel](#) was created by Dr. Oludurotimi Adetunji, a physicist at Brown University. It is important for students to see culturally diverse scientists involved in scientific endeavors. You can project this for students to view or allow them to view on individual laptops.

- 4 Have students complete the L column of the [K-W-L chart](#). Explain to students that they will be investigating how errors in cell replication can lead to genetic diseases. These are the genetic diseases that biomarkers can help indicate.

Small Group (25 minutes)

- 1 Place students in small groups. Have students read the [DNA Fact Sheet](#) produced by The National Human Genome Research Institute.

Teacher Note > Suggest to students that they take a look at brief bios of Research Investigators, so that students can see the full diversity of people involved in cutting-edge research endeavors.

- 2 As they read, have the students create a list of the steps from DNA → Protein in the correct order.

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Day 1

Continued

COMPUTATIONAL THINKING IN ACTION

Students are putting the computational thinking strategy to use as they translate the mRNA sequence and identify mutation types. This exercise helps students understand how mutations form patterns, like family traits that are passed down through generations.

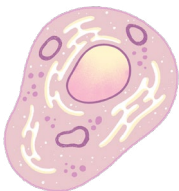
Procedure

- 3 Distribute to students the *Mutation Type Effects Capture Sheet*. Inform students that the nucleotide sequences on the capture sheet are mRNA, as they have already been transcribed from DNA. Ask students why these strands look different. (It is the Uracil instead of Thymine.) Students will be translating the mRNA sequences into amino acids, and then matching those amino acids to words like a cypher. They will use the mutations in the sequences and the subsequent changes to the sentence to help visualize a selection of mutation types.
- 4 The class will work on the first sentence together. Project a copy of the capture sheet on the board or write the first sequence where everyone can see it. Walk students through the steps of deciphering the code:
 - a First, students should divide the sequence into groups of three.
 - b Next, tell students to look at the first codon and match it to its appropriate amino acid using the supplied codon chart. Make sure to explain how to use the codon chart.
 - c Students will then see which word the amino acid represents and write out each word sequentially, so that it makes a sentence.
 - d The first sentence contains no mutations. In the following examples, students also need to determine which type of mutation has occurred.

Individual Work (5 minutes)

Have students record their thoughts on mutations.
Why are genetic mutations important?

Teacher Note > *This individual reflection may be used as an exit ticket to assess students' understanding of the topic. If necessary, the teaching plan may be adjusted for the next day or a word cloud graphic of student responses could be created.*



Day 2

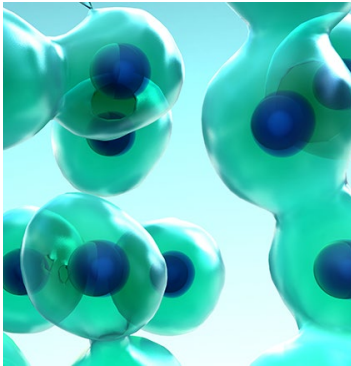
Procedure

LEARNING OUTCOMES

Students will be able to:

Identify positive, neutral, and negative effects of mutations.

Examine various stances on genetic intervention.



Whole Group (20 minutes)

- 1 Begin a class discussion by pointing out that when we think about the word “mutation” we tend to think about harmful effects like disease and disability. However, “mutation” is simply change, which can be either positive, harmful, or neutral. As a class, discuss how mutation may cause positive changes. Record answers on the board. Students may think about evolutionary changes, genetic mutations that make people more resistant to disease, or mutations that change superficial features like hair and eye color.
- 2 Project for the class this video on [The Effects of Mutation](#) as it relates to positive or neutral changes. As students watch, have them record two to three mutations that can be positive, two to three mutations that can be harmful, and two to three mutations that can be neutral. Be sure to pause the video for a moment in appropriate places to allow students to record their answers. For example, you may want to pause at 3:41 and at 05:03 into the video.
- 3 After the video, create three columns (Positive, Neutral, Harmful) on the board and have students volunteer some of their answers using the CLR Participation Protocol: [Raise a Righteous Hand](#). After you have collected a number of answers, address the “Harmful” column. Students will most likely have listed different forms of disease and disability. Ask students how people living with these illnesses might feel about being filed in a column labeled “Harmful.”

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INDUSTRY AND CAREER CONNECTIONS

Students will need to exhibit professional behavior as they discuss the disease and disability. They will focus on this soft skill similar to how genetic counselors need to be professional when interacting with and helping people from all backgrounds and abilities.

Day 2

Continued

Procedure

Small Group (20 minutes)

- 1 Have students move into groups of two or three. If the student groupings are going to be differentiated for English language learners or advanced readers, ensure that groups read the appropriate article. Together, they will read one of three articles:

The eugenics debate isn't over—but we should be wary of people who claim it can fix social problems—King's College London

Perspectives on gene editing—Harvard University

CRISPR, a Crossroads in Genetic Intervention: Pitting the Right to Health against the Right to Disability *advanced reading

Teacher Note > *Remind students that genetic research is done all around the world and that they might want to note the diversity of research contributors in these articles.*

- 2 After reading, have students complete the *Difference vs Disease Capture Sheet* to record their thoughts about genetics and the disability community.

Whole Group (10 minutes)

- 1 Have students use the instructional strategy: *Take a Walk* to discuss what they discovered in their research. Allow students to consider the following questions:
 - a Why do you think genetic intervention elicits a strong response from so many people?
 - b. What factors do people consider when taking a stance on genetic intervention?
 - c. How will the decisions we make as a society now influence diseases and people in the future?

Teacher Note > *Another option is to collect answers as an exit ticket, to gauge how students are processing and reflecting upon this topic. This may highlight areas that require further explanation, investigation, or discussion.*



Day 3

Procedure

LEARNING OUTCOMES

Students will be able to:

Analyze DNA sequences and identify where mutations exist on the genetic code.

Calculate the Mitotic Index and compare the rate of cell division in normal tissue and cancerous tissue.

COMPUTATIONAL THINKING IN ACTION

Here, students are using the computational thinking strategy of decomposition to break down the process of mitosis into component stages.

COMPUTATIONAL THINKING IN ACTION

As students analyze healthy and cancerous cells, they are using the computational thinking strategy of finding patterns.

COMPUTATIONAL THINKING IN ACTION

In order to calculate the mitotic index for the tissue samples, students are using the computational thinking strategy of collecting data. They then analyze the data they collected to evaluate their chart and answer the questions on the Cell Cycle and Cancer Lab.

Small Group (45 minutes)

- 1 In small groups, have students analyze four DNA sequences from healthy and cancerous cells, and identify the mutated sequence and corresponding amino acid.
- 2 *Cell Cycle and Cancer Lab:* This can either be done with microscopes and actual slides of normal and cancerous cells (preferred) or virtually using a teacher-generated presentation with pictures of slides of normal and cancerous cells.
- 3 Introduce students to the role of the **Medical Laboratory Technologist** by projecting the infographic from [Stautzenberger College](#). Explain that one of the roles of this technologist is examining biopsies to look for cancerous cells.
- 4 Project onto the board an image showing the stages of mitosis. Then, use *Train or Pass it On* to lead the class in detailing what noticeable features differentiate the different stages. These characteristics will be recorded by students during the activity, and displayed for the remainder of today's activities.
- 5 Have students examine the different stages of mitosis as shown in different tissue samples. The three types of tissue analyzed will be **stomach, ovary, and lung**. Normal and cancerous examples of the three tissue types will be analyzed. Ask students to label each stage of the cell cycle. If they used a microscope, they can sketch and label each stage. If they used a virtual presentation, they can insert text boxes with arrows for each stage.
- 6 Have students record the number of cells in each cell cycle stage analyzed in the given data table. Remind them to analyze each normal and cancerous examples of the three cell types.
- 7 Have students calculate the Mitotic Index (the ratio between the number of a population's cells undergoing mitosis to its total number of cells) for the normal tissue images. They should record data.

