

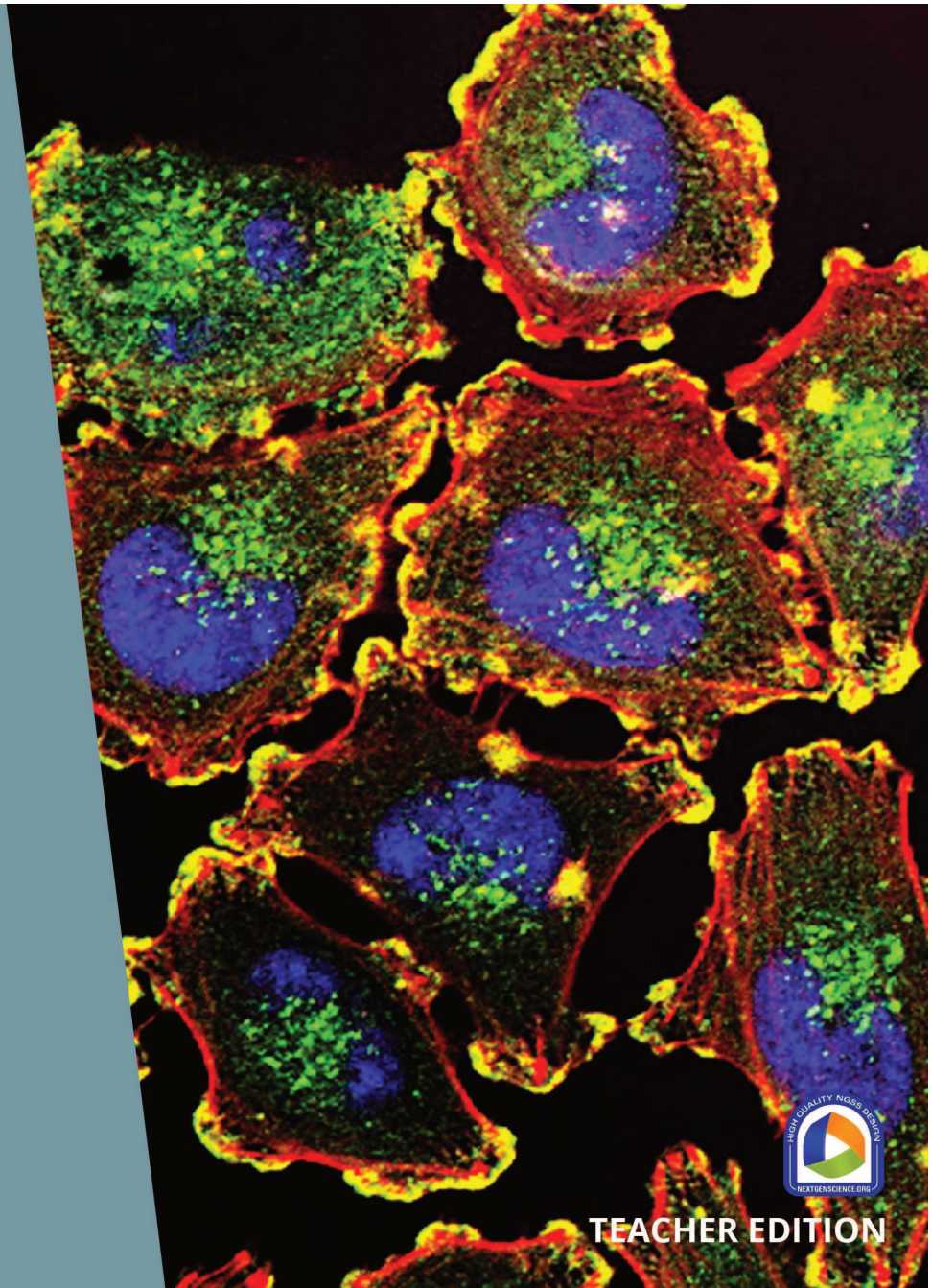
BIOLOGY

Inheritance &
Variation of Traits

**Who gets cancer
and why?
What can we do
about it?**



HIGH SCHOOL SCIENCE



TEACHER EDITION

Who gets cancer and why? What can we do about it?

Inheritance & Variation of Traits: Cancer

OpenSciEd Unit B.3





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The development of this material was supported by the Bill & Melinda Gates Foundation, Carnegie Corporation of New York, Walton Family Foundation, and William and Flora Hewlett Foundation.

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UNIT OVERVIEW

Who gets cancer and why? What can we do about it?

This unit is designed to deepen student understanding of inheritance and variation of traits through an exploration of cancer as a phenomenon. In the first lesson set, students explore the genetic basis of cancer by investigating what cancer is and how mutations that can increase risk for cancer occur. While there are many genes implicated in cancer, the unit focuses on p53, a tumor suppressor gene that is involved in many different cancers. In Lesson Set 2, students investigate cancer caused by mutations that occur throughout our lifetimes, inherited mutations, and how the environment can cause mutations. In the third lesson set, students investigate additional factors that explain differences across the US in both instances of cancer and mortality, access and feasibility of treatment options, and explore the role of health navigator as a way to advocate for and help support friends and family that may be experiencing cancer.

Throughout the unit students will do the following:

- Develop a model and ask questions to explain and predict the causal factors of cancer and the possible protective effects from p53.
- Construct an explanation based on evidence about how mutations occur and the role of p53 in their repair.
- Use a model to illustrate the relationships between DNA structure and the structure and function of p53.
- Use a computer simulation as evidence to develop and revise a model that predicts how the rate of cell division affects the likelihood of cancer.
- Develop and use multiple models to explain how the inheritance of p53 alleles and other gene alleles can cause cancer in multiple generations of a family through new combinations of alleles.
- 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.
- Obtain, evaluate, and communicate information about current treatment options, using criteria related to human systems, and predict outcomes for individuals.
- Propose a solution about how to use health navigators in cancer prevention and treatment that considers a wide range of constraints within the context of the healthcare system.

Building Toward NGSS Performance Expectations

HS-ETS1-3:

Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, reliability, and aesthetics, as well as possible social, cultural, and environmental impacts.

HS-LS1-1:

Construct an explanation based on evidence for how the structure of DNA determines the structure of proteins, which carry out the essential functions of life through systems of specialized cells

HS-LS1-2:

Develop and use a model to illustrate the hierarchical organization of interacting systems that provide specific functions within multicellular organisms

HS-LS1-4:

Use a model to illustrate the role of cellular division (mitosis) and differentiation in producing and maintaining complex organisms.

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

HS-LS3-3:

Apply concepts of statistics and probability to explain the variation and distribution of expressed traits in a population.

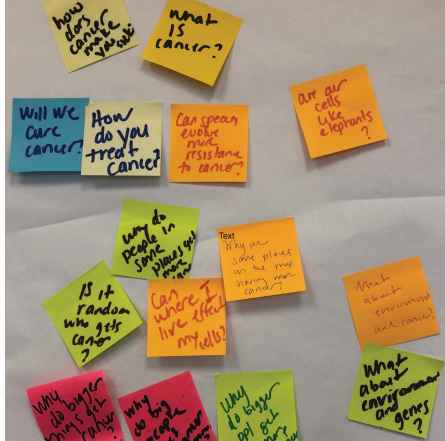
UNIT STORYLINE

Unit Question: Who gets cancer and why? What can we do about it?

