Lesson 3: Genetics: Cancer Genetics

Lesson Summary:
In this lesson, students revisit the story of Steve and Nikki, who are learning more about the role genetics can play in cancer risk. Students engage with a brief history of advances in cancer research since the 1950s. They are introduced to the BRCA1 and BRCA2 genes and how substitutions, additions, and deletions in their underlying genetic code lead to mutated genes with changed function. Students practice transcribing and translating the DNA strand into amino acid sequences for both normal and mutated genes and compare them.

Next, students learn about genetic counseling and how family history of cancer influences cancer risk. They role-play a genetic counseling session and chart a family history to analyze the cancer risk of Steve and Nikki’s parents. As their homework, students look at their own family history as an example.

Finally, students learn about genetic testing, including an exploration of two methods: gel electrophoresis and Sanger sequencing.

Lesson Duration: One or two 45–60-minute class periods

How to Use This Guide
This lesson plan was created to aid instructors in planning their lesson. It provides slide-by-slide details so educators will be prepared to engage, explain, discuss, and analyze every part of the lesson. The lesson is designed to be two 45–60-minute class periods, but it is flexible, depending on the students’ needs and time available. Note there are several activities that are optional and can be deleted or modified for specific classroom needs. All handouts are included in this guide, as well as additional resources for more learning activity ideas.

Objectives:
- Upon completion of this lesson, students will be able to:
  - Describe the history of cancer research and related technological advances
  - Summarize the relationships among DNA, genes, and chromosomes
  - Examine the effects of different mutations on gene sequences and resulting proteins
  - Transcribe and translate genetic sequences
  - Explain the role of family history in determining cancer risk
  - Describe genetic counseling
  - Discuss genetic testing
  - Describe and analyze gel electrophoresis
  - Interpret a family tree and discuss inherited traits
Materials:
- Handout: Genetics Review Worksheet (optional prep assignment)
- Handout: Cancer Innovations and Pop Culture Events cards
- Handout: BRCA1 Protein
- Handout: BRCA2 Protein
- Handout: Genetic Mutations Worksheet
- Handout: Codon Chart
- Handout: Williams Family Pedigree
- Handout: Williams Family Pedigree Analysis
- Handout: Genetic Counseling Script
- Handout: Sample Patient Letter
- Handout: Gel Electrophoresis Simulation Worksheet
- Handout: Genetic Test Results
- Activity Instructions: Gel Electrophoresis Activity
- Homework assignment: My Family Health Portrait website:
- Virtual Lab: Gel Electrophoresis
  - http://learn.genetics.utah.edu/content/labs/gel/
- Video: Sanger Sequencing Presentation
- Lesson 3 Quiz
- Answer Keys
- Interactive white board (optional)
- Computer with Internet access/LCD projector

Subjects:
- Health
- Language Arts and Literacy
- Science

Vocabulary:
allele, amino acid, BRCA1, BRCA2, carrier, codon, deletion, DNA, DNA sequencing, dominant, family health history, founder mutation, frameshift mutation, gel electrophoresis, gene, gene expression, genetic counselor, genetic testing, genetics, genotype, heredity, heterozygous, homozygous, insertion, mRNA mutagen, mutation, nucleic acid, nucleotide, peptide bond, phenotype, point mutation, Polymerase Chain Reaction (PCR), protein, recessive, ribosome, RNA transcription, trait, translation
Advance Preparation:

Day 1

**Real-World Scenario—Steve and Nikki**
- Review Steve and Nikki’s real-world scenarios in all of the lessons so that you can effectively use their story in the classroom.

**Genetics Review Worksheet (optional pre-work)**
- Make one copy per student of the Genetics Review Worksheet. This can be assigned in advance as a homework assignment as a refresher or introduction to genetics terminology. If used, this should be reviewed at the start of Day 1.

**Timeline of Cancer Research Innovations**
- Make several copies of the Cancer Innovations Cards and Pop Culture Events Cards, one copy per group of students (3–5 students per group). The correct answers for class review are on the Cancer Innovations Handout.

**Translation and Transcription Activity**
- Make 1 copy per student (or alternatively, one per group of 3–5 students) of the blank Genetic Mutations Worksheet and the Codon Chart handout for the genetic mutations activity. The codon chart can also be projected for the whole class, if this activity is done during class time.
- Make several copies of the BRCA1 and BRCA 2 Sequence Handouts to distribute to groups during the founder mutations activity.

**Create and Analyze a Family History**
- Make 1 copy per group of the blank (partially filled out) Williams Family Pedigree and Williams Family Pedigree Analysis Handout for students to complete in class or as homework.

Day 2

**Role Play a Genetic Counseling Session**
- Make one copy per three students of the Genetic Counseling Script.
- Optional: Make only one copy for the trio of students who role-play the script for the entire class.

**Homework: Write a Letter to Mr. and Mrs. Williams**
- Print one copy per student of the Sample Patient Letter for students to use for their homework.

**Gel Electrophoresis Lab**
- Review the Gel Electrophoresis Virtual Lab (http://learn.genetics.utah.edu/content/labs/gel/) to ensure it will work in the classroom.
- Make one copy per student of the Gel Electrophoresis Simulation Worksheet for students to complete as they go through the Lab.
- Life-Size Gel Electrophoresis Activity (Optional)
- Print and review the Gel Electrophoresis Activity supplement for this optional classroom activity simulating gel electrophoresis.

**Sanger Sequencing Presentation**
- Review the presentation video; ensure LCD projector works properly
  http://www.yourgenome.org/teachers/sequencing.shtml

**Analyze Genetic Test Results**
- Print one copy per student of the Genetic Test Results for Mr. and Mrs. Williams for students.
Career Connection

- Physician
- Genetic Counselor
- Researcher

A Note for the Teacher about Cancer
Cancer is a disease that unfortunately touches many people. You may have students with a parent, guardian, or loved one affected by cancer. Adolescents affected by cancer cope in their own ways. Some students may want to share their personal experiences, while others may not. Reassure students that you want them to be comfortable in the classroom and will not require them to share any personal or private experiences.

You may learn a student is personally affected prior to or while implementing the curriculum. If you discover a student is affected by cancer, speak with them privately and make sure they are comfortable with participating in the learning activities, discussions, and explorations.

If you know a student is affected by cancer prior to starting the curriculum:
- Give the student a brief summary of the lessons, and ask how they feel about it. Tell the student it may not bother them now, but they should let you know if it does.

If you learn a student is affected by cancer while implementing the curriculum:
- Ask whom they have spoken with about the cancer. If the answer is no one, ask if they would like to talk to someone, such as a guidance counselor or other trusted adult.

Connect students with support. Possible sources include the following:
- Guidance counselors
- Family friends
- Family doctors or pediatricians
- Faith-based counselors

Look for warning signs. Keep an eye out for signs of distress, such as
- Changes in academic performance
- Changes in behavior with other students
- Evidence of alcohol or drug use
- Evidence of anxiety or depression
Lesson 3 Plan – Day 1: Cancer Genetics

Optional Pre-Lesson Prep: Genetics Review Worksheet

- [Slides 1–2] Distribute the optional pre-lesson prep assignment, the Genetics Review Worksheet. If you have covered genetics in class already, students may be able to do this entirely on their own; if not, it can be paired with a relevant reading from a biology text or web resource to help them complete the two-page fill-in-the-blank worksheet.

ENGAGE
Scenario: Steve and Nikki

- [Slide 5] Reintroduce Steve and Nikki. They know about their mother’s diagnosis and have been learning about the role of genetic factors in her breast cancer.
- [Slide 6] Learning Activity: Small Group Brainstorm. Review the connection between Steve's message and what the class knows so far about genetics and cancer.
  - Divide the class into small groups and have students brainstorm their thoughts about Steve's questions. Ask each group to organize their thoughts and decide how to respond to Steve's questions below. Assign roles, such as a recorder, if needed.
    - What does a gene have to do with cancer?
    - How do they even know it exists?
    - Did my mom get it from her mom?
    - Can Nikki get it?
  - Do not be too concerned with what students write at this point. This is meant to be an open-ended activity to assess what students know about genetics and cancer.

EXPLORE
Advances in Cancer Activity

- [Slides 7–8] To introduce the timeline activity and elicit students’ prior knowledge, take about 5 minutes to ask students what they think have been some of the major discoveries in cancer research.
  - Tell the class they will be doing an activity to create a timeline of cancer innovations.
  - For any discoveries they propose, ask if they know the approximate time period (e.g., double helix structure discovered → 1950s). Write students’ ideas on the board.
  - Divide the class into small groups. Give each group one set of Cancer Innovations Cards and Pop Culture Events Cards. Tell the groups to match each innovation card with a pop culture event card and put them in order from oldest to most recent. Students should use their knowledge of genetics to order the innovations, but the pop culture events can provide hints.
  - After groups have finished, review the correct sequence and highlight what year the innovations and pop culture events occurred.
Note: The correct sequence is in a separate handout with the cards.

EXPLAIN

Breast Cancer Genetics: BRCA1 and BRCA2

- [Slides 9–10] Introduce BRCA1 and BRCA2, which were discovered in 1990 and 1994 respectively. BRCA1 is on chromosome 17 and BRCA2 is on chromosome 13.
- [Slides 11–14] Each slide has a blank for which you can call on students to fill in:
  - Slide 11: BRCA1 and BRCA2 are tumor suppressor genes, normally expressed in cells of breast and other tissue.
  - Slide 12: Both genes play an important role in repair of DNA double strand breaks.
  - Slide 13: These genes themselves are normal. Mutations of these genes are abnormal.
  - Slide 14: There are approximately 2,000 known mutations of BRCA1 and BRCA2.
- [Slides 15–19] Introduce the key metaphor that a body's DNA is like a complex recipe in a cookbook.
  - The DNA is the instructions.
  - The bases are the ingredients.
  - Proteins are the end result, like a cake.
  - There can be substitutions, deletions, and additions to the recipe ingredients, all of which will change the resultant protein in some way.
  - Some of the changes will not make a big difference; others will have a significant difference in effect (such as substituting applesauce versus broccoli for oil).
  - Since the BRCA genes are tumor suppressor genes, mutations can increase risk for tumors and cancer.

Genetic Mutations Activity

- [Slide 20] Explain the process by which DNA code leads to the creation of a protein:
  - The code is transcribed into RNA code.
  - The code is then translated at the ribosome into an amino acid code.
  - The amino acid is created based on this code.
- [Slide 21] Distribute copies of the BRCA1 and BRCA2 protein sequences, several copies of the Genetics Mutations worksheet, and the Codon Chart. (You can also project these using the overhead projector.)
  - Review the blank Genetic Mutations worksheet with the class. You can complete the worksheets as a class, or divide students into groups to complete it together.
  - Explain how the BRCA1 mutation 187delAG is notated and what each symbol means.
Walk through the process of finding the normal (non-mutated) sequence for part of the BRCA1 gene.

- [Slide 22] Locate the 187th nucleotide to begin the sequence. This is the coding strand DNA or **sense strand**.
- [Slide 23] Explain that the **anti-sense strand** is a mirror image of the sense strand, completing the base pair.
- Use the table to replicate the sense strand into the anti-sense strand.
- [Slide 24] Use table to **transcribe** the anti-sense strand into an **mRNA** sequence.
- [Slide 25] Use the **codon chart** to translate each codon in the mRNA sequence into an amino acid. For example, GGU → glycine.
- [Slide 26] Make a note of the final amino acid sequence; this is the sequence for the non-mutated BRCA1 gene.