To calculate the Mitotic Index (average % cells dividing) in normal tissue:

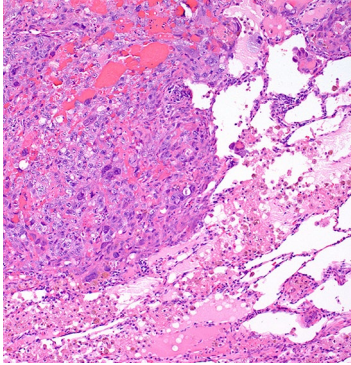
$$\frac{(\# \text{ cells in mitosis in Sample 1} + \# \text{ cells in mitosis in Sample 2})}{2} = \text{avg. \# cells dividing}$$

$$(\text{avg. \# cells dividing} / \text{total \# cells}) * 100 = \text{average \% cells dividing}$$

Continues next page >

Day 3

Continued



Procedure

-
- 8 Tell students to calculate the average percentage of cells at rest for the normal tissue images. They should record their data.

To calculate the average percent cells at rest in normal tissue:

$$\frac{(\# \text{ cells in Interphase in Sample 1} + \# \text{ cells in Interphase in sample 2})}{2} = \text{avg. \# cells at rest}$$

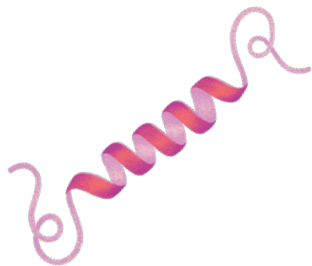
$$\left(\frac{\text{avg. \# cells at rest}}{\text{total \# cells}} \right) * 100 = \text{average \% cells at rest}$$

- 9 Direct students to repeat steps c and d for the cancerous tissue samples and to record data. Have them answer questions on the [Cell Cycle and Cancer Lab Capture Sheet](#) after the data tables are completed.

Sources for Virtual Slides:

[Virtual Slide List](#)

[The Leeds Virtual Pathology Project](#)



Day 4

Procedure

LEARNING OUTCOMES

Students will be able to:

Create a patient medical report.

Describe the characteristics of Marfan Syndrome.

Analyze medical history and symptoms to make an informed diagnosis.

Small Group (20 minutes)

- 1 Using the information from Cell Cycle and Cancer Lab, have students separate into groups of four for a role-play activity. The background information is as follows:

We are going 19 years back in time when the patient was 15 years old. We will name him Richard. Richard is taller than most of his classmates. At 15, he is already 6'3" and is a huge basketball fan. While he is a bit gawky and clumsy, he has been convinced that his height will give him an advantage on the basketball court over others his age. His parents want to support his dream, but they want him to see his pediatrician before the regular team physicals. They suspect that one of the parent's medical issues may be a result of a genetic abnormality that could have been passed down to Richard.

Ask students to place themselves in the position of Richard's parents. Ask them, "Would you allow Richard to try out for the basketball team? Why or why not?"

Explain that Richard and his parents went to see a genetic counselor. This requires that his genetic case be presented to some specialists to make a determination on his exact condition.

Teacher Note > *This is a good time to touch on some of the "soft skills" needed for success in the career of a genetic counselor: openness to learning, organizational skills, good attention span, professional behavior, detail-oriented, time management and ability to set priority, motivated learner, organized, sense of commitment, professional.*

- 2 Ask students to assume the roles of the genetic counselor and three medical specialists: Orthopedist (skeletal system), Cardiologist (heart and circulatory system), and Pulmonologist (respiratory system).

Teacher Note > *This role play helps with the priority of "Advancing Inclusive Research" as students immerse themselves in these roles and facilitate analysis and academic discourse. Sentence starters can be used to help model how students can add to and build upon other ideas in their discussions. Perhaps even invite students to challenge themselves to incorporate certain discipline-specific vocabulary.*

- 3 Each medical specialist group member will receive information corresponding to their specialty. The whole group will also be provided with a patient medical report form.
- 4 Have students read the information. Record what students have learned about Richard's medical history and physical exam.

Continues next page >

Day 4

Continued



COMPUTATIONAL THINKING IN ACTION

By using the computational thinking strategy of finding patterns to compare Richard's symptoms and the symptoms of Marfan's syndrome, students can identify relationships and make predictions about what might happen to Richard if he continues playing basketball.

Procedure

Whole Group (20 minutes)

- 1 Lead the class on an analysis of the combined pedigree/DNA sequence of a patient with Marfan Syndrome using the [Marfan Syndrome Pedigree](#).
- 2 Ask students to observe the image for one minute, writing down everything they notice (things that are familiar, things that are unfamiliar, etc.).
- 3 After the minute elapses, ask random students to share what they wrote down. If not mentioned by the students, ask the class to compare the DNA sequences in this image with the DNA sequences they analyzed last class.
- 4 Lead a brief discussion with the class about the things that make people with undiagnosed Marfan Syndrome desirable for certain sports. Discuss how this leaves them susceptible to early death from hidden heart ailments (i.e., aortic aneurysm and aortic dissection) which are a characteristic of the disease.
- 5 Have students connect the information presented in the Marfan syndrome video with the medical information about the patient and his relatives. Which parent had Marfan syndrome? How can you tell? Compare their medical symptoms.

Whole Group (5 minutes)

- 1 Have students discuss whether they believe Richard's medical history is connected to any of the diseases they have examined and what evidence they have to support each of their judgments.
- 2 The final five minutes will consist of volunteers from each group sharing their conclusions about whether Richard's medical issues are connected to the diseases they have examined in class.
- 3 Ask students, if you were Richard and found out you did have the condition, would you change your mind about playing basketball? Why or why not?
- 4 Invite students to use their **Design Journal** to capture how content learned in this lesson connects to the overarching problem we are investigating. Students should summarize that errors in cell replication can lead to genetic diseases. Biomarkers can help us identify genetic diseases.

National Standards

Next Generation Science Standards

LS3.B: Variation of Traits

In addition to variations that arise from sexual reproduction, genetic information can be altered because of mutations. Though rare, mutations may result in changes to the structure and function of proteins. Some changes are beneficial, others harmful, and some neutral to the organism.

Science and Engineering Practices

Obtaining, Evaluating, and Communicating Information

Critically read scientific literature adapted for classroom use to determine the central ideas or conclusions and/or to obtain scientific and/or technical information to summarize complex evidence, concepts, processes, or information presented in a text by paraphrasing them in simpler but still accurate terms.

Analyzing and Interpreting Data

Analyze data using tools, technologies, and/or models (e.g., computational, mathematical) in order to make valid and reliable scientific claims.

Crosscutting Concepts

Cause and Effect

Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.

Career and Technical Education (CTE)

A4.4:

Explain the basic concepts of cell growth and reproduction, DNA replication, mitosis, meiosis, and protein synthesis.

A5.1:

Use the Internet and World Wide Web to collect and share scientific information.

A6.1:

Apply knowledge of symbols, algebra, and statistics to graphical data presentation.

4.3:

Use information and communication technologies to synthesize, summarize, compare, and contrast information from multiple sources.

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National Standards

CTE*Continued*

5.4:

Interpret information and draw conclusions, based on the best analysis, to make informed decisions.

5.6:

Read, interpret, and extract information from documents.

Mutation Type Effects**ANSWER KEY****Do not share with students**

Today, you will be translating mRNA into amino acids. However, instead of building a protein, you will be building a sentence. As with normal cellular translation, the sequence can only begin with the START amino acid, Methionine. Additionally, all coding will cease when one of the STOP codons is present.

Directions

Begin by translating this mRNA sequence:

AUGCACAGGUCAGCUAUUUGA

1. Divide the mRNA sequence into sets of three.

AUG|CAC|AGG|UCA|GCU|AUU|UGA

Use the *Codon Chart* to determine your amino acid.

Met His Arg Ser Ala Ile STOP

Compare your amino acid sequence to the cypher.

START The Cat Is Very Fluffy STOP

Now, continue your work with the same mRNA sequence after it has undergone mutation.

2. Divide the sequence into sets of three and underline the mutation.

AUG|CAC|AGA|UCA|GCU|AUU|UGA

What is the amino acid sequence?

Met His Arg Ser Ala Ile STOP

What is the sentence?

START The Cat Is Very Fluffy STOP

How would you characterize this type of mutation?

Silent Point Mutation

3. Divide the sequence into sets of three and underline the mutation.

AUG|CAC|AGG|UCA|GCU|GCU|GCU|AUU|UGA

What is the amino acid sequence?

Met His Arg Ser Ala Ala Ala Ile STOP

What is the sentence?

START The Cat Is Very Very Very Fluffy STOP

How would you characterize this type of mutation?

Duplication Mutation

4. Divide the sequence into sets of three and underline the mutation.

AUG|CAC|UGG|UCA|GCU|UGA

What is the amino acid sequence?