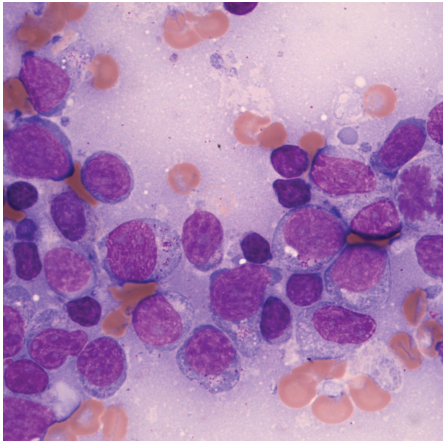
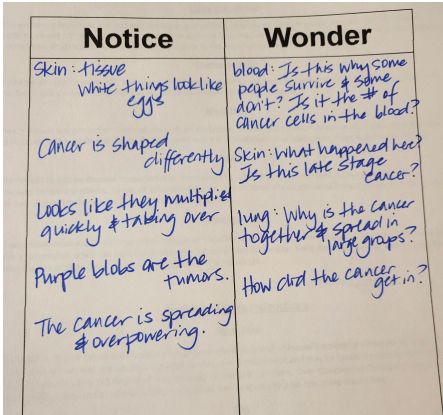
How students will engage with each of the phenomena



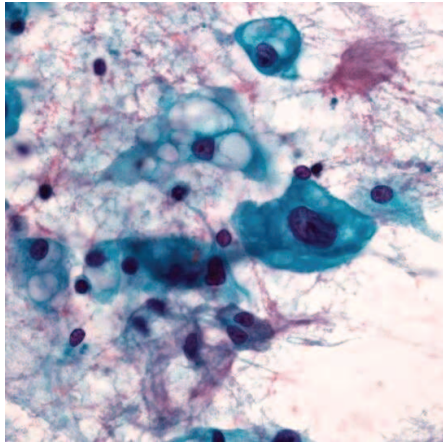
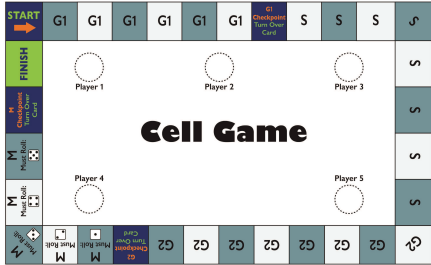
Lesson Set 1: What is cancer?

Lesson Question	Phenomena or Design Problem	What we do and figure out	How we represent it
LESSON 1 Lesson Set 1 3 days Who gets cancer and why? Anchoring Phenomenon 	 <i>Humans and nonhuman animals get cancer at different rates due to a number of factors.</i>	We explore cancer data and factors that might affect who gets cancer, such as geographic location and genetics. We figure out: • Cancer affects all of us through our relationships. • There are differences between the most commonly diagnosed and most commonly fatal cancers. • Cancer incidence differs by geographic location. • For humans, taller and older individuals have higher rates of cancer. • Scientists expected this to be true for other mammals, but it is not. • There is a gene called p53 that protects some animals from cancer.	

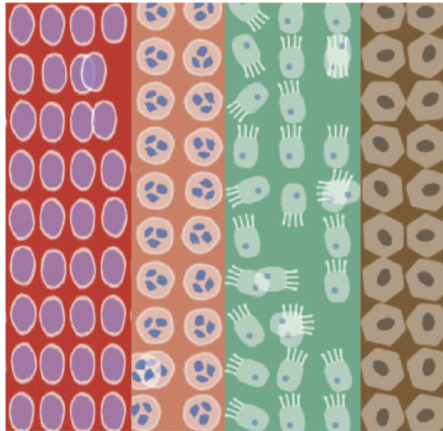
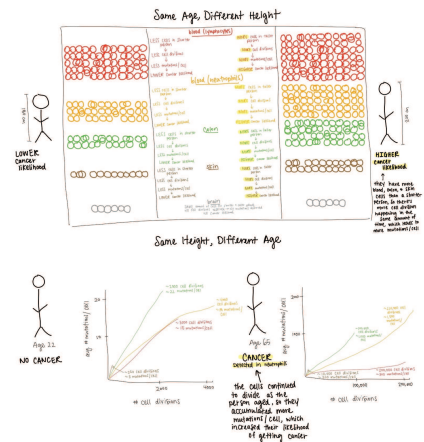
↓ Navigation to Next Lesson: We decide we need to know more about what cancer is and how cancer cells are different from non-cancer cells.

Lesson Question	Phenomena or Design Problem	What we do and figure out	How we represent it
LESSON 2 Lesson Set 1 2 days What is cancer? Investigation 	 <i>Cancer cells look different from non-cancer cells.</i>	We look at pictures of cancer and non-cancer cells and read about what happens when cancer cells stick together. We figure out: • How cancer cells look different from non-cancer cells. • Cancer cells have irregular shapes and tend to stick together. • When cancer cells stick together, they can form tumors, which can invade tissues, disrupt system function, and make us sick.	 <i>Illustrations created by OpenSciEd in BioRender</i>

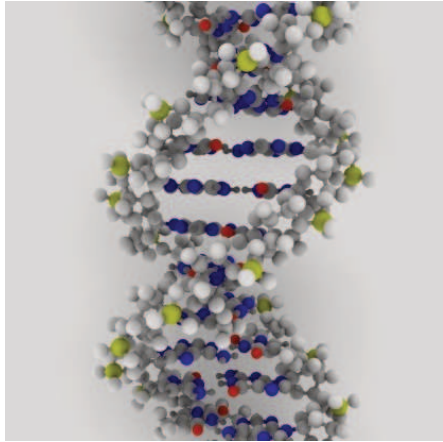
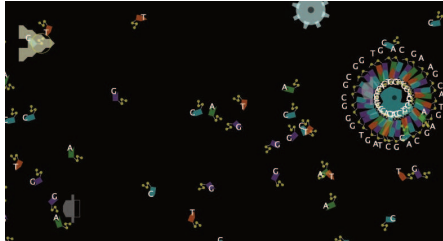
↓ **Navigation to Next Lesson:** We figure out that cancer cells are different from non-cancer cells in important ways and that they can disrupt system function and make us sick. We wonder how non-cancer cells become cancer cells.

Lesson Question	Phenomena or Design Problem	What we do and figure out	How we represent it
LESSON 3 Lesson Set 1 3 days How do non-cancer cells become cancer cells? Investigation 	 <i>The cell cycle has several steps with checkpoints and controls that govern whether cell division occurs. In cancer, these checkpoints and controls work differently.</i>	We use a Cell Game and scientific model to investigate how non-cancer cells can make cancer cells. We figure out: - Cell division happens in all cells through a series of phases, ending with mitosis when one cell forms two new cells. - The formation of new cells is typically regulated by p53, which provides feedback at specific checkpoints to ensure that a cell does not proceed until sufficient resources are acquired. - When p53 fails to regulate cell division, non-cancer cells may form cancer cells. - Cancer cells differ from non-cancer cells in that there are differences in their chromosomes.	

⚡ **Navigation to Next Lesson:** We figure out that cell division is regulated by p53 through a series of checkpoints and that sometimes cells can pass the checkpoints without everything they need and have differences in their chromosomes. We wonder how they got those differences.

Lesson Question	Phenomena or Design Problem	What we do and figure out	How we represent it
LESSON 4 Lesson Set 1 1 day Why are some kinds of cancer more common than others in older and taller people? Investigation 	 <i>Cell division happens at different rates, which affects cancer rates, especially in older and taller people.</i>	We use a simulation to investigate the relationship between cell division rates and the likelihood of cancer. We model these relationships for different cell types and how they impact older and taller people. We figure out: • Some cell types divide more than others. • The longer you live, the more your cells divide. • The taller you are, the more your cells divide. • The more divisions there are, the more chances for mutations to happen. • The more mutations a person has, the higher their likelihood of getting cancer.	