Now repeat this process for the mutated gene, using 187delAG. Ask the class for answers to portions of the process this second time through.

- [Slide 27] Begin the process again using the mutated sequence. Find the sense strand.
- [Slide 28] Replicate the mutated coding strand to find the anti-sense strand. Then transcribe the anti-sense strand into mRNA.
- [Slide 29] Use the codon chart to translate the mutated mRNA codons into the amino acid sequence.
- Note: This is a good place to remind students the difference between **transcription** and **translation**:
  - **Transcription** is the process by which the anti-sense strand is converted to an mRNA sequence.
  - **Translation** is the process by which mRNA codons are converted into an amino acid sequence.
- [Slide 30] Once you have completed translating the mutated sequence, compare the normal and mutated amino acid sequences.
  - Ask the class what effects they observe as a result of the mutation.
  - Note that compared to the normal BRCA1 protein, the mutated amino acid sequence has been changed and shortened. The resulting protein will also be shortened (**truncated**) and may not function properly.

**Group Activity: Explore Founder Mutations**

- [Slide 31] Explain what founder mutations are and present them in the table of example founder mutations identified in BRCA1 and BRCA2.
  - Distribute the **BRCA1 and BRCA2 DNA Sequence handouts** if you have not already. Note that the sequences in the handouts are abbreviated from the complete nucleotide sequence.
  - Assign each group 2–3 mutations from the table to investigate, not including 187delAG, which you have already translated. You may also allow groups to choose their mutation to analyze.
o Some mutations may not list deleted bases; for example, in BRCA2 mutation 1536del4, four bases are deleted, beginning at position 1536.
o Some mutations are insertions: for example, in the BRCA1 mutation 1136insA, an A is inserted at the 1136th position.

• **Note:** If class time is running short, you may want to assign this activity as homework. Have each student choose 1–2 mutations to investigate and compare with the normal version of the gene. Tell them to come prepared to show the differences between the normal and mutated genes and discuss the possible effects of these differences.

**ELABORATE**

*Introduction to Genetic Counseling*

- **[Slide 32] Learning Activity: Class Discussion.** Ask students if they have ever heard of genetic counselors, using the questions on the slide as a guide. Record students' preconceptions on a whiteboard or overhead.
  o What do you know about genetic counseling?
  o What is its purpose?
  o What information do genetic counselors use to make recommendations?

- **[Slide 33] Explain what genetic counselors do, starting with genetic counselors in general (left column) and continuing to cancer genetic counselors (right column), who are more specialized in cancer-specific counseling.

- **[Slides 34–35] Reintroduce the scenario of Steve and Nikki.** Their parents visited a genetic counselor for advice regarding genetic tests associated with cancer. Steve writes an e-mail to the counselor to ask some questions:
  o If mom's cancer may have been genetic, does that mean I have this mutated BRCA gene?
  o How does a family tree work?
  o What information do I have to gather to fill out the tree?

- **[Slide 35] Learning Activity: Think-Pair-Share Activity.** Divide the class into small groups (2–3 students) and have them brainstorm responses to Steve's e-mail for 1-2 minutes.
  o Ask each group to organize their thoughts and decide how they would respond to Steve.
  o Assign roles, such as recorder, if needed.
  o Debrief the activity by asking groups what information they came up with. Record the information on a whiteboard or projector.
  o Do not be too concerned about what students write at this point; this is meant to be an open-ended activity to assess students' preconceptions about cancer.
**Family History Discussion**

- [Slide 36] Ask students to compare their responses to Steve's questions with those of the genetic counselor, Ms. Smith. Go over the important information in a family pedigree needed in order to begin an analysis of a family's cancer risk:
  - History of cancer in the family and number of generations affected (If cancer is found in every generation, there is a greater possibility that a genetic mutation is present.)
  - Types of cancer present (Certain genetic mutations are associated with more than one type of cancer. For example, BRCA2 mutations cause increased risk of breast and ovarian cancer in women and breast and prostate cancer in males. Therefore, if these types of cancer are present in one family, there may be a BRCA mutation present.)
  - Age of cancer diagnosis (Since the main risk factor for cancer is age, a diagnosis of cancer before age 50 strongly suggests there may be an inherited genetic mutation present.)
  - Multiple cancers in one generation
  - Other causes of death
  - Current age or age of death

- Note to students that not all cases of breast cancer are caused by an inherited mutation; only 5–10 percent of breast cancer is inherited. Most cancer may be the result of environmental exposures, or a combination of both genetic and environmental factors.

**Group Discussion and Activity: Williams Family Pedigree**

- [Slides 37–38] Explain to students that they will use the family history information that Nikki found to complete a pedigree of the Williams family.
- [Slide 39] Learning Activity: Discussion. Distribute copies of the *Incomplete Williams Family Pedigree* and ask students to fill in the missing information in small groups or as a class. As a class, discuss relevant information from the incomplete Williams Family Pedigree worksheet, including the following:
  - History of cancer in the family and number of generations affected (If cancer is found in every generation, there is a greater possibility that a genetic mutation is present.)
  - Types of cancer present (Certain genetic mutations are associated with more than one type of cancer. For example, BRCA2 mutations cause increased risk of breast and ovarian cancer in women and breast and prostate cancer in males. Therefore, if these types of cancer are present in one family, there may be a BRCA mutation present.)
  - Age of cancer diagnosis (Since the main risk factor for cancer is age, a diagnosis of cancer before age 50 strongly suggests there may be an inherited genetic mutation present.)
  - Multiple cancers in one generation
  - Other causes of death
  - Current age or age of death
• [Slides 40–41] Learning Activity: Group Activity. Divide students into groups of 3–4 students each. Distribute copies of the Williams Family Pedigree Analysis handout. Allow 5–7 minutes for students to work together to answer the questions on the handout:
  o How many generations are shown in the pedigree?
  o What does the pedigree reveal about the family's history of breast cancer?
  o If someone has a mutated BRCA gene, does that mean they have or will have breast cancer? Why?
  o BRCA mutations are dominant. Who could potentially have an inherited BRCA mutation? Why?
• Have students share their responses to the questions and clarify any misunderstandings.

EVALUATE
Homework Assignment: Create Your Own Family Pedigree
• [Slide 42] Tell students they will use information from their family to create a family pedigree, or family health history, using a site like My Family Health Portrait (Located at https://familyhistory.hhs.gov/FHH/html/index.html).
  o Explain to students that this exercise is to help them build understanding of the kinds of information that can be important for family members to know, but they will NOT be required or asked to submit their pedigrees for review.
  o Explain that their family pedigree may help them make decisions about their health now and in the future, but they are private.
  o Note: Some students may not have access to their own family history—for example, if they are adopted. In this case, they can research their adoptive family history for practice, but should be aware that it does not affect their health.

Lesson 3 Plan – Day 2: Cancer Genetics

ENGAGE
Review of Homework/Discussion
• [Slide 44] Begin a discussion of the homework assignment—using the family health history tool to create and explore students' own family history. Use the reflection and discussion questions below to begin this conversation.
• NOTE: Be careful not to ask students to share personal or family health information. The purpose of the activity is exploration of the tool, not the specific results of any one student’s search.
  o What kind of information is important to know before building a family pedigree or health history?
  o Did anything surprise you about this process?
  o How many generations were you able to find information about? What was challenging about this?
EXPLORE
Role Play a Genetic Counseling Session

- [Slide 46] Share the following additional detail with students about what happens in a typical genetic counseling session:
  - Collect a detailed personal medical and family history
  - Perform a cancer risk assessment
  - Discuss the implications of genetic testing for the individual and the family
  - Identify the most appropriate person to test in the family
  - Discuss potential medical management options
  - For the patient and the family
  - Discuss genetic testing process
  - Ordering the test
  - Insurance Preauthorization
  - Informed Consent

- [Slide 47] Learning Activity: Role Play. Explain to students that they will experience a genetic counseling session to learn more about the risks and genetics of breast cancer and to see what a genetic counseling session is like.
  - Divide students into pairs and distribute the Genetic Counseling Script to each student. Once students have chosen their roles and are familiar with the script, allow time for each pair to role-play the genetic counseling session.
  - Debrief the role-play by asking students to share their thoughts about the role of genetic counselors in cancer diagnosis and treatment. Assess whether any of their preconceptions about genetic counseling have changed.
  - Advise students that they will be doing a homework assignment related to genetic counseling.

Homework Assignment: Letter to Mr. and Mrs. Williams

- [Slide 48] Distribute the Sample Patient Letter and the Genetic Counseling Script to students for their homework assignment. Review the template and answer any student questions about the assignment.

  Homework Assignment. Tell students that after a genetic counseling session, the counselor writes a letter to the patient.
  - The purpose of the letter is to summarize the session so the patient has a written record of what was discussed.
  - Tell students they will assume the role of a genetic counselor and write a letter to Mr. and Mrs. Williams regarding whether or not they should be tested based on the Williams’ pedigree.
  - Students should include their recommendation for both parents and provide at least two to three reasons for their choice in the letter.
  - Students should also address the pros and cons of getting tested.
  - A Sample Patient Letter is provided.
EXPLAIN

Genetic Testing Introduction

- [Slide 49] Learning Activity: Small Group Brainstorm. Divide the class into small groups and have students brainstorm their thoughts about Nikki’s question: How do they look at the genes in a genetic test?
  - Ask each group to organize their thoughts and decide how they will answer Nikki’s questions. Assign roles, such as recorder, if needed.
  - Debrief the activity by recording groups’ preconceptions about genetic testing on a whiteboard or overhead projector.
  - Do not be too concerned about what students write at this point. This is meant to be an open-ended activity to assess what students know about genetics and cancer.
- [Slide 50] Tell students that a genetic test is the analysis of human DNA, RNA, chromosomes, proteins, or certain metabolites in order to detect alterations in genes.
  - With advances in technology, BRCA1 and BRCA2 are now analyzed with modern automated DNA sequencing instruments. However, historically, genes were analyzed through various methods, including gel electrophoresis.
  - Gel electrophoresis allows for separation of DNA fragments based on their size and charge.

Virtual Lab and Research Activity: Gel Electrophoresis

- [Slide 51] Distribute the Gel Electrophoresis Simulation Worksheet, which students can complete as they go through the activity.
- Tell students they will conduct an interactive simulation gel electrophoresis activity online. Direct students to the Gel Electrophoresis Virtual Lab at http://learn.genetics.utah.edu/content/labs/gel/. The simulation takes approximately 10 minutes to complete.
- Debrief the activity by going through the sheet with the class and discussing students’ findings.

Optional Activity: Life-Size Gel Electrophoresis

- [Slide 52] This activity requires a large space, such as an open room, gym, or outside area to represent the “gel.” The area should accommodate 4 rows or “lanes” that students will navigate through.
  - If you plan to conduct the activity in a classroom, use desks or chairs to create lanes.
  - If you plan to conduct the activity outside, mark off lanes with chalk, yarn, or other natural markers, such as trees or rocks.
- Tell students they will be doing an activity to explore gel electrophoresis. Review the Gel Electrophoresis Activity supplement for full instructions on this activity.
Video Presentation: Sanger Sequencing

- [Slide 53] This video presents another method of genetic testing without gel electrophoresis: Sanger sequencing.
  - Direct students to the video at: [http://www.yourgenome.org/teachers/sequencing.shtml](http://www.yourgenome.org/teachers/sequencing.shtml)
  - Alternatively, present the video for the class using a projector.