Met His Trp Ser Ala Ile STOP

What is the sentence?

START The Pirate Is Very Fluffy STOP

How would you characterize this type of mutation?

Point Missense Mutation

Continues next page >

Mutation Type Effects**ANSWER KEY****Do not share with students***Continued*

5. Divide the mRNA sequence into sets of three.

AUG|CAC|AGU|GUC|AGC|UAU|UUG|A

What is the amino acid sequence?

Met His Ser Val Ser Tyr Leu...

What is the sentence?

START The Is They Is Pudding Thief...

How would you characterize this type of mutation?

Frameshift Nonsense Mutation

6. Divide the sequence into sets of three and underline the mutation.

AUG|CAC|AGG|UAA|GCU|AUU|UGA

What is the amino acid sequence?

Met His Arg STOP

What is the sentence?

START The Cat

How would you characterize this type of mutation?

Point Nonsense Mutation

7. Write your own sentence using the words available in the cypher.

Accept all reasonable answers.

What would be the required amino acid sequence?

Accept all reasonable answers.

What could be a possible mRNA sequence?

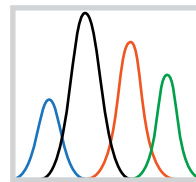
Accept all reasonable answers.

Find the Cancer: Mutation 1**ANSWER KEY****Do not share with students**

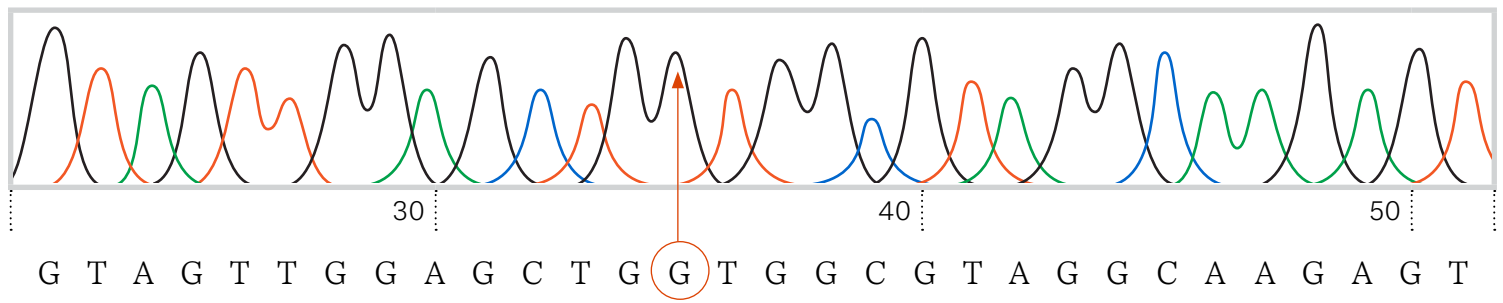
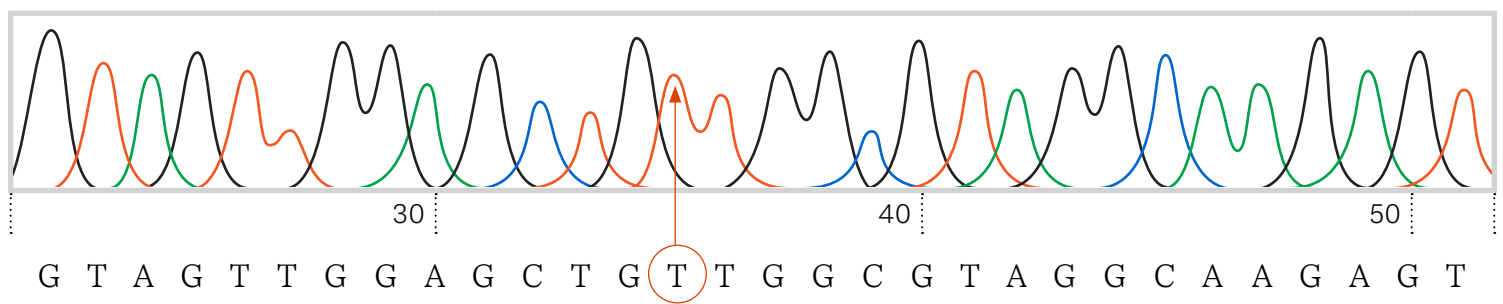
Below are sections of a DNA sequence from a particular gene. When mutated, the normal cell cycle is disrupted, thereby turning a cell from healthy to cancerous.

Directions

Using the key, compare the healthy DNA sequence with the tumor DNA sequence. If any differences are found, circle the letter(s) that have changed from one sequence to the next. Then complete the table using the provided genetic code.

**Key**

C Cytosine
G Guanine
T Thymine
A Adenine

Healthy Cell DNA**Tumor Cell DNA**

Amino Acid Number	Healthy DNA Sequence	Tumor DNA Sequence	Healthy Amino Acid	Tumor Amino Acid
12	GGT	GTT	Glycine (G)	Valine (V)

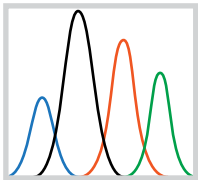
Find the Cancer: Mutation 2

ANSWER KEY

Do not share with students

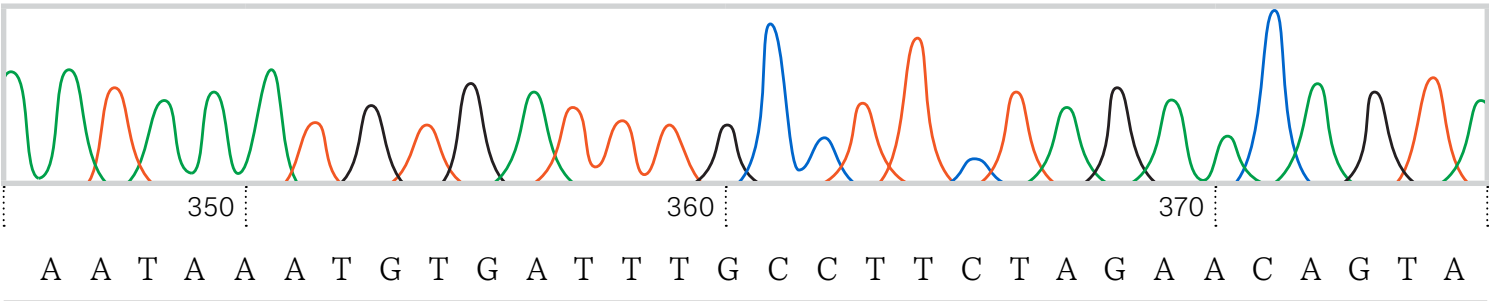
Below are sections of a DNA sequence from a particular gene. When mutated, the normal cell cycle is disrupted, thereby turning a cell from healthy to cancerous.

Directions
Using the key, compare the healthy DNA sequence with the tumor DNA sequence. If any differences are found, circle the letter(s) that have changed from one sequence to the next. Then complete the table using the provided genetic code.

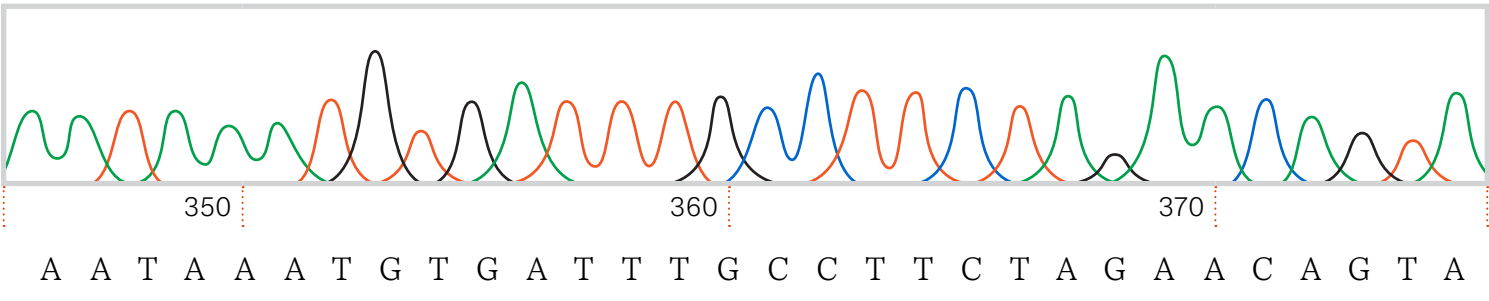


- Key**
- C Cytosine
 - G Guanine
 - T Thymine
 - A Adenine

Healthy Cell DNA



Tumor Cell DNA



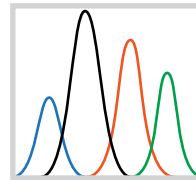
Amino Acid Number	Healthy DNA Sequence	Tumor DNA Sequence	Healthy Amino Acid	Tumor Amino Acid
N/A There are no mutations on the tumor DNA sequence.				