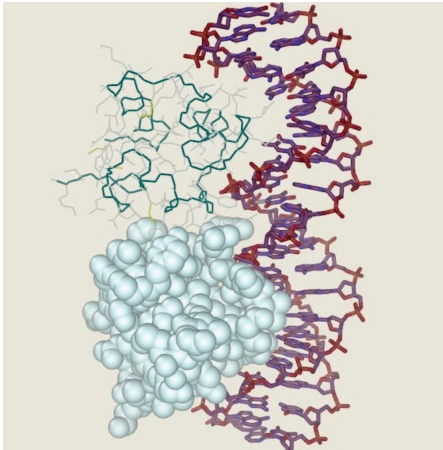
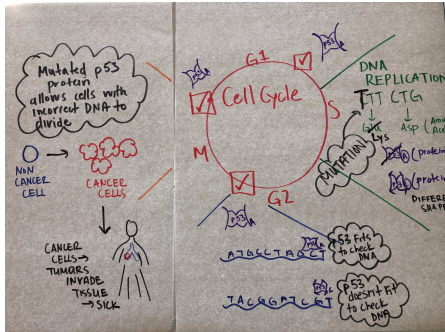
↓ **Navigation to Next Lesson:** We figure out that different types of cells divide at different rates and that the cell division rate is directly related to the number of mutations present in cells, which leads to more or less likelihood of cancer. But we know that there are other ways that people get cancer. We wonder why cancer seems to run in some families.

LESSON 5 Lesson Set 1 2 days How do cancer cells end up with differences in their chromosomes and what is the role of p53 in preventing the differences? Investigation 	 <i>DNA replication can result in differences in DNA, which can lead to cancer.</i>	We interact with a computer simulation and a reading to understand how DNA replication happens and where the mutations that cause cancer come from. We figure out: • Genes are regions of DNA containing information that determines traits. • DNA is organized in chromosomes. • During DNA replication, mutations can occur. • These mutations can change chromosomes. • p53 can correct those errors, but it does not always work. • Non-cancer cells have identical chromosomes, but the chromosomes in cancer cells are different.	 <i>Wilensky, U. 1999. NetLogo. http://ccl.northwestern.edu/netlogo/. Center for Connected Learning and Computer-Based Modeling, Northwestern University, Evanston, IL.</i>
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↓ **Navigation to Next Lesson:** We will investigate why there are different versions of p53 and how we get them.

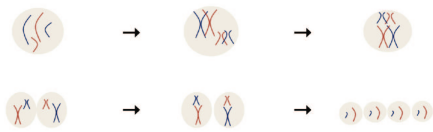
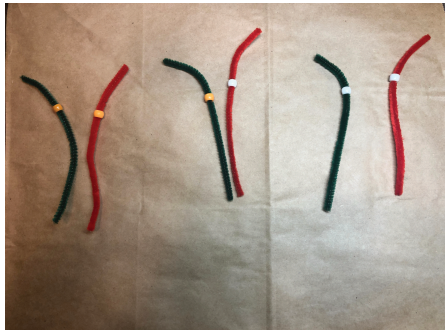
Lesson Question	Phenomena or Design Problem	What we do and figure out	How we represent it
LESSON 6 Lesson Set 1 2 days How do we make p53, and why is it different sometimes? Investigation 	 <i>DNA codes for proteins, and protein shape affects function.</i>	We work with a kinesthetic model and a reading to make sense of gene expression. We figure out: • DNA is organized into genes in chromosomes. • Each gene codes for a protein through a process called gene expression. • Mutations in genes can lead to different structures and functions in proteins. • If the code in DNA is different, the sequence of amino acids and the protein may be different. • Additional mutations can occur during gene expression. • Not all DNA codes for proteins.	

↓ **Navigation to Next Lesson:** We figured out how gene expression works and pause to acknowledge how many ideas we have worked with in Lesson Set 1.

Lesson Question	Phenomena or Design Problem	What we do and figure out	How we represent it
LESSON 7 Lesson Set 1 1 day What is the genetic basis of cancer? Putting Pieces Together 	 <i>Mutations in the p53 gene can lead to proteins that function differently, which eventually can lead to cancer.</i>	We develop our class consensus model to connect ideas from Lesson Set 1. We return to our Driving Question Board to update our questions and prioritize next steps. We figure out: - Cells are part of a hierarchical organization system of organisms' tissues, organs, and systems. - When cancer cells stick together, they can form tumors that can invade tissues, disrupt systems, and make us sick. - Cancer cells form when p53 is not working. - Cell division happens in all cells through a series of phases, ending with mitosis when one cell forms two new cells with identical chromosomes. - Cancer cells have differences in their chromosomes. - Chromosomes are made of DNA copied during DNA replication when mutations occur. - p53 can correct those errors, but not all versions of p53 work the same. - Each gene codes for a protein through a process called gene expression. - p53 is a protein coded for by a gene. - Mutations in genes can lead to different structures and functions in proteins.	

↓ **Navigation to Next Lesson:** We wonder about how being taller and older increases the likelihood that you will get cancer.

Lesson Set 2: What are the causes of cancer?

Lesson Question	Phenomena or Design Problem	What we do and figure out	How we represent it
LESSON 8 Lesson Set 2 2 days Why do some cancers appear to run in families? Investigation 	 <i>p53 mutations can be inherited in families.</i>	We watch videos about two young individuals, Lakita and Lauren, who survived multiple cancers. We model Lakita's family in a pedigree and use a second model to try to understand more about Lauren's family. We figure out how mutations that increase the risk of cancer can be inherited in families. We decide to investigate mutations due to the environment next. We figure out: • People with Li-Fraumeni syndrome have an increased risk of developing cancer because of an inherited p53 allele. • Pedigrees show the occurrence of traits in families and can help model inheritance. • During meiosis, chromosome pairs can swap regions of DNA in a process called <i>crossing over</i>. • Crossing over can result in new combinations of alleles along a chromosome and thus more genetic variation.	

↓ **Navigation to Next Lesson:** We figured out some cancers can be caused by inherited mutations. We wonder how the environment leads to other cancers.

LESSON 9
Lesson Set 2

3 days

How do genes interact with the environment to affect who gets cancer?

Investigation

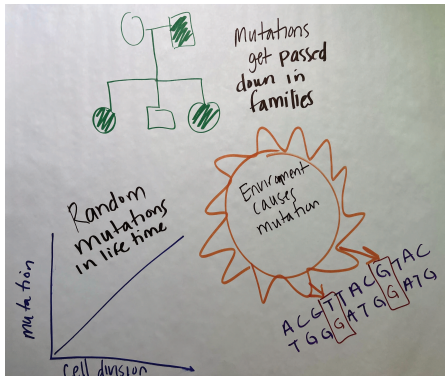
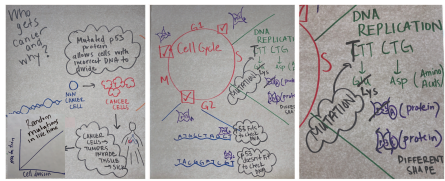
UV radiation affects the structure of DNA and the function of proteins.

We read about the mechanism of UV radiation causing mutations in our cells and about a protective mechanism in our skin. We investigate scientific data related to incidence of skin cancer and design and carry out our own investigations. We figure out:

- UV radiation can cause mutations in DNA.
- Those mutations can cause changes in protein structure and function and lead to cancer.
- Skin has a protective mechanism against damaging UV radiation that is governed by a protein called melanin.
- Variations in exposure to UV radiation and variations in melanin production lead to different levels of risk in the human population.