ELABORATE

Analyze Genetic Test Results

- [Slides 54–55] Distribute the [Genetic Test Results](#) handout (2 pages—one each for John and Sarah's results).
- Distribute the genetic test results (2 pages—one each for John and Sarah). Lead a class discussion of what the results mean and how this affects the cancer risk of the family members in the family tree (John, Sarah, Steve, Nikki, and Jen).
  - Ask the class what their answer to Steve’s question would be—Should Nikki or I get tested, or one of our cousins?
  - Remind the class that Steve, Nikki, and their cousins should not be tested. According to the genetic counselor in the role-play activity, it is not recommended to get BRCA gene mutation testing until at least age 25. Steve and Nikki are not at increased risk for cancer while they are still young. If they do decide to pursue genetic testing as adults, they should have the same pre-test counseling process that Sarah and John went through so they understand the implications.

EVALUATE

- **Homework Assignment.** Tell students that after a genetic counseling session, the counselor writes a letter to the patient.
  - The purpose of the letter is to summarize the session so the patient has a written record of what was discussed.
  - Tell students they will assume the role of a genetic counselor and write a letter to Mr. and Mrs. Williams regarding whether or not they should be tested based on the Williams’ pedigree.
  - Students should include their recommendation for both parents and provide at least two to three reasons for their choice in the letter.
  - Students should also address the pros and cons of getting tested.
  - A [Sample Patient Letter](#) is provided.

- **Lesson 3 Quiz**
Additional Resources

- American Cancer Society, The History of Cancer. Use “History of Cancer” as a search term or visit http://www.cancer.org/docroot/CRI/content/CRI_2_6x_the_history_of_cancer_72.asp?sitearea=&level
- Genetic Science Learning Center, University of Utah, http://learn.genetics.utah.edu
- http://highschoolbioethics.georgetown.edu/
Next Generation Science Standards

Performance Indicators

HS-LS3 Heredity: Inheritance and Variation of Traits

- HS-LS3-1. Ask questions to clarify relationships about the role of DNA and chromosomes in coding the instructions for characteristic traits passed from parents to offspring
- HS-LS3-2. Make and defend a claim based on evidence that inheritable genetic variations may result from: (1) new genetic combinations through meiosis, (2) viable errors occurring during replication, and/or (3) mutations caused by environmental factors.

Science and Engineering Practices

Asking Questions and Defining Problems

- Ask questions that arise from examining models or a theory to clarify relationships. (HS-LS3-1)

Engaging in Argument from Evidence

- Make and defend a claim based on evidence about the natural world that reflects scientific knowledge, and student-generated evidence. (HS-LS3-2)

Disciplinary Core Ideas

LS1.A: Structure and Function

- All cells contain genetic information in the form of DNA molecules. Genes are regions in the DNA that contain the instructions that code for the formation of proteins. (secondary to HS-LS3-1) (Note: This Disciplinary Core Idea is also addressed by HS-LS1-1.)

LS3.A: Inheritance of Traits

- Each chromosome consists of a single very long DNA molecule, and each gene on the chromosome is a particular segment of that DNA. The instructions for forming species’ characteristics are carried in DNA. All cells in an organism have the same genetic content, but the genes used (expressed) by the cell may be regulated in different ways. Not all DNA codes for a protein; some segments of DNA are involved in regulatory or structural functions, and some have no as-yet known function. (HS-LS3-1)

LS3.B: Variation of Traits

- In sexual reproduction, chromosomes can sometimes swap sections during the process of meiosis (cell division), thereby creating new genetic combinations and thus more genetic variation. Although DNA replication is tightly regulated and remarkably accurate, errors do occur and result in mutations, which are also a source of genetic variation. Environmental factors can also cause mutations in genes, and viable mutations are inherited. (HS-LS3-2)
Crosscutting Concepts

Cause and Effect

- Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. (HS-LS3-1),(HS-LS3-2)
Appendix I: Supplemental Materials

Genetics Review Worksheet

Page 1 of 2

Name: ___________________________ Date: __________

Answer the following questions:

Word Bank

Activities Guanine Nucleus Transcribed
Adenine Meiosis Protein Translated
Cytosine Mitosis RNA
Function Mutation Thymine

1. The four nitrogen bases are: __________________________

2. Adenine always bonds with ____________ and Cytosine always bonds with ____________

3. In eukaryotic cells, DNA is found in the organelle called the ____________

4. DNA contains a coded message which controls all cell ____________

5. This code is replicated during the S phase of the cell cycle and passed on to daughter cells during ____________

6. This code is ___________________________ into a _______________ code which is then ___________________________ at the ribosome into an amino acid code which makes up a ____________

7. Any change to the DNA code is called a _______________ and may affect the amino acid sequence in the coded protein.

8. A defective amino acid sequence may affect the 3-dimensional structure and _______________ of the protein.

9. Transcribe the following DNA sequence into mRNA:

5’TAC CAT GAT ACA ATC3’

10. Translate the mRNA sequence into an amino acid sequence:
Genetics Review Worksheet

Page 2 of 2

Answer the following questions:

Word Bank

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<th>Dominant</th>
<th>Genotype</th>
<th>Phenotype</th>
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<td>Introns</td>
<td>Recessive</td>
</tr>
<tr>
<td>Forty-six (46)</td>
<td>Many</td>
<td>Traits</td>
</tr>
<tr>
<td>Gene</td>
<td>One (1)</td>
<td>Twenty-three (23)</td>
</tr>
</tbody>
</table>

11. Normal human somatic (body) cells contain _______ chromosomes.

12. A section of a chromosome that codes for one particular protein is called a ________________.

13. Proteins determine ________________ (whether you have brown or blue eyes).


15. As a result of sexual reproduction, offspring receive ______ copy of each gene from each parent.

16. The combination of genes received from your parents is called your ________________ and determines what you look like (your ________________).

17. A gene is ________________ when only one copy of the gene is needed in order to see that trait in your phenotype.

18. Traits that require two of the same gene be present for expression of the trait are called ________________.

19. When DNA is transcribed, some intervening pieces are not incorporated into the resulting mRNA. These sections are called ________________.

20. The remaining sections of the gene that are transcribed (expressed) and that code for the gene protein are called ________________.
Genetics Review Worksheet

Answers

Page 1 of 2

Answer the following questions:

Word Bank

<table>
<thead>
<tr>
<th>Activities</th>
<th>Guanine</th>
<th>Nucleus</th>
<th>Transcribed</th>
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<tr>
<td>Adenine</td>
<td>Meiosis</td>
<td>Protein</td>
<td>Translated</td>
</tr>
<tr>
<td>Cytosine</td>
<td>Mitosis</td>
<td>RNA</td>
<td></td>
</tr>
<tr>
<td>Function</td>
<td>Mutation</td>
<td>Thymine</td>
<td></td>
</tr>
</tbody>
</table>

1. The four nitrogen bases are: **Adenine, Thymine, Guanine and Cytosine**.
2. Adenine always bonds with **thymine** and Cytosine always bonds with **guanine**.
3. In eukaryotic cells, DNA is found in the organelle called the **nucleus**.
4. DNA contains a coded message which controls all cell **activities**.
5. This code is replicated during the S phase of the cell cycle and passed on to daughter cells during **mitosis**.
6. This code is **transcribed** into a **RNA** code which is then **translated** at the ribosome into an amino acid code which makes up a **protein**.
7. Any change to the DNA code is called a **mutation** and may affect the amino acid sequence in the coded protein.
8. A defective amino acid sequence may affect the 3-dimensional structure and **function** of the protein.
9. Transcribe the following DNA sequence into mRNA:

   **SENSE STRAND**
   
   STAC CAT GAT ACA ATC3'
   
   **ANTISENSE STRAND**
   
   3ATG GTA CTA TGT TAGS
   
   mRNA
   
   UAC CAU GAU ACA AUG

10. Translate the mRNA sequence into an amino acid sequence:

   mRNA
   
   UAC CAU GAU ACA AUG

   Tyrosine  Leucine  Aspartine  Threonine  Isoleucine
Genetics Review Worksheet
Answers
Page 2 of 2

Answer the following questions:

Word Bank

<table>
<thead>
<tr>
<th>Dominant</th>
<th>Genotype</th>
<th>Phenotype</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exons</td>
<td>Introns</td>
<td>Recessive</td>
</tr>
<tr>
<td>Forty-six (46)</td>
<td>Many</td>
<td>Traits</td>
</tr>
<tr>
<td>Gene</td>
<td>One (1)</td>
<td>Twenty-three (23)</td>
</tr>
</tbody>
</table>


12. A section of a chromosome that codes for one particular protein is called a gene.

13. Proteins determine traits (whether you have brown or blue eyes).


15. As a result of sexual reproduction, offspring receive one (1) copy of each gene from each parent.

16. The combination of genes received from your parents is called your genotype and determines what you look like (your phenotype).

17. A gene is dominant when only one copy of the gene is needed in order to see that trait in your phenotype.

18. Traits that require two of the same gene be present for expression of the trait are called recessive.

19. When DNA is transcribed, some intervening pieces are not incorporated into the resulting mRNA. These sections are called introns.

20. The remaining sections of the gene that are transcribed (expressed) and that code for the gene protein are called exons.
## Cancer Innovations

<table>
<thead>
<tr>
<th>Event</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>James Watson, Francis Crick and Rosalind Franklin</td>
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</tr>
<tr>
<td>The number of chromosomes in humans</td>
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</tr>
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<td>The genetic code was cracked, demonstrating that a sequence of three</td>
<td>nucleotide bases (a codon) determines each of 20 amino acids.</td>
</tr>
<tr>
<td>First human tumor-suppressor genes were discovered</td>
<td></td>
</tr>
<tr>
<td>Gel electrophoresis was developed to sequence DNA using an electric</td>
<td>current.</td>
</tr>
<tr>
<td>A technique for making many copies of a specific DNA sequence, the</td>
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</tr>
</tbody>
</table>
## Cancer Innovations

Cancer was linked to damage at cell cycle checkpoints.

A mutation on a single gene in 5-10% of women with breast cancer was determined to be linked to breast cancer.

The gene on chromosome 17 is named the Breast Cancer 1 gene.

The BRCA1 gene was cloned. People could now be screened for BRCA1 mutations.

The entire sequence of DNA composing human chromosomes was completed.

FDA approved three-dimensional mammography for routine screening as diagnostic tool for breast cancer.