Find the Cancer: Mutation 3**ANSWER KEY****Do not share with students**

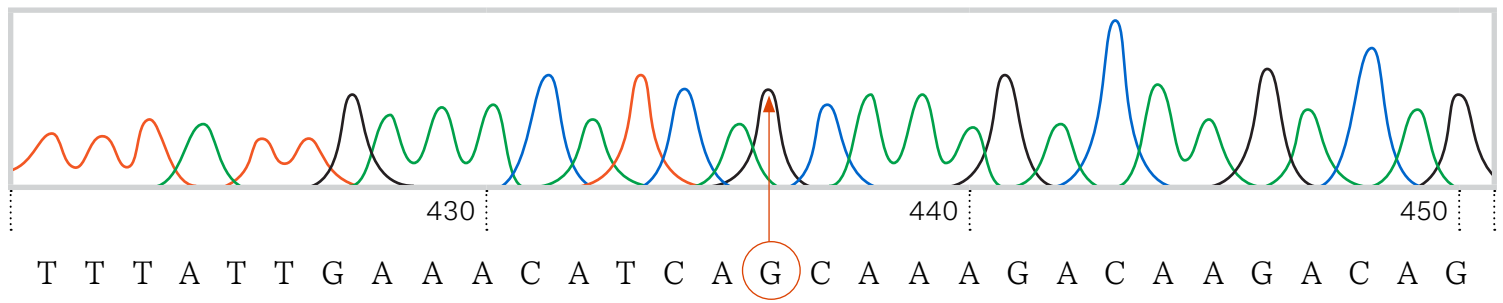
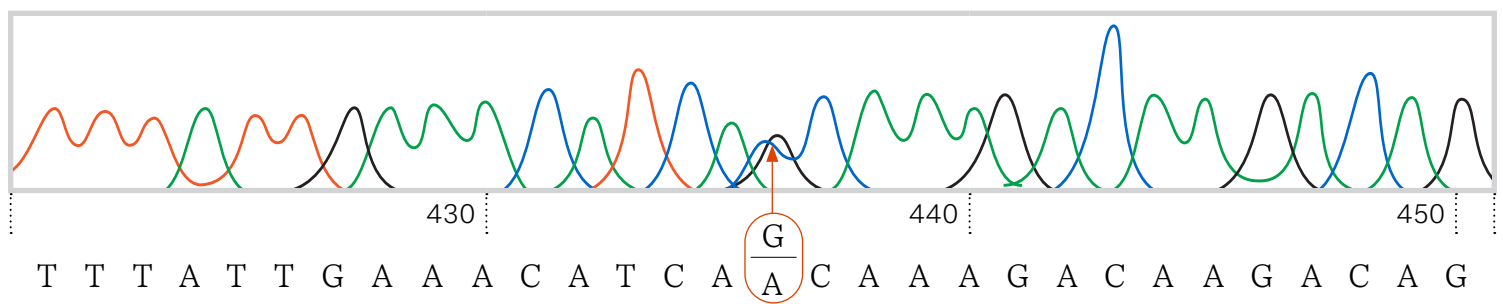
Below are sections of a DNA sequence from a particular gene. When mutated, the normal cell cycle is disrupted, thereby turning a cell from healthy to cancerous.

Directions

Using the key, compare the healthy DNA sequence with the tumor DNA sequence. If any differences are found, circle the letter(s) that have changed from one sequence to the next. Then complete the table using the provided genetic code.

**Key**

C Cytosine
G Guanine
T Thymine
A Adenine

Healthy Cell DNA**Tumor Cell DNA**

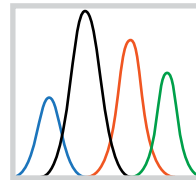
Amino Acid Number	Healthy DNA Sequence	Tumor DNA Sequence	Healthy Amino Acid	Tumor Amino Acid
146	GCA	CCA	Alanine (A)	Proline (P)

Find the Cancer: Mutation 4**ANSWER KEY****Do not share with students**

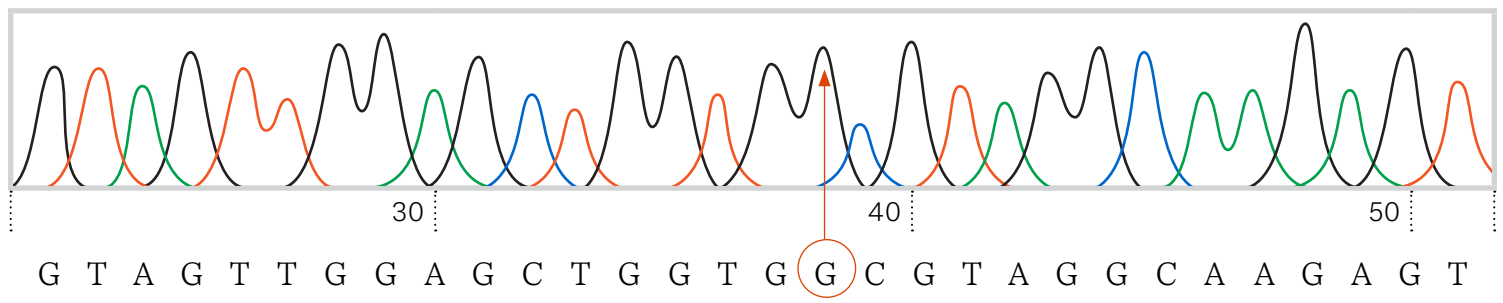
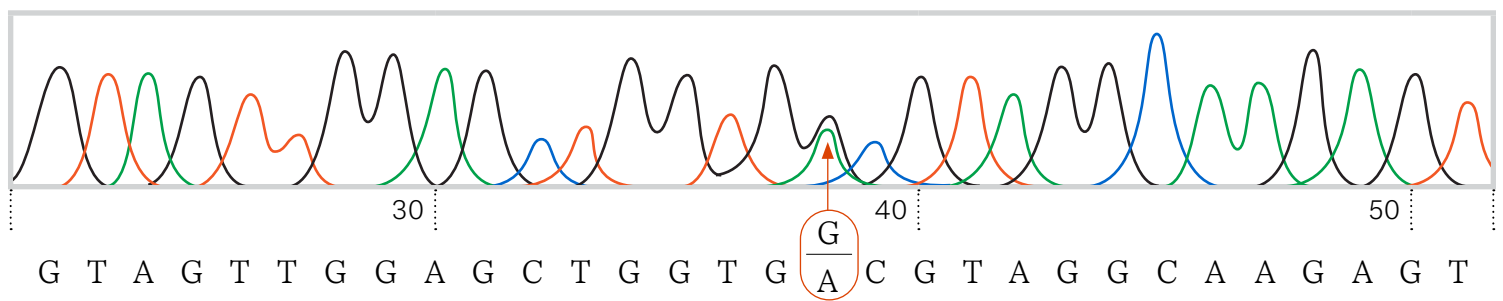
Below are sections of a DNA sequence from a particular gene. When mutated, the normal cell cycle is disrupted, thereby turning a cell from healthy to cancerous.

Directions

Using the key, compare the healthy DNA sequence with the tumor DNA sequence. If any differences are found, circle the letter(s) that have changed from one sequence to the next. Then complete the table using the provided genetic code.