Group	Drawing of Petri Dish	Observations
1		Some growth all over the dish. A medium amount compared to others.
2		Extensive all over the dish. A high amount compared to others.

↓ **Navigation to Next Lesson:** We figure out how environmental factors such as UV radiation can cause mutations that lead to cancer. We decide to figure out more about why people in different groups and places get cancer at different rates.

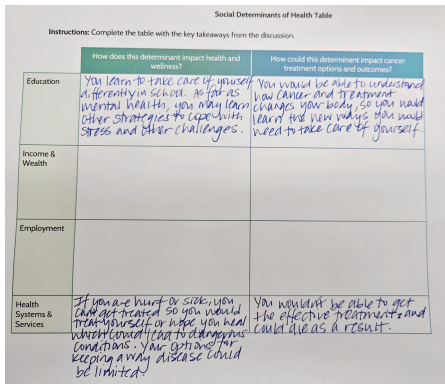
Lesson Question	Phenomena or Design Problem	What we do and figure out	How we represent it
LESSON 10 Lesson Set 2 2 days Who gets cancer and why? Putting Pieces Together 	 <i>Mutations can be inherited, come from exposure to the environment, or can occur randomly to affect a person's cancer risk.</i>	We develop our consensus model that puts together all of the ideas that we figured out about random mutations, inheritance, and environmental factors. We acknowledge that we have made a lot of progress since the last consensus model and pause to put these new ideas together. We decide that we need to figure out if our ideas would hold up in a different context and complete a transfer task to continue to make progress on figuring out who gets cancer and why. We figure out: • The more your cells divide, the greater the chance of accumulating mutations. • Li-Fraumeni Syndrome is an inherited condition. • Meiosis is a process where a cell undergoes two divisions to produce gametes. • During meiosis, chromosome pairs can swap regions of DNA in a process called crossing over. • UV radiation and other environmental factors can cause mutations in DNA.	

↓ Navigation to Next Lesson: We wonder how cancer is treated.

Lesson Set 3: What can we do about cancer?

Lesson Question	Phenomena or Design Problem	What we do and figure out	How we represent it
LESSON 11 Lesson Set 3 2 days How do cancer treatments work? Investigation 	 <i>Cancer treatment options affect cancer and non-cancer cells.</i>	We consider what we already know about cancer treatment options and hear about different treatments that Lakita and Lauren experienced. We explore how different treatments work and revise our Cell Game model to predict the relationship between treatment and the cell cycle. We wonder about access to treatment in different places. We figure out: • Chemotherapy, radiation, surgery, and immunotherapy are common cancer treatments. • These treatments affect cancer cells and non-cancer cells and can disrupt body systems. • There are a number of constraints that affect decisions about cancer treatment.	

↓ Navigation to Next Lesson: We figured out how cancer treatments work, and we wonder why not everyone gets the same treatments.

LESSON 12 Lesson Set 3 3 days What can we do to support people in our communities who have cancer? Investigation 	 <i>Social determinants of health are additional factors that affect cancer incidence and mortality.</i>	We decide to further investigate cancer incidence and mortality data and conclude that both are affected by geography and access to health services. We learn about social determinants of health and the impact they have on access to treatment. We hear about advocates called health navigators who can support friends and family in cancer treatment and develop an interview protocol as a resource. We figure out: • There were differences in national cancer incidence and mortality data. • Social determinants impact health and wellness, and we may not have control over them. • There is specific evidence about how distance from cancer specialists and changes in health insurance impact health outcomes. • Even as students, there are ways that we can be a solution in co-constructing equitable and effective treatment plans.	
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↓ Navigation to Next Lesson: This is the last lesson in the unit.

LESSONS 1-12

26 days total

TEACHER BACKGROUND KNOWLEDGE

Lab Safety Requirements for Science Investigations

It is important to adopt and follow appropriate safety practices when conducting hands-on science investigations and demonstrations, whether in an instructional space (traditional laboratory or classroom) or in the field. To this end, teachers must be aware of any school or district safety policies, legal safety standards, and better professional safety practices that are applicable to the activities being undertaken.

Science safety practices in instructional spaces require engineering controls and personal protective equipment (e.g., sanitized safety goggles or safety glasses with side shields as appropriate, non-latex aprons and gloves, eyewash/shower station, fume hood, appropriate ventilation, and fire extinguishers). **Science investigations should always be directly supervised by qualified adults, who should review safety procedures annually, and also before initiating any hands-on activities or demonstrations.** Prior to each investigation, students should be reminded of the specific safety procedures they must follow. Each lesson within the OpenSciEd units includes teacher guidelines for applicable safety procedures for setting up and running an investigation, as well as disassembling, disposing of, and storing materials.

Prior to the first investigation of the year, a safety acknowledgment form for students and parents/guardians should be provided and signed. You can access a model safety acknowledgment form for high school activities here: <https://static.nsta.org/pdfs/SafetyAcknowledgmentForm-HighSchool.pdf>

Disclaimer: The safety precautions provided for each activity are based in part on use of the specifically recommended materials and instructions, as well as legal safety standards and better professional safety practices. Be aware that selecting alternative materials or procedures for these activities may affect the activity's level of safety, and is therefore at the user's own risk.

Please follow these lab safety recommendations for any science investigation:

1. Wear sanitized safety goggles (specifically, indirectly vented chemical splash goggles) or safety glasses with side shields, as appropriate, a non-latex apron, and non-latex gloves during the set-up, hands-on investigation, and take-down segments of the activity.
2. Safety goggles are required when working with liquid biological or chemical hazards (e.g., microbes, acids, bases, etc.). Safety glasses with side shields or safety goggles may be used when working with physical hazards (sharp, springs, glass, projectiles, etc.).
3. Immediately wipe up any spilled liquid (e.g., water) and/or granules on the floor, as this is a slip-and-fall hazard.
4. Follow your *Teacher Guide* for instructions on disassembling and storing materials and disposing of waste materials.
5. Secure loose clothing, remove loose jewelry, wear closed-toe shoes, and tie back long hair.
6. Wash your hands with soap and water immediately after completing the activity.
7. Never eat any food items used in a lab activity.
8. Never taste any substance or chemical in the lab.
9. Use only GFCI protected circuits when using electrical equipment, and keep away from water sources to prevent shock.
10. Use caution when working with glassware, which can shatter if dropped and cut skin.
11. Use caution when using sharp [tools/materials], which can cut or puncture skin.
12. Never pour chemicals, either used or unused, back into their original containers. Dispose of chemicals according to your teacher's instructions.
13. If you get a hazardous chemical on your clothing or have a clothing fire, use the emergency shower.
14. If you get a chemical in your eye, use an eyewash station immediately.
15. Point the test tubes, beakers, or other vessels away from yourself and other people when the vessels contain reactants or other substances.
16. When diluting acids or bases, the acid or base should be added to water and not water to the acid or base.
17. Projective trajectory zones must be well defined and free of any obstacles. No participant is to be in the zone during operation of the projectile..
18. Make sure the ventilation system meets the needs relative to removal of flammable vapors produced. Also make sure there are no active flames or sparks in the work zone.



Specific safety precautions are called out within the lesson using this icon and a call-out box.

Where does this unit fall within the OpenSciEd Scope and Sequence?