Two vaccines (called Gardasil and Cervarix) have the market to protect against two types of HPV (HPV-16 & HPV-18) cancer causing viruses.
# Pop Culture Events

- First Academy Awards (Oscars) televised.
- First McDonald’s opened in Des Plaines, Illinois.
- Color TV became popular.
- Disney World opened in Orlando, Florida.
- Motorola obtained patent for first portable (cell) mobile phone.
- Micheal Jackson’s “Beat It” topped charts.
## Pop Culture Events

<table>
<thead>
<tr>
<th>Event</th>
<th>Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>First episode of <em>The Simpsons</em> aired.</td>
<td>1989</td>
</tr>
<tr>
<td><em>Pretty Woman</em> and <em>Home Alone</em> premiered.</td>
<td>1990</td>
</tr>
<tr>
<td>Justin Bieber was born.</td>
<td>1994</td>
</tr>
<tr>
<td>Facebook was founded.</td>
<td>2004</td>
</tr>
<tr>
<td>The final Harry Potter movie, <em>Harry Potter and the Deathly Hallows: Part 2</em> was released.</td>
<td>2011</td>
</tr>
<tr>
<td>The ALS Association raised $115 M from the ALS Ice Bucket Challenge.</td>
<td>2014</td>
</tr>
</tbody>
</table>
# Cancer Innovations and Pop Culture Events

## Answers

<table>
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<tr>
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<th>Pop Culture Event</th>
</tr>
</thead>
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BReast CANcer Gene 1 (BRCA1) Sequence

Sense Stand 5'→3'
BReast CAncer Gene 1 (BRCA1) Sequence

Sense Strand 5’→3’
BRReast CANcer Gene 1 (BRCA1) Sequence

Sense Stand 5’–3’

2821 cca gcc atg gtc taa aaa tct tga ttg aat tac cac ctt ttc att tcc aga cac ccc tat
2881 tta aaa tta cca cac ccc cag cac aca ctt tat ctt cta ttc ctg ctt ctc cat aac
2941 act gat tac tag ctg aca ttc tat gta atg tat cca ttt ttt atc tct agt ccc aca gaa
3001 tgt aaa ctc cag gat ggg att ttt gtt ttc ttt aca tac atc tgt atg ttc agt agt tag
3061 aac ggt act tgg gac cta gtt gcc act caa taa aca ttt gtc aaa taa ata aca taa
3121 act aaa tta gtt ctt taa ttt taa ata tgg tga tgg tta gta gtt agt aac att caa
3181 aaa atg tga aaa gtt gta cca ttt ctt acc cac aat aac ggg taa att ctt
3241 ttc tgc ttt atg aaa gtt gtt ttt cat att tga agt caa gtt aat cag att aag gaa aat
3301 gta tgt tgt gtt ttc aga ggc ata caa gat tta taa ata acc atc ctc tcc ctt gcc ctt
3361 caa cat tat agc taa aca aaa ata aga gga aaa cac gat tca caa ttt atc aat tta ttg
3421 aac aat ctc ata gcc ata gaa gcc gca aat gac att gta gga aac lgc ttt tga aaa agc
3481 aca aat ctt act cat gac aat cag tga tca gga aac tcc tca ata gtg tgg cat ttt gat
3541 aca ttt atg ttt cat ttc cat ggg aga gag tca taa aaa tag gat gtt ctt ctt cat tct
3601 ggc aat tta aac cat caa tta aaa act cag ata cat aat aat tag aag aat gaa
3661 aat gct aat tgg tta ttt tca atc aac tat tat gtt ttc tag ctt ttc att gct ttt ttc
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3961 gtt ggt ctc gaa ctc ctg acc tca gtt gat cct cct gcc tgg gcc tcc gaa agt gct ggg
4021 att aca ggc gtg agc cac cgc tcc cag act ttt tgt ttt gtt ttt tgt ttt tgt ttg gag
4081 aca cgg tct cgc tct gct gcc tag gct gga gtg cag tgg cac gat ctt gcc tca ctt cca
BReast CAncer Gene 1 (BRCA1) Sequence

Sense strand 5'→3'

4141 gct ccc cct ccc ggg ttc agg cca ttc tgc ctc agc ctc ccc agt agc tgg gac tac
4201 agg cgc cca cca cta tgc ccc gct aat ttt ttg tat tat tag tag aga cgg ggt ttc acc
4261 atg tta gcc aag atg gtc tgg atc ttc tga cct tgt gat cca ccc gcc tca gcc ttc cca
4321 aat gct ggg att ata gtc ctt agc cac tgc gcc cgg cct gga cct ttt ttc ggg gtt
4381 ggg ggt tgt agt ctt gtc tgt tgg ccc agg ctc gat lgc agt ggc gcc atc ttg gct gcc ctc
4441 tgc aac ctc cgc ctt cca ggt tca agt tca agc gct tct cct gcc tca gcc tcc tga gta
4501 gct ggg att ata ggc gca cgc cac cgt gcc cgg cta att ttg ttt tag tag aga tag
4561 gtt ttc atc agc ttg gtc agg ctt gtc tgt aag tcc tga tct cg t gat cca ccc gcc ccc
4621 gcc ttc cca aag atg gct gcc gtt agc cac tgc gcc tgg ctt aag att aat ttt ttg ttt ttg
4681 tgt ttt tga gac gga gtc tgg ctt ctc ttt cca gcc cgg aag gtt gcc gtt gcc ctt cgg
4741 ctc act gca agc tcc gcc cgg ggt ttt ccc gac ctt ctc cct ctt cgg ccc ccc aag tag
4801 gtt gga cta cag gcc tcc acc acc acg ccc gcc taa ttt ttt cta gta gta gag acg
4861 ggg ttt ccc cct ggt tgg cag gat ggt ctt ccc ccc ttc gta gcc ccc ccc ccc gcc
4921 gcc ctc cca aag tgt tgg gat acg ctt gat agg gct taa ccc cgg ccc gcc ccc ctt aga tta atg
4981 ttt atg gtt ttt tac att cat ttg tat gga aag ttc tag gat agg gat cat att tca ctt
5041 cct ttt aat ata gta cag tat agc atc tat gtc tta ata ttt gat cag gaa
5101 tga tca tga ctt gaa aca atg ttt gtt gta gct ata ggg tag gta agg ttt tca gcc
5161 tgt ttt agg ttt ctt gaa cta aaa ttc ctt ctt cgg tct ttc tct ttc atg tca cta gca gcc gtt
5221 att tct gac aat tgg tag ttg ttc gtc act ttt tct atc cta cta cta taa ctt ttt gta ctt
5281 tca gaa gaa ttt gct taa atg tgg ttc ccc cgg ggt ggt tgt ttt tca acc taa acc tgg ttt acc
5341 ctt ctt ctt atc gcc act tat cgc nat tgg aag ctc aat cca cta atc agt tgg cct
5401 aat aat tgt cct gtt tgg aat ggt att tca aat gca cta ctt tta ttt cca ta tta aat ttg gcc ccc ctc
5461 tac tct cag gag cta gaa cgg gaa ctt tat ttg ctt ttt ttt ccc ccc ctt cca gag
5521 tct ctc ttc aac ttt cat cag ctt ttt cca tat cgg aag ttt ttt cat atg tcc aac aat tgg ttt
BRaeast CANcer Gene 2 (BRCA2) Sequence

Sense Stand 5'→3'

1  gtg gcg cga gct tct gaa act agg cgg cag agg cgc tgt ggc act gct gcg cct
2  ctt ctc cgc ctc ggg tgt ctt tgg cgg cgg tgt gcg ggc ggg aga agc gtt agg gga
3  cag att tgt gac cgg cgc ggt ttt tgt cag ctt act ccc ggc aaa aaa gaa ctt cac ctc
4  tgg agc ggg tta gtt gtg gta gtt ggt tgt gac gag cgc gtc ttc cgc agt ccc agt
5  cca gcg tgt cgg ggg agc ggc tca gcg ccc ggg tgg ctt cgg cgg ctt ctt gcc ctt tgg
6  ctc ctc cca acc ccc acc cat gcc tga gag aaa ggt cct tgc ccc aag gca gat ttt cgc
7  cca gca aat tcc gcc ccc gcct ccc gcc ctg ctg gcc cgct ccc cag cgg cct
8  tgg gcg tcc gcc ttc agc tca aga ctt aac ttc ctg ccc agc tgt ccc aga tga cgc cat
9  ctt gaa att ctg gga aac acg atc act tta acg gaa tat tgc tgt ttt ggg gaa gtt ttt
10  tac agc tgc tgg gca cgc tgt att tgt ctt act taa gcc ccc ggt aat tgc tgt att ccc
11  aag aca tgc tga tgt gaa tta cca ggc ggc gtt ggt ctt cta ctt gta gag ggg cct ccc gcc ccc
12  act agc cac gcg tca ctg gtt agc gtt att gag act aaa tgg tat gaa aat cct ctt ctc
13  tag tcg cac tag cca cgt ttc gac tgg tta atg tgt ctt gta gtt gca cgc gtt tgg aca gca
14  cag ctt taa aat gtt ccc atc atc atc aca gta agc tgt tac cgt tcc agg aga tgg gac tga
15  att aga att caa aca aat ttt cca gcg ctt ctg agt ttt ccc atc aca gcc cca taa gga
16  atg cat ccc tgt gta agt gca ttt tgg tct ttc ctt tgt cag act tat tta cca agc att
17  gga gga atg tca cgg tag gta aaa atg cct att gga tcc aca aaa gag agg cca aca ttt ttt gaa
18  att ttt aag aca cgc tgt aac aaa gca ggt att gac aaa ttt tat ata act tta aat att
19  aca ccc aga aag tgt ctt cta aaa aat gct tgc taa aca ccc aag cag tca cag tgt tgc
20  tta gaa cca taa act gtt cct tat gtt gta ata aat cca gtt aac ata atc atc gtt
21  tgc agg tta acc aca tga taa ata tag aac gtc tag tgg ata aag agg aaa ctg gcc ctc
22  tga cta gca gta gga aca att act aac aaa tca gaa gca tta atg tta ctt tat gcc ago
BReast CANcer Gene 2 (BRCA2) Sequence

Sense Strand 5'→3'

1321 agt tgt cca act ttt tgg ttt cag tac tcc tta tac tct taa aaa tga tct agg acc ccc
1381 gga gtg ctt ttg ttt atg tag ctt acc ata tta gaa att taa aac taa gaa ttt aag gct
1441 ggg cgt ggt gcc tcc ctc gta aac cag ccc ttt ggg agg ccc agg tgg gcc gct gat cac
1501 ttt agg cca gaa gtt tga gac cag cct ggc caa cat ggt gaa acc cta tct cta cta aac
1561 ata cca aac atg tgc tgc gtt tgg tgg gtc cct gta atc cca gct aca cgg gac ggt
1621 gag gca gga gaa tgc ctt gaa ccc tgg agg cag agg tgg cag tga gcc aag tct atg cca
1681 ctg ctc ctg agc ctg gcc cac ata gca tga ctc tct ctc aca aac cca aca aca aca
1741 aac taa gaa ttt aac gtt aat tta ctt aac aat gaa agc taa acc att gca tat tat
1801 cac aac att ctt agg aaa aat aac ttt tgg aaa aca agt gag tgg aat agt ttt tac att
1861 ttt gca gtt ctc ttt aat gtc tgg cta aat aga gat agc tgg att cac tta tct gtt tct
1921 aat ctg tta ttt tgg tag aag tatt gtg aca aca aat taa cct cag gaa aag agg aat
1981 att tta ata gtt ttc agt tac ttt tgg gta att ttc ttt gta ctt ctt tgc ata gat ttt cca
2041 aag atc taa tag ata tac agc agg tct ttc cca tgt cgc aac atc atg cag tga tta ttt
2101 gga aga tag tgg tgt tct gaa tta tac aca gtt tcc aaa tat tga taa att gca tta aac
2161 tat ttt aai aat ctc att cat taa tac cac cat gga tgt cag aaa agt ctt tta aga tgg
2221 ggt aga aat gag cca ctg gaa att cta att ttc att tga aag ttc aca ttt tgg tgt tga
2281 cca cca act gtt ttc ctt gca gca aca aga tca ctt cat tga ttt tgtg aca aat tgt cta
2341 cca aat tat tta agt tga aat aac ttt gtc agc tgg tct ttc aag taa aac tga ctc ttt
2401 att gaa aac att gct tgt tca gat cac agc tca aca tga tgt ctt ttc tag gca gta tgg
2461 tac ttc agt att cag aag tgc ttt atg tat gct ttc ttt tgg aga gat tat taa aag
2521 aag tgc taa agc att gag ctt cga aat taa ttt tta ctg ctt cat tag gac att ctt aca
2581 tta aac tgt cat tat tat cat tat ttt taa cca gga cac tca tgg gta agg aat ata
2641 atg gct act agt att agt tgg gta cca ctg cca taa ctc atg cca aat tgc cag cag ttt
**BRReast CAnCancer Gene 2 (BRCA2) Sequence**