**Key**

C Cytosine
G Guanine
T Thymine
A Adenine

Healthy Cell DNA**Tumor Cell DNA**

Amino Acid Number	Healthy DNA Sequence	Tumor DNA Sequence	Healthy Amino Acid	Tumor Amino Acid
13	GGC	GAC	Glycine (G)	Aspartic Acid (D)

Medical Specialty Report Form**ANSWER KEY****Do not share with students****Physician Name:**

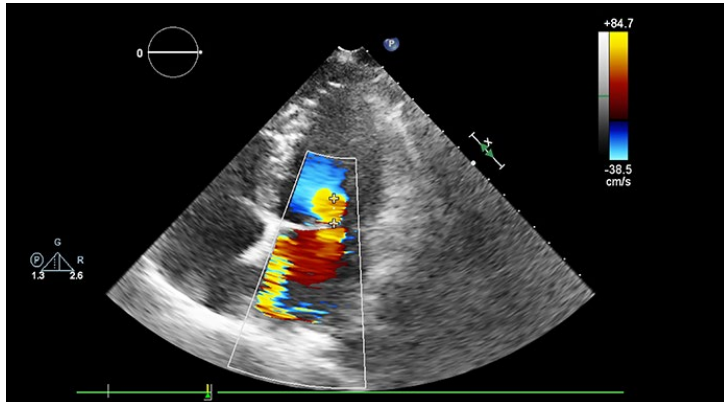
Student Name

Medical Specialty:

Cardiologist

Patient Medical History:

The patient was diagnosed previously with heart murmur. Further tests were done to determine the cause. Echocardiogram determined the murmur stems from a mitral valve prolapse and an enlarged aorta. The patient suffered mitral valve regurgitation three years ago.

**Possible Causes:**

Some types of connective tissue disorders are Graves' disease, Ehlers-Danlos syndrome, Marfan syndrome, or muscular dystrophy. More tests and consultation with other specialists will be needed before coming to a diagnostic consensus.

Physical Exam Results:

Confirmed heart murmur and arrhythmia in the patient. Results of the cardiac stress test were lightheadedness, dizziness, and shortness of breath in the patient. Repeat of echocardiogram also confirmed mitral valve prolapse.

Medical Specialty Report Form**ANSWER KEY****Do not share with students****Physician Name:**

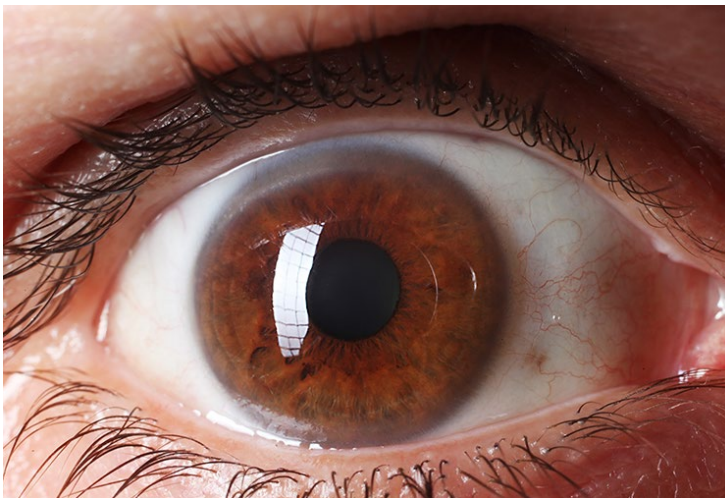
Student Name

Medical Specialty:

Ophthalmologist

Patient Medical History:

The patient is myopic (nearsighted). He has worn glasses since eight years of age. At the time of examination, it was discovered that the patient had a dislocated right lens.

**Possible Causes:**

Possible causes of the patient's condition are Ehlers-Danlos syndrome, Marfan syndrome, or some other connective tissue syndrome. More tests and consultations are needed.

Physical Exam Results:

An eye exam confirmed that the patient was indeed myopic and had a repaired detached right lens.

Medical Specialty Report Form**ANSWER KEY****Do not share with students****Physician Name:**

Student Name

Medical Specialty:

Pulmonologist

Patient Medical History:

The patient has been diagnosed with asthma. At eight years old, the patient suffered a collapsed lung.

**Physical Exam Results:**

A lung exam confirmed the earlier diagnosis of asthma. Chest X-ray was normal and lung volume was within normal levels.

Possible Causes:

The patient's cause for asthma may be environmental in nature or a result of some genetic disorder. More testing and consultation with other specialists will be needed.

Medical Specialty Report Form**ANSWER KEY****Do not share with students****Physician Name:**

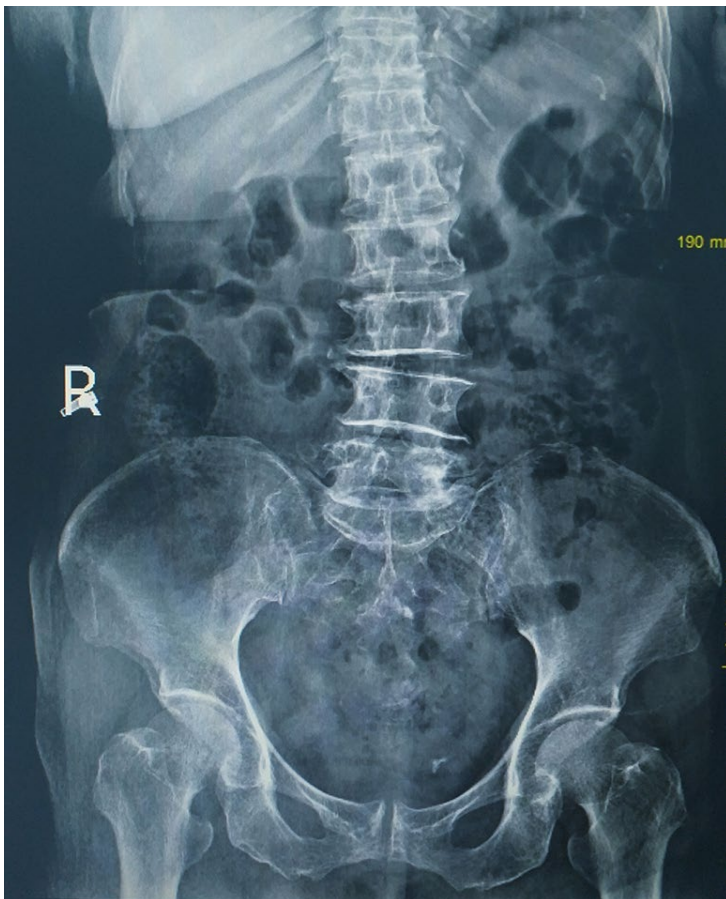
Student Name

Medical Specialty:

Orthopedist

Patient Medical History:

The patient was diagnosed with mild scoliosis (curvature of the spine) at age 10. His curvature was less than 20 degrees (11 degrees); no back brace or surgical correction was needed.

**Physical Exam Results:**

Physical exam and X-ray confirmed the presence of mild scoliosis. Spine curvature was measured at 14 degrees which was a 3-degree increase from the X-ray taken five years ago. It was also noted that the patient has uncharacteristically long and slender fingers, feet, and arms.

Possible Causes:

The patient's cause for scoliosis may be AIS (adolescent idiopathic scoliosis), Marfan syndrome, scleroderma, muscular dystrophy, or some other genetic disorder. Further consultation will be needed.

Mutations K-W-L Chart

Directions

Answer the below questions in your own words.
Pay careful attention to the word in bold.

	K <i>Three things I already knew about mutations</i>	W <i>Three things I want to know about mutations</i>	L <i>Three things I have learned about mutations</i>
1			
2			
3			

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Mutation Type Effects

Today, you will be translating mRNA into amino acids. However, instead of building a protein, you will be building a sentence. As with normal cellular translation, the sequence can only begin with the START amino acid, Methionine. Additionally, all coding will cease when one of the STOP codons is present.

These tools will help you answer the questions on the following pages.

Continues next page >

Codon Chart

Locate your first letter in the vertical column 1, the second in the horizontal column 2 and the third in the vertical column 3.