This unit is the third in the OpenSciEd High School Biology course sequence. It is designed to build on student ideas about inheritance and variation of traits from middle school. In the units that follow this one (*OpenSciEd Unit B.4: How does urbanization affect nonhuman populations, and how can we minimize harmful effects? (Urbanization Unit)* and *OpenSciEd Unit B.5: What will happen to Arctic bear populations as their environment changes?(Speciation Unit)*) students will use what they figure about inheritance and variation of traits to make sense

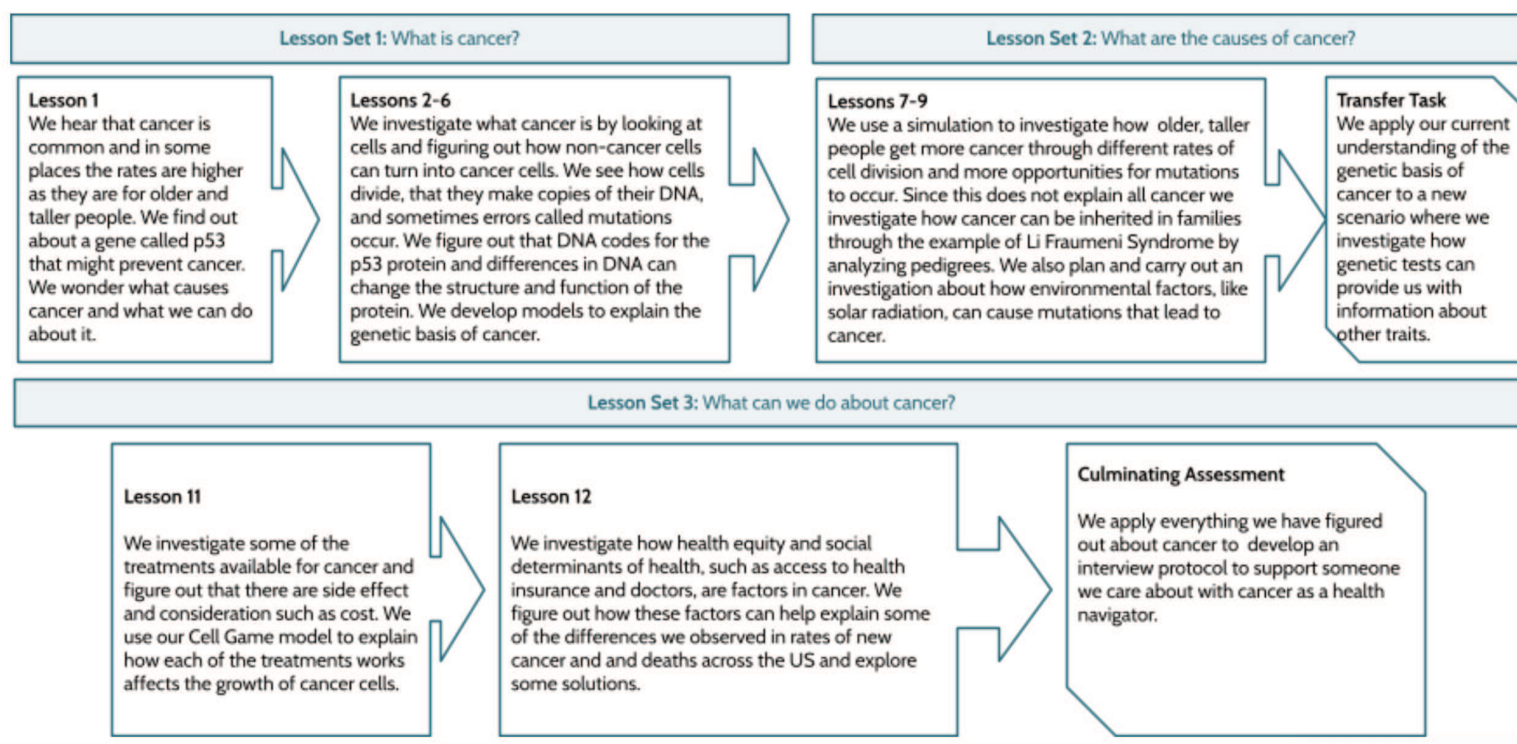
of evolution by natural selection and speciation.

What is the anchoring phenomenon and why was it chosen?

In the anchoring phenomenon, students explore cancer statistics, including rates of new cases by cancer and state. They notice some differences that are hard to explain. Then they investigate factors such as age and height and figure out that people in different demographic groups have higher and lower risk of cancer. They hear from a scientist who has studied cancer and are introduced to animal models. They read about incidence of cancer and discover that there is something called p53 that might prevent cancer in other organisms. They develop initial models and generate questions that need to be answered to fully explain it. This phenomenon was chosen as the anchor because it generated high student interest across racial and gender identities in a national survey.

How is the unit structured?

The unit is organized into three lesson sets. **Lesson Set 1** (Lessons 1-6) focuses on the genetic basis of cancer. It ends with the development of a class consensus model. **Lesson Set 2** (Lessons 7-10) helps students begin to explore the different causes of the mutations that lead to cancer, including mutations accumulated through our lifetimes, inherited mutations, and environmental mutations caused by interactions with the environment. This lesson set ends with a transfer task. **Lesson Set 3** (Lessons 11-12) helps students explore treatment for cancer and the social systems that affect healthcare outcomes. This unit culminates with a transfer task where students develop an interview protocol that they could use to support someone they care about who has cancer.



What elements of NGSS three dimensions are developed in this unit?

This unit is designed to introduce students to inheritance and variation of traits. **Developing and using models** is intentionally developed across this unit, beginning in Lesson 1, where students develop initial models to explain differences they notice in the incidence of cancer across various factors. In Lessons 2, 3, 5, 6, 7, 10, and 11, students develop and revise models to explain and/or predict the growing understanding of inheritance and the variation of traits in the context of cancer. In Lessons 3 and 8, they use multiple models to

explain their ideas about the cell cycle and inheritance.

Student models use **cause and effect** and **structure and function** to explain interactions in the system, and these concepts are **intentionally developed throughout the unit**.

The use of **asking questions and defining problems** is **intentionally developed in this unit**. In **Lessons 1, 2, and 9** students ask questions from careful observation to clarify or seek additional information. In **Lesson 9**, they ask questions that can be answered in the high school laboratory.

This unit builds toward these performance expectations:

HS-LS1-1 Construct an explanation based on evidence for how the structure of DNA determines the structure of proteins, which carry out the essential functions of life through systems of specialized cells.

HS-LS1-2 Develop and use a model to illustrate the hierarchical organization of interacting systems that provide specific functions within multicellular organisms.

HS-LS1-4 Use a model to illustrate the role of cellular division (mitosis) and differentiation in producing and maintaining complex organisms.

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.

HS-LS3-3 Apply concepts of statistics and probability to explain the variation and distribution of expressed traits in a population.

HS-ETS1-3† Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics as well as possible social, cultural, and environmental impacts.

*This performance expectation is developed across multiple units. This unit reinforces these NGSS PEs in a physics context.

†This performance expectation is developed across multiple courses. This unit reinforces or works toward these NGSS PEs that students will have previously developed in the OpenSciEd chemistry and/or biology courses.