Sense Stand 5’→3’

2701 tac cca gca tca tct ttg cac ttt tga tac aaa tga caa cat cac gaa aaa ggg aaa tga
2761 ttc cat agc gtt att atg aaa gta gtt ttg aac tgg aat ggt aga gga tga ata gct cac
2821 aat caa aat ttg tca ttt ccc ttt aag aga gaa ttc cca ttt tat gtt aga gta cac atg
2881 ttc ctc ata ccc ata gtt tgc cac atc ttg agt act ctt cag aat tat ttg aat ttt ttg
2941 aat ttt atc tgt gga atg tat ttt ttt ttt ctt ttt tga gac aca gta tgt ctc tgt
3001 tgc cca ggc tgt aat gca gtg ggc tgt tct cgg ctc act gca acc acc gcc tcc tgg gtt
3061 cca gtt att ctc tgt tgg cag cct cgg gag tag ctg gga cta cag ggc tgt ggc acc atg
3121 ctt ggc taa ttt ttg ttt tta gta aag atg ggg ttt cca cgt gtt agc aag gtt ggt
3181 ctc gatctga cctcgtagc tgcctgccct acgcctccca aagttgggga ttacaggccgt
3241 gag ccc cct gcc cag ctc gtc gcc gaa ttt tat cgt gga atg tat tct taa tgg gaa tag ttt ttg
3301 att cgc aac cat gaa taa taa gaa aat aaa taa aat tta aat gaa aat aag taa tat tat
3361 ata cag ctt tta ata ata tag tta aat gcc atc ttg taa ctt ttg tga act ctt gtt aca
3421 cct ttc tat aga ttc gca aga gaa tgg att aat gat ctt gtt taa tta ata tga ctt aac
3481 aaaa agt aat cca tag tca aga tct tta aac tgc taa gca ttt ttc ttc tta ttg aac tct att
3541 tgt cac aaa ttg tgt ctc tgt tgg tta aaaa cta agg tgg gat ttt ttt ttt ttt aat tag aat
3601 tag gac caa taa gtc tta att ggt ttg aag aac ttt ctt cag aag ctc cac ctt ata att
3661 ctt gac ctt cag aag aat cag aac ata aaaa aca aca att acg aac caa acc tat tta aaaa
3721 ctc cac aaa gga aac cat ctt ata atc agc tgg ctt cta ccc aca taa tat tca aag agc
3781 aag ggc tga ctc tgc cgc tgt acc aat ctc ctt taa aag aat tag ata aat tca aat tag
3841 act tag gta aat gca ata ttg tag act ggg gag aac tac aaaa cta gga aatt tag gca
3901 aac ctc tgt taa aat ctt agc tca ttc att aat tgt gtc atg ctt ggc aaca tca gtc tct
3961 ctt gcc tct ttt tcc tca ctc gaa aaaa tgg aga cga tga aaaa taa tgt ctc ata ggt ttg
BReast CAncer Gene 2 (BRCA2) Sequence

Sense Strand 5’–3’

4021 gat taa att aaa taa tgt agg tac tta gta aat gtt ctc ttt cat ccc tcc ttt gat aac
4081 ttt gcc aac tga gat tgt ctg aat tac gtc ttt ctt atg cca aaa aac cct agg act tgt
4141 ttt gat gtt aat taa act aaa cta tat ttc tgc aag cta tca cag aggg aca gac att att
4201 tta ccc ata tac tat aag tat cat gat tgt gaa gga gtt ccc ctg gcc gag tag tgt ccc cat
4261 gtt cct aag cca tta tgt aat aag att atat tca gtc att cca ata att att acc tac
4321 ttt aca taa gta aag aac ccc ttt tct tca gac tgt taa tct cta gta agg gga aca
4381 aag agt aca cag ata aag tat agt gta agg tgt aat gta gta tgt gct aag aga aaa ata
4441 taa aaa agt ata atg aga gtt gac aag aac gac ata gta tgt gcc aac gtt agg ccc
4501 tta ttc ctg tga gct aat aac ccg tga agg ata ggt gac aga tta aag tgt aag aga ccc
4521 tag agt gat aat tgt cta gcc aga ggg aac aac atg aga aag aat atg tgt gtt cag
4621 gaa ata gca agt aat tca ggt tgt tgg ctt tgg tgt cgg tgt gcc tga aag gga cca ata gac
4681 aag gca aac aag cag act aac ggc agg cat tga atg cca agt taa aag aat tgt aat tgc
4741 tgt gtt ggt tgt cgg gcc gag aag aca ctc cat gcc atc atg ctt atg tgt gtc tca
4801 aac ctt aca tca ccc ccc ttt gtc att ata gca aat tct taa aat gat atg gct ttc aag
4861 ttc ctc tgt gat cag gcc cct gat tta cac ctc tgg ctc agc tgt gca tct cca tcc tct
4921 cac cta tct tca ttt gcc att cat tcc tac tga att tct ttt cgt tac cca aac cac aat
4981 gct ctc tgg ctc ttt att aca cat att gtt acc tct acc cac aac aac ctc cca ctt ttt ccc tac
5041 ttt tgt cct agc taa ttt cgg tgt ctt tgt ctt ggt gta cca tgt gaa gct ctc aat gct ctc ggt
5101 aac ttc tgg ggg tgg tgt gtt cgg gtt ctt ctc cgg cgg cgg gtt gg ctc cgg gtt aag gaa aat gat tta
5161 agt gtt ata cat gct tgg aat aac ggg atat cgg ggc tat agg gac tga ata tac aat gaa ggt aat
5221 ata ggt aat ggg cca ata ttt aca tgt atg tta tgt gat acc aac tgg tat aca tag gat
5281 tca gta aat att tgt aca gtt ctt aag gta att ttt gat cct aag gct ctt gct gtc cca tga gaa tgt tct ctt
5341 aca gca gtc tt ggt gga gat aac gtt ttt cca atat gtc atg tgt ctc gca cag cta gaa tct ccc
5401 aga ctc ctc att gaa agg aca gat tcc agg ccc ccc ctc gaa tct ctt aat tta taa ttt
**BReast CAncer Gene 2 (BRCA2) Sequence**

Sense Stand 5’--3’

5461 ttg gaa atg atg ccc atg agt cta cat ttt aca cta cct gaa tcc cta tag aaa gag
5521 aac act gga ggt agg aag atc agt tag ggg atg tgt aat ggt cta ggt gat aga gac aag
5581 tgc ctg aat tac agt aat aac agt gaa agt aaa tat gga aca taa aac tat agg acc ttg
5641 cag tag tct aga tat gga gga ttc aaa aaa agg aac aaa tga cag ggc aaa gca tat gca
5701 gaa cac agt agt aag aat ggg ggt cag ctc tgc tgc aaa tac tta
5761 gtt ctc tct tgg gtt cca cct gct cgg cat taa gga taa tag aag taa gat gtc
5821 ctt tga cct cta agt act cag tct ctg aag cac gtc tgg taa gca cat ctt ggt tgc ttc
5881 cat aag aat aca cca ctg ctc ttc agt aca aag gca cct ctc ctg tgg taa gca aag taa gag
5941 tga gca gcc atc tct ggt tgg tca gaa aac gct tcc taa aag ctt tgc tga tca tgc ttt
6001 aag gat ata cct gca aaa tgg tta att ctt taa tca taa cct gct aga att gat cta
6061 taa cca agg aag gat aag gaa tta ata agg cca ctc tca act cac tgc aag gcg gtt
6121 aac ttt tgg aag gct gta ata cat aaa tct gct gac tag tct gtt gac ctt gtt tca gtt ctt
6181 tac gtt tac ttt agt agg atg aag gaa taa gag tta tgg act taa gct gtt gtt ctt ccc
6241 aac ctg ttt tgt tca gtt cta aca agt aat att att ttt taa aca att att cct aac gtt ctc
6301 tga gga att gtt ctt cgg cct ctc cgc agt cct ccc ctc ttt ttg ctt aca tca tag tga gca
6361 ttt ctc tta cca tcc ttc agc tta tta atg gga tca cgg ctt ttc tca gtt ctc gaa aat gtt tat
6421 tgt atg cca ctt tca ttc ctg tgg cca ctt tca att tta aat aag ctc ctt gta ttc tca aat gta gaa ctt ttt tta taa ctg ttc ctt gaa ccc ttg cca tgg ttc tat gga ttt tga caa att gta taa tgt cgt atc
6541 ctt tag agt ctc ccc tgt gtt ttc tat gga ttt tga caa att gta taa tgt cgt atc
BReast CAncer Gene 2 (BRCA2) Sequence

Sense Strand 5’→3’

6601  tct gcc att atg gca tta tac aga ata att ttg ctc ccc taa aaa tct ccc gag ttc cac
6661  ctt ctc acc cat ccc tcc tcc tga gcc cct ggc agc cac tga tct ttt tac tgc tct tat
6721  agt ttt gcc ttt tcc aga atg tca tgg agt tgg aat cat aca gaa tat agc att ttc aga
6781  ctt gct ctt ttc act tag caa tat gcc gag acc agc tcc att gta gac acc cta acc cag
6841  cgg cac tag agg aat taa agg cac aca gaa ata tag cgg tgt gga gtt gga aat cag ggg
6901  tct cac agc ctt ttt aca gca agc cag tga taa gca ttt cta tag att ata gat taa
6961  ctt aaa gta ttc ctt agg gga aat aca ggg ctt gcc cga agt aan ggg atg ggt ctt gct
7021  agt tat ctc cag cag gag aat gtc ctt aag gca cag gtc gct gat agt ttt cgg ttt
7081  aag aac gcc ttt aag cgg ttt tct gcc ccc ggg ggt gtt ggg cca ggt gtt ctc tct ccc ctt ctc ccc
7141  ggt aca taa ggg ttt tct tta tgg ccc ggg gga gtg ggg cca ggt gcc ttt ccc cac aac agc aat ttg ttt ttc
7201  cag aga ttt ttg tta tgg ccc ggt ttt cgg ggg cca ggt gcc ttt ccc cac aac agc aat ttg ttt ttc
7261  ttc ttc cat gtc ttt taa tga ttt cat gct gaa taa tat tcc aac gtg ttt ctt tgg atg tgg cag
7321  agc tgt ttt atc cat tca tct att gaa gga cag cat ctt gat tgc ttc caa att ttt gcc aat
7381  atg aat aaa gcc ggt atg ata att cac ata cag tgt tgt cct gta aat ttt taa cac ctc
7441  att tgt gtt cac acc aaa aag cac gagac gat tgg cgg atc ata tag taa gag tat tgt tag ttt
7501  tga cag taa cta cca gct ctc ttc cca aat gcc tgg tgt cca acc cac aag gag aag tgg ttt tgc gag gtt tgg aat
7561  tga atg aga gtt ctt gtt gct cac atc ctc acc agc att tgg tgt gtc agt gtt ttg aat
7621  tct agc cat tct aac aag tgt gta gtc gta cct tct ttc ctc ccc att ttc ttt ttt
7681  ttt ttt ttt cgg agg aga tca aat ctc gct tgt gcc ccc agg ggc gag tgt ggccc gtc atc
7741  ttt gct cac tgc aag ctc cgt gcc ccc cca ggt tca cgc cac tct tcc gcc tta gcc tcc tga
7801  gta gct ggg act aca gcc acc ccc cac cac gcc ccc gtt attt tgt tat tac tag
ggc tgg ggt tgt ctc gtt cgt tta gcc gag atg gtt gtt atg gcc ttc gat ggc ggc cgg tcc
gtc ggc ctc caa atg gct ggg att aca gcc gttcg agc cat gcc cgg cct gtg tta
7981  ttt ttt aat gcc gtt ctt tgt aca tag ttc ctt ctc gca gtt aat aca ggg gtt gca atg ggc ggt ccc aag ttc
7931  ttt ttt aat gcc gtt ctt tgt aca tag ttc ctt ctc gca gtt aat aca ggg gtt gca atg ggc ggt ccc aag ttc
Genetic Mutations