1	2				3
	U	C	A	G	
U	UUU } Phe UUC } UUA } Leu UUG }	UCU } Ser UCC } UCA } UCG }	UAU } Tyr UAC } UAA stop UAG stop	UGU } Cys UGC } UGA stop UGG } Trp	U C A G
C	CUU } Leu CUC } CUA } CUG }	CCU } Pro CCC } CCA } CCG }	CAU } His CAC } CAA } Gln CAG }	CGU } Pro CGC } CGA } CGG }	U C A G
A	AUU } Ile AUC } AUA } AUG } Met	ACU } Thr ACC } ACA } ACG }	AAU } Asn AAC } AAA } Lys AAG }	AGU } Ser AGC } AGA } Arg AGG }	U C A G
G	GUU } Val GUC } GUA } GUG }	GCU } Ala GCC } GCA } GCG }	GAU } Asp GAC } GAA } Glu GAG }	GGU } Gly GGC } GGA } GGG }	U C A G

Key

Ala = Alanine (A)	Leu = Leucine (L)
Arg = Arginine (R)	Lys = Lysine (K)
Asn = Asparagine (N)	Met = Methionine (M)
Asp = Aspartate (D)	Phe = Phenylalanine (F)
Cys = Cysteine (C)	Pro = Proline (P)
Gln = Glutamine (Q)	Ser = Serine (S)
Glu = Glutamate (E)	Glu = Threonine (T)
Gly = Glycine (G)	Thr = Tryptophan (W)
His = Histidine (H)	Tyr = Tyrosine (Y)
Ile = Isoleucine (I)	Val = Valine (V)

Amino Acid Cypher

Ala = Very	Gly = Are	Pro = Dog
Arg = Cat	His = The	Ser = Is
Asn = A	Ile = Fluffy	Thr = Lanky
Asp = Purple	Leu = Thief	Trp = Pirate
Cys = Accountant	Lys = Delicious	Tyr = Pudding
Gln = Ostrich	Met = START	Val = They
Glu = And	Phe = You	

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Mutation Type Effects

Continued

Directions

Begin by translating this mRNA sequence:

AUGCACAGGUCAGCUAUUUGA

1. Divide the mRNA sequence into sets of three.

Use the *Codon Chart* to determine your amino acid.

Compare your amino acid sequence to the cypher.

Now, continue your work with the same mRNA sequence after it has undergone mutation.

2. Divide the sequence into sets of three and underline the mutation.

AUGCACAGAUUCAGCUAUUUGA

What is the amino acid sequence?

What is the sentence?

How would you characterize this type of mutation?

3. Divide the sequence into sets of three and underline the mutation.

AUGCACAGGUCAGCUGCUGCUAUUUGA

What is the amino acid sequence?

What is the sentence?

How would you characterize this type of mutation?

4. Divide the sequence into sets of three and underline the mutation.

AUGCACUGGUCAGCUUGA

What is the amino acid sequence?

What is the sentence?

How would you characterize this type of mutation?

Continues next page >

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Mutation Type Effects

Continued

5. Divide the sequence into sets of three and underline the mutation.

AUGCACAGUGUCAGCUAUUUGA

What is the amino acid sequence?

What is the sentence?

How would you characterize this type of mutation?

6. Divide the sequence into sets of three and underline the mutation.

AUGCACAGGUAAGCUAUUUGA

What is the amino acid sequence?

What is the sentence?

How would you characterize this type of mutation?

7. Write your own sentence using the words available in the cypher.

What would be the required amino acid sequence?

What could be a possible mRNA sequence?

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Difference vs Disease Capture Sheet

Directions

Use the information found in your article to complete the following questions.

1. What point was your article trying to convey?

2. Why is eradicating genetic mutations controversial?

3. What are three questions you have after finishing your article?

4. What are the three things you think should be considered when discussing potential gene therapies?

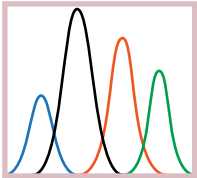
5. Explain how the career of a bioethicist can overlap with that of a genetics counselor.

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Find the Cancer: Mutation 1

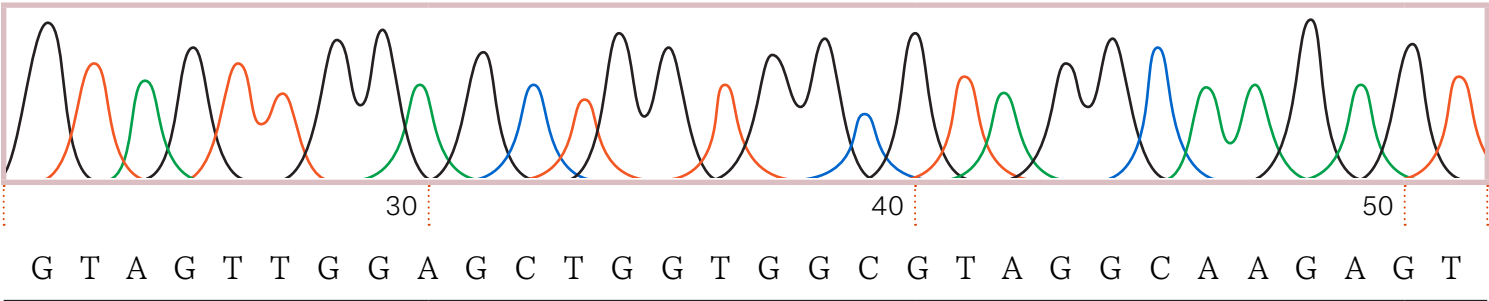
Below are sections of a DNA sequence from a particular gene. When mutated, the normal cell cycle is disrupted, thereby turning a cell from healthy to cancerous.

Directions
Using the key, compare the healthy DNA sequence with the tumor DNA sequence. If any differences are found, circle the letter(s) that have changed from one sequence to the next. Then complete the table using the provided genetic code.

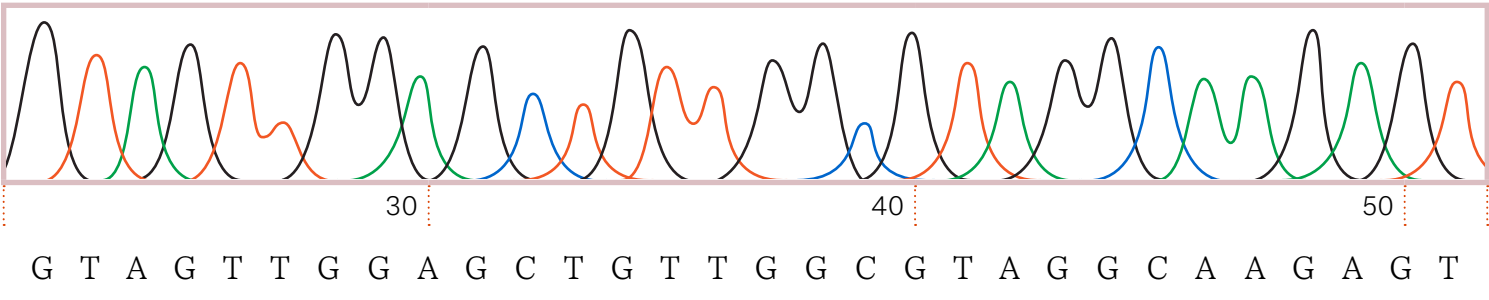


- Key**
- C Cytosine
 - G Guanine
 - T Thymine
 - A Adenine

Healthy Cell DNA



Tumor Cell DNA



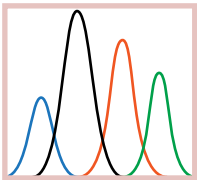
Amino Acid Number	Healthy DNA Sequence	Tumor DNA Sequence	Healthy Amino Acid	Tumor Amino Acid

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Find the Cancer: Mutation 2

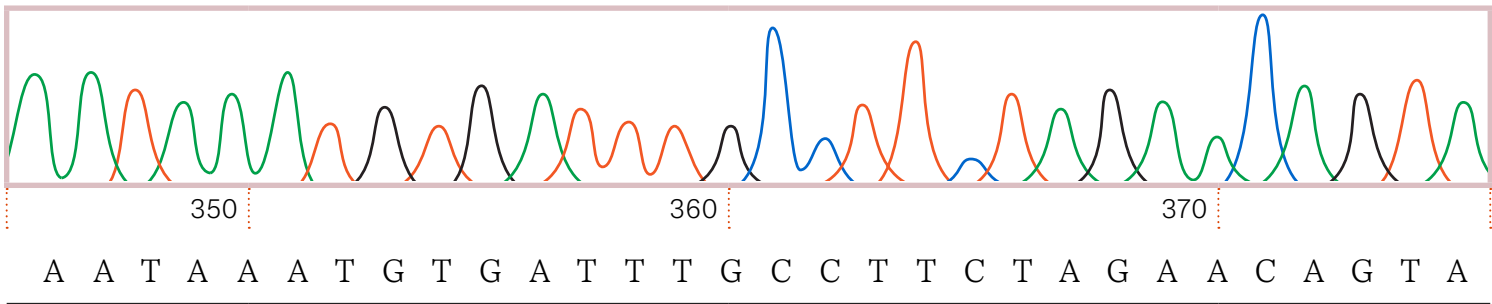
Below are sections of a DNA sequence from a particular gene. When mutated, the normal cell cycle is disrupted, thereby turning a cell from healthy to cancerous.