This unit intentionally develops students' engagement in these practice elements: Asking questions and defining problems: • Ask questions that arise from careful observation of phenomena, or unexpected results, to clarify and/or seek additional information. • Ask questions that can be investigated within the scope of the school laboratory, research facilities, or field (e.g., outdoor environment) with available resources and, when appropriate, frame a hypothesis based on a model or theory. Developing and using models: • Develop, revise, and/or use a model based on evidence to illustrate and/or predict the relationships between systems or between components of a system. • Develop and/or use multiple types of models to provide mechanistic accounts and/or predict phenomena, and move flexibly between model types based on merits and limitations. The following science and engineering practices are also key to the sensemaking in this unit: Constructing Explanations and Designing Solutions: • Construct and revise an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future. • Apply scientific ideas, principles, and/or evidence to provide an explanation of phenomena and solve design problems, taking into account possible unanticipated effects. Engaging in Argument from Evidence • Make and defend a claim based on evidence about the natural world or the effectiveness of a design solution that reflects scientific knowledge and student-generated evidence. Obtaining, Evaluating, and Communicating Information • Compare, integrate, and evaluate sources of information presented in different media or formats (e.g., visually, quantitatively) as well as in words in order to address a scientific question or solve a problem.	LS1.A: Structure and Function • Systems of specialized cells within organisms help them perform the essential functions of life. • 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, which carry out most of the work of cells. • Multicellular organisms have a hierarchical structural organization, in which any one system is made up of numerous parts and is itself a component of the next level. LS1.B: Growth and Development of Organisms • In multicellular organisms, individual cells grow and then divide via a process called mitosis, thereby allowing the organism to grow. The organism begins as a single cell (fertilized egg) that divides successively to produce many cells, with each parent cell passing identical genetic material (two variants of each chromosome pair) to both daughter cells. Cellular division and differentiation produce and maintain a complex organism, composed of systems of tissues and organs that work together to meet the needs of the whole organism. (HS-LS1-4) 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.* LS3.B: Genetic Variation • 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. • Environmental factors also affect expression of traits, and hence affect the probability of	This unit intentionally develops students' engagement in these crosscutting concept elements: Cause and Effect • Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. • Cause and effect relationships can be suggested and predicted for complex natural and human-designed systems by examining what is known about smaller-scale mechanisms within the system. Structure and Function • The functions and properties of natural and designed objects and systems can be inferred from their overall structure, the way their components are shaped and used, and the molecular substructures of its various materials. The following crosscutting concepts are also key to the sensemaking in this unit: Patterns • Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena. Systems and System Models • Systems can be designed to do specific tasks. • Models can be used to predict the behavior of a system, but these predictions have limited precision and reliability due to the assumptions and approximations inherent in models.
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Communicate scientific and/or technical information or ideas (e.g. about phenomena and/or the process of development and the design and performance of a proposed process or system) in multiple formats (i.e., orally, graphically, textually, mathematically).	occurrences of traits in a population. Thus, the variation and distribution of traits observed depends on both genetic and environmental factors. ETS1.B: Developing Possible Solutions When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts.	
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Connections to the Nature of Science (NOS) and Engineering, Technology, and Applications of Science (ETS)

Connections to the Nature of Science (NOS)	
Which elements of NOS are developed in the unit?	How are they developed?
Scientific investigations use a variety of methods. Science investigations use diverse methods and do not always use the same set of procedures to obtain data.	Students design and carry out multiple investigations using models in the format of a game (Lesson 3), in computer and kinesthetic simulations (Lessons 4 and 5), and in laboratory investigations they design themselves. Each of these investigations support students in generating evidence that can be used to support student explanations.
Science knowledge is based on empirical evidence.	Beginning in Lesson 1, students consider the difference between correlation and causation and consider how evidence can support causal explanations.
Science is a human endeavor. Scientific knowledge is a result of human endeavor, imagination, and creativity.	In Lesson 1, students hear from a scientist whose work has contributed to the body of knowledge related to cancer and cancer treatments.

Connections to Engineering, Technology, and Applications of Science (ETS)	
Which elements of ETS are developed in the unit?	How are they developed?
Influence of Engineering, Technology, and Science on Society and the Natural World. - New technologies can have deep impacts on society and the environment, including some that were not anticipated. - Analysis of costs and benefits is a critical aspect of decisions about technology.	In Lesson 11, students investigate various treatments for cancer and consider the cost and benefits of those treatments.

How does the unit build three-dimensional progressions across the course and the program?

This unit uses and builds upon **disciplinary core ideas (DCIs)** and other science ideas that students should have previously developed in OpenSciEd Middle School or another middle school science program.

- MS-LS1.A: Structure and Function (*OpenSciEd Unit 6.6: How do living things heal? (Healing Unit), OpenSciEd Unit 8.5: Why are living things different from one another? (Muscles Unit)*)

- All living things are made up of cells, which is the smallest unit that can be said to be alive. An organism may consist of one single cell (unicellular) or many different numbers and types of cells (multicellular). (MS-LS1-1)
- Within cells, special structures are responsible for particular functions, and the cell membrane forms the boundary that controls what enters and leaves the cell. (MS-LS1-2)
- In multicellular organisms, the body is a system of multiple interacting subsystems. These subsystems are groups of cells that work together to form tissues and organs that are specialized for particular body functions. (MS-LS1-3)
- MS-LS3.A: Inheritance of Traits. (*Muscles Unit*)
 - Genes are located in the chromosomes of cells, with each chromosome pair containing two variants of each of many distinct genes. Each distinct gene chiefly controls the production of specific proteins, which in turn affects the traits of the individual. Changes (mutations) to genes can result in changes to proteins, which can affect the structures and functions of the organism and thereby change traits.
- MS-LS3.B: Heredity: Inheritance and Variation of Traits (*Muscles Unit*)
 - 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.
- MS-ETS1.B: Developing Possible Solutions (*OpenSciEd Unit B.1: How do ecosystems work, and how can understanding them help us protect them? (Serengeti Unit)*)
 - There are systematic processes for evaluating solutions with respect to how well they meet the criteria and constraints of a problem. (MS-ETS1-2), (MS-ETS1-3)

This unit begins the development of **disciplinary core ideas (DCIs)** and other science ideas that students will utilize and continue building in subsequent units in the OpenSciEd Biology, Chemistry, and Physics course:

- HS-ETS1.B: When evaluating solutions, it is important to take into account a range of constraints including cost, safety, reliability, and aesthetics and to consider social, cultural, and environmental impacts. (secondary) *OpenSciEd Unit B.4: How does urbanization affect nonhuman populations, and how can we minimize harmful effects? (Urbanization Unit)*, *OpenSciEd Unit B.5: What will happen to Arctic bear populations as their environment changes? (Speciation Unit)*, *OpenSciEd Unit P.1: How can we design more reliable systems to meet our communities' energy needs? (Electricity Unit)*, *OpenSciEd Unit P.3: What can we do to make driving safer for everyone? (Vehicle Collisions Unit)*

	Questions	Models	Investigations	Data	Math	Explanation	Argument	Obtaining
Biology	<i>Cancer Unit</i>	<i>Serengeti Unit, Fires Unit</i>	<i>Fires Unit, Natural Selection Unit</i>	<i>Natural Selection Unit, Cancer Unit</i>	<i>Serengeti Unit</i>	<i>Fires Unit, Cancer Unit, Natural Selection Unit</i>	<i>Speciation Unit</i>	<i>Cancer Unit, Speciation Unit</i>
Chemistry	<i>Polar Ice Unit</i>	<i>Electrostatics Unit, Space Survival Unit, Oysters Unit</i>	<i>Polar Ice Unit</i>	<i>Fuels Unit</i>	<i>Polar Ice Unit</i>	<i>Fuels Unit</i>	<i>Oysters Unit, Fuels Unit</i>	<i>Electrostatics Unit, Space Survival Unit</i>
Physics	<i>Electricity Unit, Cosmology Unit</i>	<i>Electricity Unit, Microwave Unit</i>	<i>Microwave Unit</i>	<i>Electricity Unit, Earth's Interior Unit, Vehicle Collisions Unit, Meteors Unit</i>	<i>Vehicle Collisions Unit, Meteors Unit</i>	<i>Electricity Unit, Earth's Interior Unit, Vehicle Collisions Unit</i>	<i>Vehicle Collisions Unit</i>	<i>Cosmology Unit, Microwave Unit</i>
	Patterns	Cause/Effect	Scale	Systems/Models	Energy/Matter	Structure/Function	Stability/Change	