Name: ___________________________ Date: _______
Name of Population: ______________ Location of sequence: ______________

Normal Sequence

Template Strand DNA
(Anti-Sense Strand): 3’_______________________________5’
Coding Strand DNA:
(Sense Strand): 5’_______________________________3’
mRNA: _______________________________________
Amino Acid: ____________________________________

Mutation Sequence

Template Strand DNA
(Anti-Sense Strand): 3’_______________________________5’
Coding Strand DNA:
(Sense Strand): 5’_______________________________3’
mRNA: _______________________________________
Amino Acid: ____________________________________

1. What type of mutation is this?

2. What result does the mutation have on the protein?
Genetic Mutations

Answers

Name of Population: Britsh, Location of sequence: BRCA 1 Start with 4174 End With 4197

Normal Sequence
Coding Strand DNA (Sense Strand): 5’CTC AGC CTC CCG AGT AGC TGG GAC 3’
Template Strand DNA (Anti-Sense Strand): 3’GAG TGG GAG GGC TCA TCG ACC CTG 5’
mRNA: CUC AGC CUC CCG AGU AGC UGG GAC
Amino Acid: Leu Ser Leu Pro Ser Ser Trp Asp

Mutation Sequence 4184 Del 4
Coding Strand DNA (Sense Strand): 5’CTC AGC CTC CGA GCT GGG AC 3’
Template Strand DNA (Anti-Sense Strand): 3’GAG TGG GAG GCT CGA CCC TG 5’
mRNA: CUC AGC CUC CGA GCU GGG AC
Amino Acid: Leu Ser Leu Arg Ala Gly

1. What type of mutation is this?
   Deletion

2. What result does the mutation have on the protein?
   Codes for different amino acids and results in a shorter (truncated) protein.

Name of Population: Italians, Location of sequence: BRCA 1 Start with 5080 End With 5130

Normal Sequence
Coding Strand DNA (Sense Strand): 5’GTC TTA ATA TGT GAT CAG GAA TGA TCA TCG GAA ACA GTG TTA TGT GTC 3’
Template Strand DNA (Anti-Sense Strand): 3’CAG AAT TAT ACA CTA GTC CTT ACT ACT GAC CTG TGT CAG AAA CAG 5’
mRNA: GUC UUA AUA UUA GAG CAA GAA UCA UGA UCA UCA UCA CAG AAA GUG UUA UUA CAG
Amino Acid: Val Leu Ile Cys Val Glu Glu Ser Ser Stop Leu Glu Thr Val Leu Phe Val

Mutation Sequence 5083 Del 19
Coding Strand DNA (Sense Strand): 5’GTC GAT CAT GAC TGG AAA CAG TGT TAT TGG TGG TA 3’
Template Strand DNA (Anti-Sense Strand): 3’CAG CTA GCA TCG AGG TTT GTC ACA ATA AAC ACC AT 5’
mRNA: GUC GAG CAU GAC UGG AAA CAG UGU UAU UUG UUG UA
Amino Acid: Val Asp His Asp Trp Lys Gln Cys Thr Leu Trp

1. What type of mutation is this?
   Deletion

2. What result does the mutation have on the protein?
   Codes for different amino acids and results in a shorter (truncated) protein.
Genetic Mutations

Answers

Name of Population: Norwegians  Location of sequence: BRCA 1 Start with 1132  End With 1152

Normal Sequence
Coding Strand DNA (Sense Strand): 5'AAA TTC AGA ATT TAT GTT GTC 3'
Template Strand DNA (Anti-Sense Strand): 3'TTT AAG TCT TAA ATA CAA CAG 5'
mRNA: AAA UUC AGA AUU UAU GGU GUC
Amino Acid: Lys  Phe Arg Ile Tyr Val Val

Mutation Sequence 1136 Ins A
Coding Strand DNA (Sense Strand): 5'AAA TTA CAG AAT TTA TGT TGT C 3'
Template Strand DNA (Anti-Sense Strand): 3'TTT AAT GTC TTA AAT ACA ACA G 5'
mRNA: AAA UUA CAG AUA UUA UGU UGU C
Amino Acid: Lys  Leu Gln Asn  Leu Cys Cys

1. What type of mutation is this? Insertion
2. What result does the mutation have on the protein? Codes for different amino acids.

Name of Population: Norwegians  Location of sequence: BRCA 1 Start with 1672  End With 1689

Normal Sequence
Coding Strand DNA (Sense Strand): 5'AAG ACA GGG ACT CTG TCT 3'
Template Strand DNA (Anti-Sense Strand): 3'TTC TGT CCC TGA GAC AGA 5'
mRNA: AAG ACA GGG ACU CUG UCU
Amino Acid: Lys  Thr Gly Thr Leu Ser

Mutation Sequence 1675 Del A
Coding Strand DNA (Sense Strand): 5'AAG CAG GGA CTC TGT CT 3'
Template Strand DNA (Anti-Sense Strand): 3'TTC GTG CCT GAG ACA GA 5'
mRNA: AAG CAG GGA CUC UGU CU
Amino Acid: Lys  Gln Gly Leu Cys

1. What type of mutation is this? Deletion.
2. What result does the mutation have on the protein? Codes for different amino acids.
Genetic Mutations

Answers

Name of Population: Icelanders Location of sequence: BRCA 2 Start with 6169 End With 6192

Normal Sequence
Coding Strand DNA (Sense Strand): 5’ACC TTT TGC TTT TAC GTT TAG TTT 3’
Template Strand DNA (Anti-Sense Strand): 3’TGG AAA ACG AAA ATG CAA ATG AAA 5’
mRNA: ACC UUU UGC UUU UAC GUU UAC UUU
Amino Acid: Thr Phe Cys Phe Tyr Val Tyr Phe

Mutation Sequence 6174 Del T
Coding Strand DNA (Sense Strand): 5’ACC TTT GCT TTT AGC TTT ACT TT 3’
Template Strand DNA (Anti-Sense Strand): 3’TGG AAA CGA AAA TGC AAA TGA AAS 5’
mRNA: ACC UUU GCU UUU AGC UUU ACU UU
Amino Acid: Thr Phe Ala Phe Thr Phe Thr

1. What type of mutation is this? Deletion
2. What result does the mutation have on the protein? Codes for different amino acids and results in a shorter (truncated) protein.

Name of Population: Filipinos Location of sequence: BRCA 2 Start with 4855 End With 4875

Normal Sequence
Coding Strand DNA (Sense Strand): 5’TTC AAG TTC CTT TGT GAT CAG 3’
Template Strand DNA (Anti-Sense Strand): 3’AAG TTC AAG GAA ACA CTA GTG 5’
mRNA: UUC AAG UUC CUU UGU GAU CAG
Amino Acid: Phe Lys Phe Leu Cys Asp Gln

Mutation Sequence 4859 Del A
Coding Strand DNA (Sense Strand): 5’TTC AGT TCG TTT GTG AG 3’
Template Strand DNA (Anti-Sense Strand): 3’AAG TCA AGG AAA CAC TAG TC 5’
mRNA: UUC AGU UCC UUU GUG AUG AUC AG
Amino Acid: Phe Ser Ser Phe Val Ile

1. What type of mutation is this? Deletion
2. What result does the mutation have on the protein? Codes for different amino acids and shortens the protein.
Genetic Mutations

Answers

Name of Population: Filipinos Location of sequence: BRCA 2 Start with 4261 End With 4278
Normal Sequence
Coding Strand DNA (Sense Strand): 5’ GTT TCT AAGCAA TTA TGT 3’
Template Strand DNA (Anti-Sense Strand): 3’ CAA AGA TGC GGT AAT ACA 5’
mRNA: GUU UCU AAG CAA UUA UGU
Amino Acid: Val Ser Lys Gln Leu Cys
Mutation Sequence 4265 Del CT
Coding Strand DNA (Sense Strand): 5’ GTT TAA GCA ATT ATG T 3’
Template Strand DNA (Anti-Sense Strand): 3’ CAA ATT AAT CGT TAA TAG A 5’
mRNA: GUU UAA GCA AUU AUG U
Amino Acid: Val stop Ala Ile Met

1. What type of mutation is this?
   Deletion.
2. What result does the mutation have on the protein?
   Codes for different amino acids and results in a shorter (truncated) protein.

Name of Population: Dutch Location of sequence: BRCA 2 Start with 5572 End With 5595
Normal Sequence
Coding Strand DNA (Sense Strand): 5’ AGA GAC AAG TGC CTG AAT TAG AGT 3’
Template Strand DNA (Anti-Sense Strand): 3’ TCT CIG TIC AGC GAC TIA ATG TCA 5’
mRNA: AGA GAC AAG UGC CUG AAU UAC AGU
Amino Acid: Arg Asp Lys Cys Leu Asn Tyr Ser
Mutation Sequence 5579 Ins A
Coding Strand DNA (Sense Strand): 5’ AGA GAC AAA GTG CCT GAA TTA CAG T 3’
Template Strand DNA (Anti-Sense Strand): 3’ TCT CIG TIT CAC GGA CTT AAT GTC A 5’
mRNA: AGA GAC AAA GUG CCG GAA UUA CAG T
Amino Acid: Arg Asp Lys Val Pro Glu Leu Gln

1. What type of mutation is this?
   Insertion.
2. What result does the mutation have on the protein?
   Codes for different amino acids.
Genetic Mutations

Answers

Name of Population: African Americans Location of sequence: BRCA 2 Start with 1531 End With 1554

Normal Sequence

Coding Strand DNA (Sense Strand): 5’CAA CAT GGT GAA ACC CTA TCT CTA’
Template Strand DNA (Anti-Sense Strand): 3’GTT GTA CCA CTT TGG GAT AGA GAT 5’

mRNA: CAA CAU GGU GAA ACC CUA UCU CUA
Amino Acid: Gln His Gly Glu Thr Leu Ser Leu

Mutation Sequence 1536 Del 4

Coding Strand DNA (Sense Strand): 5’CAA CAG AAA CCC TAT CTC TA’
Template Strand DNA (Anti-Sense Strand): 3’GTT GTC TTT GGG ATA GAG AT 5’

mRNA: CAA CAG AAA CCC UAU CUC UA
Amino Acid: Gln Gln Lys Pro Try Leu

1. What type of mutation is this? Deletion.
2. What result does the mutation have on the protein? Codes for different amino acids and results in a shorter (truncated) protein.
## Codon Chart

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Williams’ Family Pedigree Analysis

Name: ___________________________  Date: __________

Complete the Williams’ Family Pedigree and then answer the following questions.