Directions
Using the key, compare the healthy DNA sequence with the tumor DNA sequence. If any differences are found, circle the letter(s) that have changed from one sequence to the next. Then complete the table using the provided genetic code.

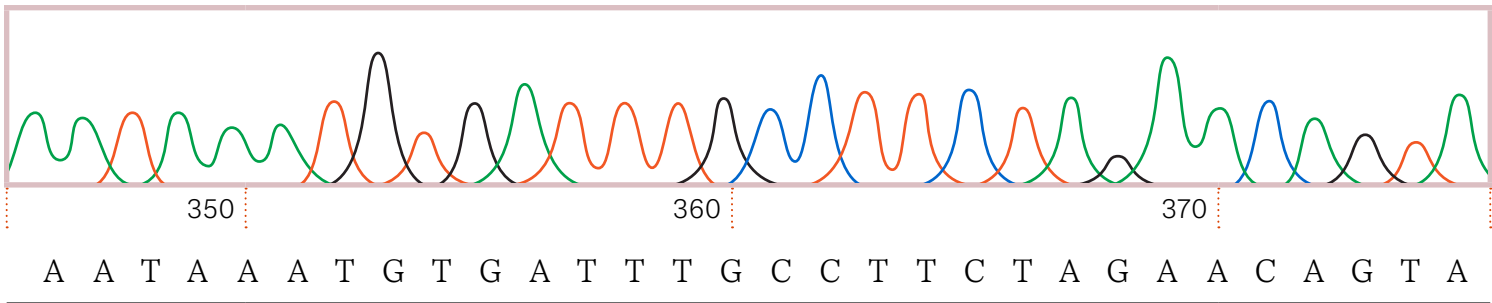


- Key**
- C Cytosine
 - G Guanine
 - T Thymine
 - A Adenine

Healthy Cell DNA



Tumor Cell DNA



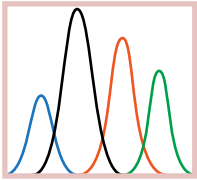
Amino Acid Number	Healthy DNA Sequence	Tumor DNA Sequence	Healthy Amino Acid	Tumor Amino Acid

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Find the Cancer: Mutation 3

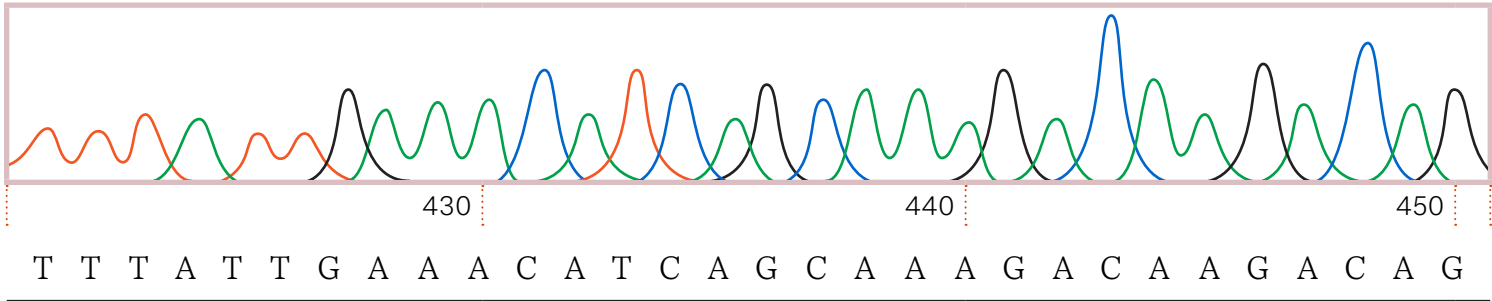
Below are sections of a DNA sequence from a particular gene. When mutated, the normal cell cycle is disrupted, thereby turning a cell from healthy to cancerous.

Directions
Using the key, compare the healthy DNA sequence with the tumor DNA sequence. If any differences are found, circle the letter(s) that have changed from one sequence to the next. Then complete the table using the provided genetic code.

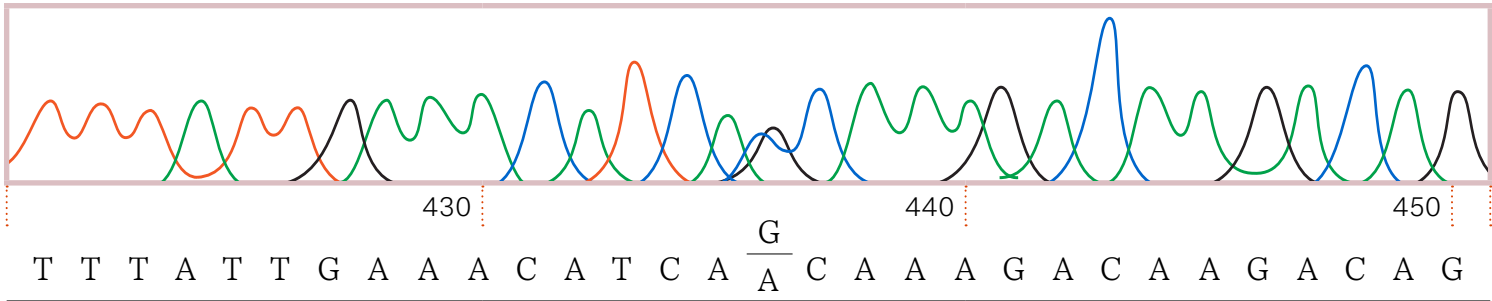


- Key**
- C Cytosine
 - G Guanine
 - T Thymine
 - A Adenine

Healthy Cell DNA



Tumor Cell DNA



Amino Acid Number	Healthy DNA Sequence	Tumor DNA Sequence	Healthy Amino Acid	Tumor Amino Acid

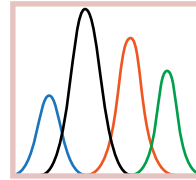
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Find the Cancer: Mutation 4

Below are sections of a DNA sequence from a particular gene. When mutated, the normal cell cycle is disrupted, thereby turning a cell from healthy to cancerous.

Directions

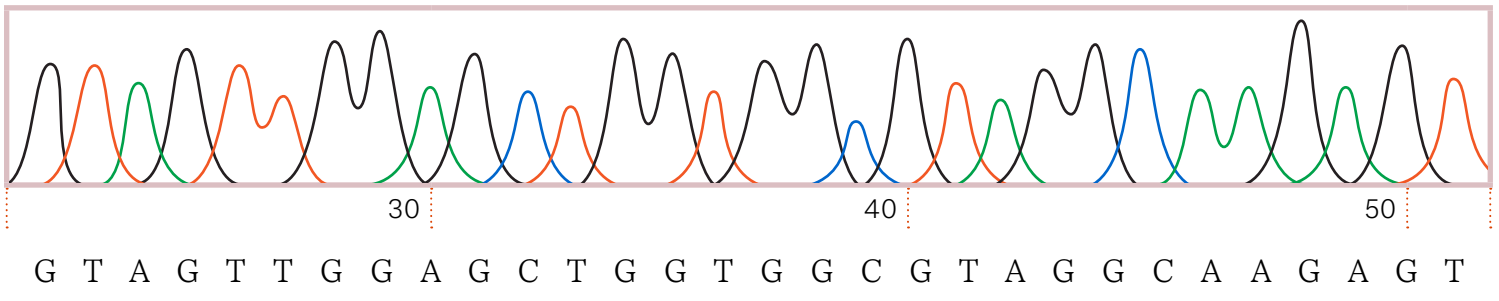
Using the key, compare the healthy DNA sequence with the tumor DNA sequence. If any differences are found, circle the letter(s) that have changed from one sequence to the next. Then complete the table using the provided genetic code.