Biology	<i>Natural Selection Unit, Speciation Unit</i>	<i>Cancer Unit, Natural Selection Unit, Speciation Unit, Serengeti Unit</i>	<i>Serengeti Unit</i>	<i>Fires Unit, Cancer Unit, Serengeti Unit</i>	<i>Fires Unit, Serengeti Unit</i>	<i>Cancer Unit</i>	<i>Speciation Unit, Serengeti Unit</i>
Chemistry	<i>Electrostatics Unit, Space Survival Unit</i>	<i>Electrostatics Unit, Oysters Unit</i>	<i>Oysters Unit</i>	<i>Polar Ice Unit</i>	<i>Polar Ice Unit, Fuels Unit</i>	<i>Space Survival Unit</i>	<i>Oysters Unit, Fuels Unit</i>
Physics	<i>Cosmology Unit, Vehicle Collisions Unit, Earth's Interior Unit</i>	<i>Vehicle Collisions Unit, Earth's Interior Unit</i>	<i>Meteors Unit, Earth's Interior Unit</i>	<i>Electricity Unit, Vehicle Collisions Unit, Microwave Unit</i>	<i>Electricity Unit, Earth's Interior Unit</i>	<i>Earth's Interior Unit, Vehicle Collisions Unit</i>	<i>Electricity Unit, Cosmology Unit</i>

What are some common ideas that students might have?

Students will come into the unit with many ideas about inheritance and variation of traits derived from previous classroom experiences, intuitive understandings of the way the world works, everyday experiences with nature, and the conversations they have had with parents, friends, and family members.

- Genes carry information about the function and behavior of cells.
- There are only two variations for each gene and you either have a trait or do not have a trait.
- One gene always directly corresponds to one trait.
- Proteins are made up of genes.

Additional information about student ideas related to genetics can be found in the following resources:

Duncan, R. G., & Reiser, B. J. (2007, January 1). Reasoning across ontologically distinct levels: Students understandings of molecular genetics. *Journal of Research in Science Teaching*, 44(7), 938–959.

Duncan, R. G., & Castro-Faix, M. (2021). How Can Learning Progressions Support the Development of Genetic Literacy? Springer International Publishing. https://doi.org/10.1007/978-3-030-86051-6_4.

It is valuable to think of ideas like these not as misconceptions that need to be replaced but as productive ideas that we can use to build understanding. Not only does this help some students feel more comfortable talking about science and build a scientific identity, it improves science learning across the board.

How will I need to modify the unit if taught out of sequence?

This is the third unit of the High School Biology Course in the OpenSciEd Scope and Sequence. Given this placement, several modifications would need to be made if teaching this unit earlier in the Biology course. These include the following adjustments:

While the science ideas in this unit could be taught without modification prior to *OpenSciEd Unit B.1: How do ecosystems work, and how can understanding them help us protect them? (Serengeti Unit)* and *OpenSciEd Unit B.2: What causes fires in ecosystems to burn and how should we manage them? (Fires Unit)*, its placement as the third unit supports student sensemaking in *OpenSciEd Unit B.4: How does urbanization affect nonhuman populations, and how can we minimize harmful effects? (Urbanization Unit)* and *OpenSciEd Unit B.5: What will happen to Arctic bear populations as their environment changes? (Speciation Unit)*, which directly follow. If students do not experience this unit in order, they will likely need additional support to review big ideas related to inheritance and variation of traits prior to engaging with evolution by natural selection and speciation.

How do I shorten or condense the unit if needed? How can I extend the unit if needed?

The following are example options to shorten or condense parts of the unit without eliminating important sensemaking for students:

- In Lesson 8, you can reduce the number of times that students interact with the pipe cleaner model to shorten the lesson.
- In Lesson 9, you can reduce the time necessary for the investigation by providing students with sample data.
- While critical to supporting students in making sense of treatments and causes for cancer, Lesson Set 3 reinforces core ideas developed earlier in the unit related to cell division and can be condensed.

To extend or enhance the unit, consider the following:

- Lesson 2: While students examine different cell types (lung, breast, skin, etc.), they will not investigate the functions of those cells and those body systems in depth. This exploration is beyond the scope of the unit. However, an extension for motivated students could include an in-depth exploration of a particular body system, how it functions, and how cancer disrupts that function. This exploration would support the development of HS LS 1.A.1.
- Lesson 3: Making connections in math: Ask students to keep track of how many cancer and non-cancer cells they produce. At the end of Round 2, ask each group to add their results to a class data table. Then students determine the percentage of cancer cells produced compared to non-cancer cells. Students engage in mathematical modeling as they develop an understanding of the likelihood that cell division results in a cancer cell when p53 is functioning typically versus when p53 is functioning differently. Emphasize to students that these percentages may not reflect reality and that any percentages calculated are a result of game mechanics only. Should most students end up with cancer cells during the game, it is important that they do not come away thinking that developing cancer is inevitable in their lifetime.
- Lesson 5: While this lesson does not explore the discovery of the structure and function of DNA, some students may benefit from an investigation that extends their learning to include topics such as the discovery of the structure of DNA in the 1950s by scientists, including James Watson, Francis Crick, and Rosalind Franklin. Today, historians wonder about the cancer that ended Rosalind Franklin's short life and the repeated exposure to the X-rays she used to determine the structure of DNA.

- Lesson 6: For students who demonstrated mastery of the standard at an earlier stage, consider an extension activity that requires them to consider the structure and function of the protein based on the charge of the amino acids. For more information, see *Optional Extension*.
- Lesson 8: As an extension, consider having students submit their photos online in a shared slide deck or flip book or collect their drawings in class.
- Lesson 9: Questions may arise about different types of sunscreens. The two most common types of sunscreen commercially available are mineral and chemical sunscreens. Mineral sunscreens contain small particles, often zinc oxide and titanium dioxide, which remain on the skin's surface and physically block UV rays from penetrating the skin. Chemical sunscreens allow UV rays to be absorbed by the skin where they react with chemicals in the sunscreen. As a result of this reaction, the energy from the UV light is converted into heat, which dissipates away from the skin. As an extension, students could investigate how these different sunscreens affect the yeast cell growth. Then students could be asked to use the ideas around structure and function to explain how the two sunscreens work differently to protect against UV damage.

What mathematics concepts will students engage with in the unit?

This unit requires students to develop mathematical models, use mathematical representations, develop algorithms, and use rates of change. Making mathematical models is a Standard for Mathematical Practice, and specific modeling standards appear throughout the high school standards.

This unit does not assume students are fluent with the mathematical practices listed below, but that students develop these practices as part of the sensemaking. Thus, these standards are not so much prerequisites as co-requisites. If students are simultaneously developing the skills and vocabulary in math class, you can help by making explicit connections to the mathematical standards below.

Talk with the math teacher(s) to identify the strategies students are familiar with for developing algorithms with words or numbers, calculating rates of change, and constructing graphical representations of data.