1. How many generations are shown in the pedigree?

2. Describe what the pedigree reveals about the family’s history of breast cancer.

3. If someone has a mutated BRCA gene, does that mean they have or will have breast cancer? Why?

4. BRCA mutations are dominant. Who could potentially have an inherited BRCA mutation? Why?
Williams’ Family Pedigree Analysis

Answers

Complete the Williams’ Family Pedigree and then answer the following questions.

1. How many generations are shown in the pedigree?

   Four.

2. Describe what the pedigree reveals about the family’s history of breast cancer.

   Both sides of the family have a history of breast cancer. Cancer is multigenerational.

3. If someone has a mutated BRCA gene, does that mean they have or will have breast cancer? Why?

   No. Every person has two copies of each BRCA gene. Even if one gene is mutated, the other may still function properly.

4. BRCA mutations are dominant. Who could potentially have an inherited BRCA mutation? Why?

   Mrs. Williams and her siblings because their mother had breast cancer. Mr. Williams and his cousin because women in his family have a history of breast and ovarian cancer at a young age.
GC: Hi, I’m the genetic counselor here. How are you the both of you?

Sarah: I’m fine thank you.

GC: I understand that you have some concerns about your personal and family history of cancer.

Sarah: Yes, our son, Steve, recently brought up our family history because he had been learning about genetics for one of his classes. My doctor also asked me to be seen for genetic counseling because I was just diagnosed with breast cancer at 53 years old and have a family history of breast cancer.

GC: Let’s draw out your family pedigree. Who has a history of cancer in your family?

Patient: My mother had breast cancer at 62 and is currently 76. My maternal grandmother had breast cancer at 69 and died at 72. My father had prostate cancer at 68 and is currently 75. My paternal uncle was diagnosed with lung cancer at 68 and died at 77.

GC: Since your husband is here with you today and you are concerned about your children, let’s get his family history as well. John, who in your family has had cancer?

John: My mom was diagnosed with breast cancer at 43 and died at 46. My maternal cousin (maternal uncle’s daughter) had ovarian cancer at 38 and died at 42. My maternal grandmother was diagnosed and died of breast cancer at 47.

GC: Sarah, based on the multiple generations of breast cancer in your family, it is possible that these cancers are all related and due to mutations in hereditary breast cancer genes, such as BRCA1/2. John, based on your family history of early onset breast cancer as well as ovarian cancer, your side of the family is also suggestive of a BRCA1/2 mutation.

Sarah: Can you tell me how a mutation in the BRCA1/2 genes causes cancer?

GC: BRCA1 and BRCA2 are tumor suppressor genes. Every person is born with two copies of each gene. When these genes are working properly, their job is to stop a cell from forming cancer. But when there is a mutation in one of these genes, they do not work, the cell divides uncontrollably, and it forms cancer. Genetic testing can look for mutations in the BRCA genes.

Sarah: Okay, so as I understand it we all have these genes in working form, but when these genes do not work, we are at increased risk for developing cancer?
GC: Yes, that’s correct. Mutations in the BRCA1/2 genes lead to an increased risk for cancer. However, it is important to remember that even if you have a mutation in the BRCA1 or BRCA2 gene, you may or may not develop cancer depending on other factors.

Sarah: By how much is the risk for cancers increased if you have a mutation in the BRCA1 or BRCA2 genes?

GC: For breast cancer, the risk is significantly increased compared to the average woman. Also, women who carry a BRCA mutation, and who have had breast cancer in the past, are at increased risk for a second breast cancer. The risk for ovarian cancer is also significantly increased compared to the average woman. Cancer risk for males with a mutation is also higher (but not as high as the risk for females) and includes male breast cancer and prostate cancer. The risk for pancreatic cancer may be increased in both men and women.

Sarah: What happens if I test positive for a BRCA mutation?

GC: If you test positive, there are medical options ranging from screening to medications to risk-reducing surgery. We will work with you and your physicians to determine which of these options are right for you. These decisions are personal, because everyone handles risk differently. If you choose to have genetic testing, we will discuss your options in detail based on your test result.

Sarah: Well, all this information may explain why I got breast cancer as well as explaining the other cancers in the family. What could this mean for my children?

GC: If you test positive for a BRCA mutation, then we have identified the cause for your cancer and the cancer in the family. Each of your children would have a 50% risk for inheriting the same mutation found in you. But it is important to remember that genetic testing is not recommended for children. We don’t recommend that people have genetic testing before the age of 25, and your children would not be at increased risk for cancer while they are still young. If they decide to pursue genetic testing as adults, we recommend that they have the same pre-test counseling process that you have gone through so they understand the implications. We have learned a great deal about how these genes cause breast and ovarian cancer, but we continue to learn more about them every day. Therefore, as science advances, medical recommendations for people with BRCA mutations may improve in the future.

Sarah: So if I test positive for a mutation, my children will have the opportunity to be proactive and to be followed more closely.

GC: Exactly. Hopefully, they won’t have to face cancer the way your generation and your parents’ generation did. They may be able to detect cancer early or even prevent it.

Sarah: Can you tell me more about the genetic testing process itself?
GC: Sure. Ideally, the first person in a family tested for a BRCA1 or BRCA2 mutation should be someone who has already had breast or ovarian cancer. Starting with this family member gives us better information because a family member with breast cancer is most likely to have the mutation. So in your family, you are the best person for genetic testing. John, in your family, you are the best person to test since there are no family members with cancer still living.

Sarah: Are the test results always accurate?

GC: Yes, this testing is highly accurate. However, it is possible that testing may not detect a mutation that is present in these genes. Also, there may be other genes that the testing may not identify, and these genes may also be responsible for the cancers in the family. There is new technology that can test for many breast cancer genes at the same time, in addition to BRCA1/2. However, both of your families are most suggestive of a BRCA1/2 mutation. Therefore, we will start testing there. Should that testing be negative, we may consider multi-gene testing for hereditary breast cancer.

Sarah: What is the cost of the test?

GC: About $2,000, but most insurance companies cover some or all of the cost.

Sarah: Will my health insurance coverage be affected if I test positive for a mutation?

GC: Some people are worried about health insurance discrimination. However, there are federal and state laws that protect genetic information and prevent health insurance discrimination. These laws also keep employers from discriminating based on genetic test results.

Sarah: Thanks very much for the information. I think I will go forward with genetic testing.

John: I didn’t think I would need to get tested, but for my future risk of cancer and more importantly, for my children’s sake, I will also like to go ahead with testing.
Sample Patient Letter

Instructions: Write a letter to the William's family from the point of view of a genetic counselor. Suggest whether or not you believe they should proceed with genetic testing. Make sure to address all topics listed below.

Dear Mr. & Mrs. Williams,

Introduction
- State the purpose of the letter. Recommend the William's family share this letter with their family.
- Describe breast cancer and the factors that may cause it (environment, diet, risk factors).
- Explain the importance of family history and breast cancer susceptibility genes (BRCA1 & 2).
- State what percentage of all cancer is due to cancer susceptibility gene.
- Describe what factors suggest a breast cancer mutation in a family (age, types of cancer, men with breast cancer).

Patient's Medical and Family History
- Describe patient's medical history.
- Review pedigree and discuss family history of breast cancer.
- Summarize if patient's family history suggests a gene mutation and explain your reasoning.

Genetic Testing Recommendations
- Explain how the patient can get a genetic test and the costs.
- Explain the implications of test results (what a positive/negative test can mean).
- Discuss genetic discrimination and federal/state laws that protect against it.

Conclusion
- Determine if you believe/do not believe the William's should get tested.
- Summarize why the patient should/should not get tested.

Sincerely,
(Your name)
Sample Patient Letter

Dear Mr. & Mrs. Williams,

Introduction
This letter summarizes our genetic counseling session. We suggest you save this letter as a part of your medical records. We also encourage you to share this letter with your family and doctors.

Breast cancer is a common disease. Many factors, such as age, family history, hormones, and other factors such as diet and environmental exposures affect risk. Researchers do not know exactly how these factors interact to cause cancer. Typically, cancer is caused by a buildup of genetic mutations that interact with the environment over a lifetime.

Family history is a risk factor for breast cancer. Approximately 5–10% of all cancers are due to a cancer susceptibility gene, such as BRCA1 and BRCA2, which may increase the risk for breast and ovarian cancer. A family may have a mutated BRCA1 or BRCA2 gene if many people in different generations have breast and ovarian cancer, cancer is diagnosed at younger ages and men have breast cancer.

Medical and Family History
Based on your personal and family history, you may/may not be a good candidate for genetic testing because...

Genetic Testing Recommendations
As we discussed, the test is simple. A nurse will take a small amount of blood from your arm using a needle. The blood sample will then go to a lab to be analyzed. The test costs about $2,000. Most insurance companies will cover some or all of the cost.

A positive result does not mean you will get cancer. A negative result does not mean there is no genetic basis for your cancer. There may be other mutations that have not been discovered yet.

We also talked about genetic discrimination. There are federal and state laws that protect genetic information and prevent discrimination.

Conclusion
After consideration, you indicated you are/are not interested in genetic testing.

Sincerely,

(Your name)
Gel Electrophoresis Simulation Worksheet

Page 1 of 3

Name: ____________________________ Date: _________

Instructions: Go to: http://learn.genetics.utah.edu/content/labs/gel/ and complete the Gel Electrophoresis Virtual Lab Activity. Answer the questions below.

1. Molecules of DNA can be separated based on their _____________ with electrophoresis.

2. Besides DNA, what other molecule can be separated with electrophoresis?

3. Describe the structure of the gel used in electrophoresis.

4. Why does DNA move through the gel?

5. What size strands move furthest from the wells at the top of the gel?

6. List the SIX things you need to make an electrophoresis gel.
   1)
   2)
   3)
   4)
   5)
   6)

7. What is agarose made from?
Gel Electrophoresis Simulation Worksheet

8. What is the buffer solution made from?

9. Why do researchers use buffer solution?

10. What must be done with the agarose/buffer mixture?

11. What do you do with the comb?

12. Explain the purpose of the comb.

13. What two things do you need to set up the electrophoresis box?

14. Besides conducting electricity, what is another job of the buffer solution?

15. To load the samples, in addition to the box with the gel, what 4 things do you need?
   1)
   2)
   3)
   4)
Gel Electrophoresis Simulation Worksheet

Page 3 of 3

16. What are two characteristics of the loading buffer that are helpful (and why are they helpful)?
   
   **Characteristic** | **Why helpful**
   --- | ---
   1) | 
   2) | 

17. Explain the purpose of the DNA standard.

18. The red end of the power supply generates a ____________ charge and the black end generates a ____________ charge.

19. DNA has a (positive/negative) charge so it will move to the (red positive/black negative) electrode which must be plugged in at the end (closest to/furthest from) the wells.