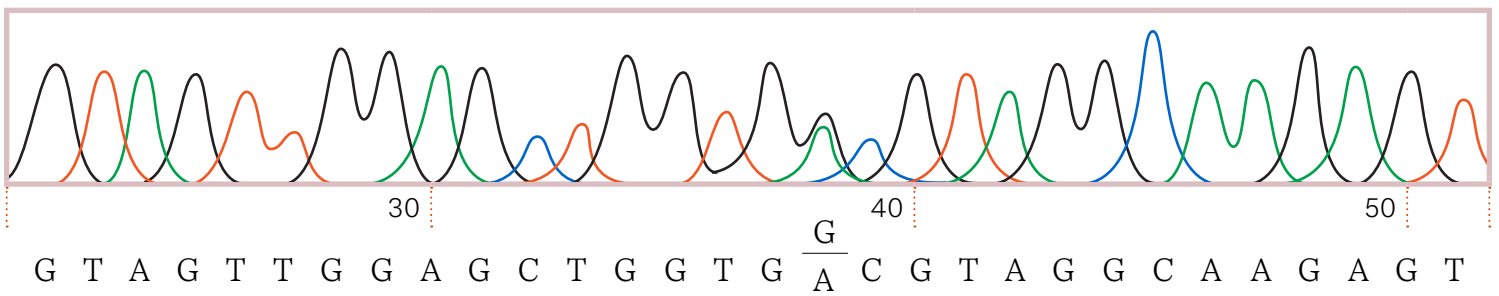
Key

C Cytosine
G Guanine
T Thymine
A Adenine

Healthy Cell DNA



Tumor Cell DNA



Amino Acid Number	Healthy DNA Sequence	Tumor DNA Sequence	Healthy Amino Acid	Tumor Amino Acid

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Cell Cycle and Cancer Lab

Directions

Examine the stages of mitosis in different tissue samples.

Table 1: Record the number of cells in each stage of the cell cycle as analyzed in normal tissues.

Tissue Type	# Cells in Interphase	# Cells in Prophase	# Cells in Metaphase	# Cells in Anaphase	# Cells in Telophase
Stomach Tissue Normal					
Ovarian Tissue Normal					
Lung Tissue Normal					

Table 2: Record the number of cells in each stage of the cell cycle as analyzed in cancerous tissues.

Tissue Type	# Cells in Interphase	# Cells in Prophase	# Cells in Metaphase	# Cells in Anaphase	# Cells in Telophase
Stomach Tissue Cancerous					
Ovarian Tissue Cancerous					
Lung Tissue Cancerous					

Table 3: Use Table 1 data to calculate the Mitotic Index (average percent of cells dividing) for each normal tissue cell type.

Tissue Type	% Cells at Rest	Mitotic Index
Stomach—Normal		
Ovarian—Normal		
Lung—Normal		

Continues next page >

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Cell Cycle and Cancer Lab

Continued

Table 4: Use Table 2 data to calculate the Mitotic Index (average percent of cells dividing) for each cancerous tissue cell type.

Tissue Type	% Cells at Rest	Mitotic Index
Stomach — Cancerous		
Ovarian — Cancerous		
Lung — Cancerous		

Formulas:

Mitotic Index = percent cells dividing (note: cells dividing are cells not in interphase):

$$(\# \text{ cells dividing} / \text{total} \# \text{ cells}) * 100 = \% \text{ cells dividing}$$

To calculate the percent cells at rest (in interphase) in normal tissue:

$$(\# \text{ cells at rest} / \text{total} \# \text{ cells}) * 100 = \% \text{ cells at rest}$$

- What does your collected data tell you about the rate of cell division in normal tissue compared to the rate of cell division in cancerous tissue? What data were needed to answer this?

- Which type of cancer appears to be the fastest-growing?

- Consider the data you have collected. If you were to examine prostate tissue, would you expect to see a difference in the cell division rate in normal prostate tissue compared to cancerous prostate tissue?

- Could you predict the average percentage of dividing cells in the cancerous prostate tissue? Explain.

- Consider the percentage of dividing cells in stomach, ovarian, and lung tissue. Why do you think there are more cells dividing in the ovarian and stomach tissue rather than the lung tissue?

- Different types of normal tissues in the human body have different mitotic indices. From the following list, which normal tissues would you expect to have the highest mitotic index: pancreatic, kidney, skin, brain, or colon? Explain.

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Marfan Syndrome Pedigree

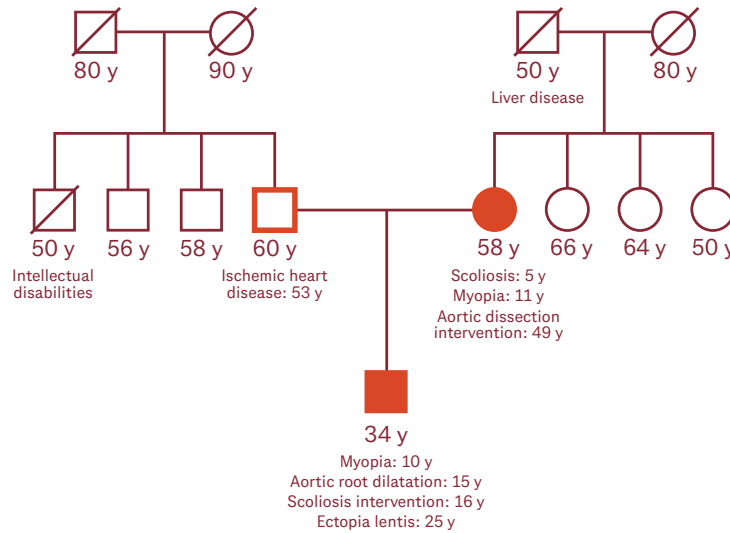
Directions

Write down your observations and critical details as you review the graphic below.

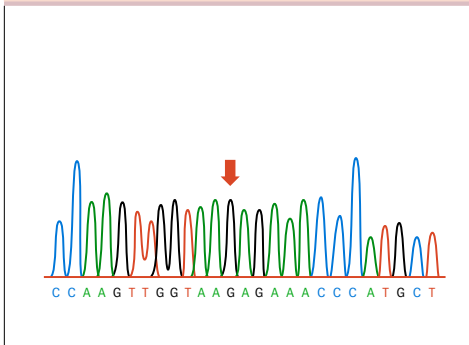
Reference

Marfan Syndrome Caused by Somatic Mosaicism in an FBN1 Splicing Mutation

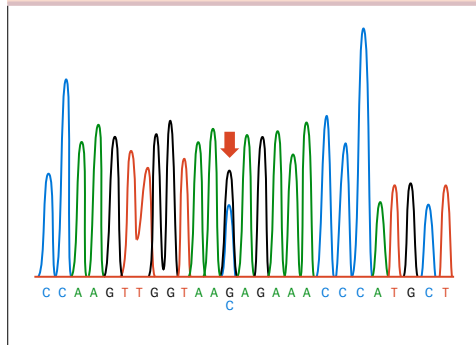
Family tree and electropherograms of the FBN1 region containing the c.2677 + 5G>C mutation (arrow). The mutated allele (cytosine, blue) is present in a lower proportion in the mother than in the proband, suggesting mosaicism.



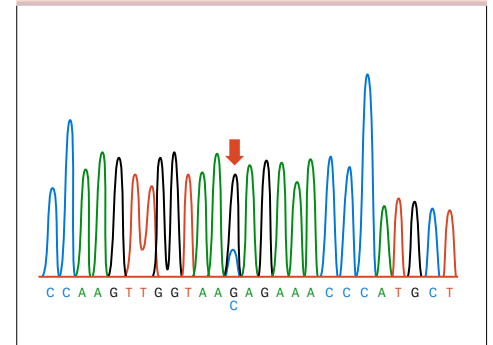
□ Father



■ Son



● Mother



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Medical Specialty Report Form

Physician Name:

Medical Specialty:

Patient Medical History:

Possible Causes:

Physical Exam Results:

FUTURELAB+

Diagnosis of Richard's Disorder

Directions

You will attempt to diagnose Richard's disorder by analyzing all of his physical symptoms and medical histories and to make an informed decision. Make a checklist of Richard's symptoms below.

	Grave's Disease	Muscular Dystrophy	Marfan Syndrome	Ehlers-Danlos Syndrome	Adolescent Idiopathic Scoliosis	Scleroderma
Heart Murmur						
Mitral Valve Prolapse						
Myopia						
Detached Lens						
Asthma						
Collapsed Lung						
Curvature of Spine						
Long Arms, Legs, and Fingers						