20. When looking in the electrophoresis box, how will you know that the current is actually running?

21. Explain the purpose of ethidium bromide.

22. What type of light do you need?

23. Where does ethidium bromide attach to DNA molecules?

24. Why must you wear gloves when working with ethidium bromide?

25. How long were each of the DNA fragments in your experiment?
   
   a. _______________ bp
   b. _______________ bp
   c. _______________ bp
Gel Electrophoresis Simulation Worksheet

Answers

Page 1 of 3

Instructions: Go to: http://learn.genetics.utah.edu/content/labs/gel/ and complete the Gel Electrophoresis Virtual Lab Activity. Answer the questions below.

1. Molecules of DNA can be separated based on their size with electrophoresis.

2. Besides DNA, what other molecule can be separated with electrophoresis?
   
   Proteins

3. Describe the structure of the gel used in electrophoresis.
   
   Spongy, with many tiny holes. Similar to gelatin.

4. Why does DNA move through the gel?
   
   DNA moves through the gel because of an electric current. The negatively charged DNA moves toward the positive end of the gel.

5. What size strands move furthest from the wells at the top of the gel?
   
   Small

6. List the SIX things you need to make an electrophoresis gel.
   
   1) Agar
   2) Buffer solution
   3) Flask
   4) Gel comb
   5) Gel mold
   6) Microwave

7. What is agarose made from?
   
   Seaweed
Gel Electrophoresis Simulation Worksheet
Answers

8. What is the buffer solution made from?
   *Salt water mixture.*

9. Why do researchers use buffer solution?
   *To conduct electricity.*

10. What must be done with the agarose/buffer mixture?
    *It is heated and poured in the gel mold.*

11. What do you do with the comb?
    *Place it into the gel.*

12. Explain the purpose of the comb.
    *To create wells so samples can be entered.*

13. What two things do you need to set up the electrophoresis box?
    *Gel and Buffer solution.*

14. Besides conducting electricity, what is another job of the buffer solution?
    *To keep the gel from drying out.*

15. To load the samples, in addition to the box with the gel, what 4 things do you need?
    1) *Loading buffer*
    2) *DNA sample*
    3) *DNA size standard*
    4) *Pipette*
Gel Electrophoresis Simulation Worksheet
Answers

Page 3 of 3

16. What are two characteristics of the loading buffer that are helpful (and why are they helpful)?

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Why helpful</th>
</tr>
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<tbody>
<tr>
<td>1) Contains dye</td>
<td>Makes the sample easy to see when loading</td>
</tr>
<tr>
<td>2) Goopy (thick)</td>
<td>Thickens DNA so it stay in wells</td>
</tr>
</tbody>
</table>

17. Explain the purpose of the DNA standard.
To serve as a size reference.

18. The red end of the power supply generates a positive charge and the black end generates a negative charge.

19. DNA has a negative charge so it will move to the red positive electrode which must be plugged in at the end furthest from the wells.

20. When looking in the electrophoresis box, how will you know that the current is actually running?
You can see tiny air bubbles coming out of the electrodes.

21. Explain the purpose of ethidium bromide.
It stains DNA by binding to it.

22. What type of light do you need?
Florescent.

23. Where does ethidium bromide attach to DNA molecules?
Between the rungs on the DNA ladder.

24. Why must you wear gloves when working with ethidium bromide?
It can damage your DNA.

25. How long were each of the DNA fragments in your experiment?
   a. 6,000 bp
   b. 3,500 bp
   c. 1,500 bp
CONFIDENTIAL

BRCA1-BRCA2 Gene Sequence Analysis Result

<table>
<thead>
<tr>
<th>Patient</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Name:</td>
<td>Williams, John</td>
</tr>
<tr>
<td>Date of Birth:</td>
<td>August 14, 1954</td>
</tr>
<tr>
<td>Patient ID:</td>
<td>B1010JK</td>
</tr>
<tr>
<td>Gender:</td>
<td>Male</td>
</tr>
<tr>
<td>Specimen:</td>
<td>Blood</td>
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</table>

<table>
<thead>
<tr>
<th>Test Result</th>
<th>Specific Gene Variant</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gene Analyzed</td>
<td>Specific Gene Variant</td>
</tr>
<tr>
<td>BRCA1</td>
<td>943ins10</td>
</tr>
<tr>
<td>BRCA2</td>
<td>None Detected</td>
</tr>
</tbody>
</table>

Interpretation

POSITIVE FOR A DELETERIOUS MUTATION

The results of this analysis are consistent with the germline BRCA1 frameshift mutation 943ins10, resulting in a stop codon at amino acid position 289 of the BRCA1 protein. Although the exact risk of breast and ovarian cancer conferred by this specific mutation has not been determined, studies of this type of mutation in high-risk families indicate that deleterious mutations in BRCA1 may confer as much as an >80% risk of breast cancer by age 70 in women (Am. J. Hum. Genet. 62: 676-689, 1998). Mutations in BRCA1 have been reported to confer up to a 1.2% risk of male breast cancer by age 70 (J Natl Cancer Ins 99: 1811-4, 2007), as well as increased (albeit low) risks of some other cancers, such as prostate cancer. The implications of BRCA1 mutations for the medical management of men, however, have not yet been established. Each first degree relative of this individual has a one-in-two chance of having this mutation. Family members can be tested for this specific mutation with a single site analysis.
CONFIDENTIAL

BRCA1-BRCA2 Gene Sequence Analysis Result

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<thead>
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<tr>
<td>BRCA1</td>
</tr>
<tr>
<td>BRCA2</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Interpretation</th>
</tr>
</thead>
<tbody>
<tr>
<td>NEGATIVE FOR A DELETEROUS MUTATION</td>
</tr>
</tbody>
</table>

No deleterious mutation was found in BRCA1 or BRCA2 in this individual. This test is designed to identify mutations in 22 exons and approximately 750 adjacent intronic base pairs of BRCA1 as well as 26 exons and approximately 950 adjacent intronic base pairs of BRCA2 (a total of over 17,600 base pairs analyzed). There are other, uncommon genetic abnormalities in BRCA1 and BRCA2 that this test will not detect. This result, however, rules out the majority of abnormalities believed to be responsible for hereditary susceptibility to breast and ovarian cancer (Ford D et al., Am J Human Genetics 62: 676-689, 1998). If this individual has never had breast or ovarian cancer, it is recommended that testing an affected relative be considered to help clarify the clinical significance of this individual's negative test result.
Life-Size Gel Electrophoresis Activity Instructions

Note: The activity requires a large space, such as an open room, gym or outside area to represent the “gel.” The area should accommodate 4 rows or “lanes” that students will navigate through. If you plan to conduct the activity in a classroom, use desks or chairs to create lanes. If you plan to conduct the activity outside, mark off lanes with chalk, yarn or other natural markers, such as trees or rocks.

1. Tell students they will be doing an activity to explore gel electrophoresis. Select ten students to conduct the activity. Other students should observe. Depending on the size of your class, you can have different groups of ten students rotate so all students can participate in the activity. Assign or have the ten students select the nitrogenous base (ATGC) they will be (the actual bases selected do not matter). Use nametags or different colored stickers to represent the different bases. Place students into groups or “fragments” of DNA.

2. Divide the ten students into the following groups:

   Fragment 1: 1 student
   Fragment 2: 2 students
   Fragment 3: 3 students
   Fragment 4: 4 students

   The students within Fragments 2–4 should be connected (all students in Fragment 2 connected, etc.). Students can hold hands or hold pieces of yarn to be connected.

3. Designate one end of the room as the Negative end of the gel and the other as the Positive end. Have each Fragment line up in a lane at the Negative end; only one group per lane (Fragments do not have to be in any particular order). Tell the class the DNA is now loaded into the gel.

   Ask students what will happen in gel electrophoresis when the electrical current is turned on. Students should note that the DNA fragments will move across the gel toward the Positive end of the gel.

4. Tell students you will call, “Go!” or “Start!” to represent the electrical current being switched on. Each fragment should quickly navigate through their lane. Tell students you will call “Stop!” to represent the electrical current being switched off. Groups must freeze when you call stop.

5. Call “Stop” when the first Fragment reaches the end of their lane. All groups should stop moving and remain where they are. Ask the class to look at every Fragment’s position and describe what they see. Students should note that due to the structure of the gel, smaller fragments are able to travel further and faster than the larger fragments.

6. Students can summarize what they learned via writing or drawing for homework. Students can also write how they would conduct the activity to relate it to the William’s family test results.
Lesson 3 Quiz

1. Transcription and translation of a gene composed of 30 nucleotides would form a protein containing no more than ___ amino acids.
   a. 3
   b. 10
   c. 60
   d. 90

2. Describe transcription and translation.

3. Where does the mutation 187delAG start in the BRCA1 DNA sequence and what effect does it have on the reading frame?

4. Explain the roles of a genetic counselor.

5. Emily has tested positive for a BRCA mutation. Explain how that affects her risk of developing breast cancer.

6. Explain how gel electrophoresis separates DNA fragments.

7. During gel electrophoresis, what size strands of DNA move furthest from the wells at the top of the gel?

8. When running a gel to analyze DNA, why is it important to run DNA standards in addition to the samples?
Lesson 3 Quiz Answers

1. Transcription and translation of a gene composed of 30 nucleotides would form a protein containing no more than ___ amino acids.
   a. 3
   b. 10
   c. 60
   d. 90

Correct Answer: b. 10

2. Describe transcription and translation.

Model Answer: Transcription is the process of converting DNA nucleotide sequence information into RNA sequence information. Both nucleic acid sequences use similar language, and the information is simply transcribed, or copied, from one molecule to the other. Translation is the production of proteins by decoding mRNA produced in transcription. In translation, messenger RNA (mRNA) is decoded to produce a specific polypeptide according to the rules specified by the genetic code.

3. Where does the mutation 187delAG start in the BRCA1 DNA sequence and what effect does it have on the reading frame?

Model Answer: 187delAG is a BRCA1 mutation that starts at nucleotide 187 and deletes nucleotides A and G. This is a deletion mutation that shifts the reading frame of the DNA sequence.

4. Explain the roles of a genetic counselor.

Model Answer: Genetic counselors are health professionals trained in areas of medical genetics and counseling. They discuss genetic testing with patients and help patients make decisions that are right for them. If a patient decides to get a genetic test, the genetic counselor explains the test results with the patient and their family, as well as offers support.

5. Emily has tested positive for a BRCA mutation. Explain how that affects her risk of developing breast cancer.

Correct Answer: BRCA1 and BRCA2 are tumor suppressor genes. That means that when they are working properly, they help prevent cancer by controlling cellular division. However, in an individual with a mutation, one of the copies of the gene is not functioning properly. This increases the risk of uncontrolled cell growth. Therefore, Emily has a higher risk of developing breast cancer than a person who does not have a BRCA mutation.
6. Explain how gel electrophoresis separates DNA fragments.

**Model Answer:** Gel electrophoresis is a technique used for the separation of DNA, RNA, or protein molecules using an electric current applied to a gel matrix. Gel electrophoresis works because DNA is negatively charged; it moves toward the positive electrode. The DNA fragments that are shortest will travel farthest, while the longer fragments will remain closest to the origin.

7. During gel electrophoresis, what size strands of DNA move furthest from the wells at the top of the gel?

**Correct Answer:** The smallest strands move the furthest.

8. When running a gel to analyze DNA, why is it important to run DNA standards in addition to the samples?

**Model Answer:** DNA standards are used to ensure that the gel electrophoresis was performed properly and the results are accurate. If the DNA standard does not produce the expected bands, the results of the gel electrophoresis may not be correct. DNA standards are also used to determine the lengths or identities of sample fragments based on similar migration distances.