Category	Code	Domain and Heading	Standard	Lesson
Mathematical Practice	CCSS.MATH.PRactice.MP2	Reason abstractly and quantitatively.	Mathematically proficient students make sense of quantities and their relationships in problem situations. They bring two complementary abilities to bear on problems involving quantitative relationships: the ability to decontextualize—to abstract a given situation and represent it symbolically and manipulate the representing symbols as if they have a life of their own, without necessarily attending to their referents—and the ability to contextualize, to pause as needed during the manipulation process in order to probe into the referents for the symbols involved. Quantitative reasoning entails habits of creating a coherent representation of the problem at hand; considering the units involved; attending to the meaning of quantities, not just how to compute them; and knowing and flexibly using different properties of operations and objects.	1, 12
Mathematical Practice	CCSS.MATH.PRactice.MP4	Model with mathematics.	Mathematically proficient students can apply the mathematics they know to solve problems arising in everyday life, society, and the workplace. In early grades, this might be as simple as writing an addition equation to describe a situation. In middle grades, a student might apply proportional reasoning to plan a school event or analyze a problem in the community. By high school, a student might use geometry to solve a design problem or use a function to describe how one quantity of interest depends on another. Mathematically proficient students who can apply what they know are comfortable making assumptions and approximations to simplify a complicated situation, realizing that these may need revision later. They are able to identify important quantities in a practical situation and map their relationships using such tools as diagrams, two-way tables, graphs, flowcharts and formulas. They can analyze those relationships mathematically to draw conclusions. They routinely interpret their mathematical results in the context of the situation and reflect on whether the results make sense, possibly improving the model if it has not served its purpose.	3

Functions	CCSS.MATH.CONTENT.HSF.IF.C.7	Analyze functions using different representations.	Graph functions expressed symbolically show the key features of the graph, by hand in simple cases and using technology for more complicated cases.	7
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What strategies are available to support equitable science learning in this unit?

OpenSciEd units are designed to promote equitable access to high-quality science learning experiences for all students. Each unit includes strategies that are integrated throughout the OpenSciEd routines and are intended to increase relevance and provide access to science learning for all students. OpenSciEd units support these equity goals through several specific strategies such as: 1) integrating Universal Design for Learning (UDL) Principles during the unit design process to reduce potential barriers and increase accessibility for students to engage in learning experiences; 2) developing and supporting classroom agreements that encourage a safe learning culture; 3) supporting classroom discourse to promote students in developing, sharing, and revising their ideas; and 4) specific strategies for supporting emerging multilingual students in science classrooms.

Many of these strategies are highlighted in the teacher guides in sidebar callout boxes with the headings of:

- Attending to Equity
- Supporting Emerging Multilingual Learners
- Supporting Universal Design for Learning
- Additional Guidance
- Alternate Activity
- Key Ideas
- Discussion callouts

The example callout below highlights how an activity can be modified to support a wider variety of learners.

*** ATTENDING TO EQUITY: Universal Design for Learning:** If it is something familiar to your students or part of their education plans, consider allowing students to use a digital graphing tool such as a graphing calculator or spreadsheet software to help them create their graphs. Students can take the data table and enter it into graphing software. Allowing alternatives for use of tools such as a calculator can remove barriers for students in *expressing* their understanding by keeping the focus on the learning goal. Use of such tools can help provide a match between a student's abilities and the demands of the task.

What are recommended adult-level learning resources for the science concepts in this unit?

The OpenSciEd instructional model focuses on the teacher being a member of the classroom community, supporting students to figure out scientific ideas motivated by their questions about phenomena. Students iteratively build their understanding of phenomena as the unit unfolds. To match the incremental build of a full scientific explanation across the unit, the science content background necessary for you to teach individual lessons incrementally builds too. Throughout the unit, we provide just-in-time science content background for you that is specific to the Disciplinary Core Ideas (DCIs) that will be figured out in a lesson. Places to look for this guidance include the “Where we are going” and “Where we are not going” sections for each lesson. Also, the expected student responses, keys, and rubrics illustrate important science ideas that should be developed in each lesson. The K-12 Science Framework is another great resource to learn more about the DCIs in this unit, including what students have learned previously and where they are headed in high school. In addition to the science content background information embedded in the lesson resources, below we provide recommended resources that can help build your understanding of phenomena and Performance Expectations bundle for this unit:

- Fred Hutchinson Cancer Research Center. (2021, August 28) *Frontiers: Intro to Cancer Unit*. <https://www.fredhutch.org/en/about/education-outreach/science-education-partnership/sep-curriculum/frontiers-intro-to-cancer-unit.html>
- Walter Flemming (1882) was the first scientist to observe and describe the movement of chromosomes during mitosis in salamanders. Later, other scientists contributed new understandings to the process of mitosis. For more information see [https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4142965/#:~:text=The%20first%20person%20to%20observe,3%20\(Paweletz%202001\).](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4142965/#:~:text=The%20first%20person%20to%20observe,3%20(Paweletz%202001).)
- Ainsworth, C. and Nature Magazine. (2018, October 22). Sex redefined: The idea of 2 sexes is overly simplistic. *Scientific American*. <https://www.scientificamerican.com/article/sex-redefined-the-idea-of-2-sexes-is-overly-simplistic/>
- Keim, Brandon. (2023, January 23). What Do We Owe Lab Animals? *The New York Times*. <https://www.nytimes.com/2023/01/23/science/what-do-we-owe-lab-animals.html>
- Davis, T. J. (2004). Meselson and Stahl: The art of DNA replication. *Proceedings of the National Academy of Sciences of the United States of America*, 101(52), 17895–17896. <https://doi.org/10.1073/pnas.0407540101>
- *Common cancer myths and misconceptions*. (2023, November 9). National Cancer Institute. <https://www.cancer.gov/about-cancer/causes-prevention/risk/myths>
- Morgenroth, T., Sendén, M. G., Lindqvist, A., Renström, E., Ryan, M. K., & Morton, T. A. (2020). Defending the Sex/Gender Binary: The role of gender identification and need for closure. *Social Psychological and Personality Science*, 12(5), 731–740. <https://doi.org/10.1177/1948550620937188>

- Wanjia's Health Diary. (2020, May 28). *Focused. Resilient. Confident. Lakita still standing strong* - Wanjia's Health Diary. Wanjia's Health Diary. <https://wanjashealthdiary.com/focused-resilient-confident-lakita-still-standing-strong/>

How do I support students' emotional needs?

In this unit, students explore the challenges associated with talking about cancer. This may bring emotions to the surface for many students, especially if a loved one has been sick from or died of cancer.

Before the start of the unit, consider letting students know that the class will be discussing cancer to give them time to process and raise any concerns they have. If a school counselor is available, consider reaching out for support and resources regarding trauma related to cancer or illness.

Be aware that students who are struggling may demonstrate a variety of behaviors including but not limited to: fidgeting, withdrawal, disruption or distraction, rapid breathing, holding their breath, and change in body language or tonation. If you notice a student might be struggling, share what you are observing and ask if they need some help.

Often in science classrooms, we are focused on evidence and data. When addressing a phenomenon or design solution that straddles the nature-cultural divide, like this one, supporting students in using an empathy or socio-emotional lens will also be important. Make space for students to process, and validate their feelings and reactions. These opportunities are built in throughout the unit.

Guidance for Developing Your Personal Glossaries

This unit refers to two categories of academic language (i.e., vocabulary). Most often in this unit, students will have experiences with and discussions about science ideas before they know the specific vocabulary word that names that idea. After students have developed a deep understanding of a science idea through these experiences, and sometimes because they are looking for a more efficient way to express that idea, they have co-developed that definition and can add the specific term to a Personal Glossary at the back of their notebooks. These “definitions we co-develop” should be recorded using the students’ own words whenever possible. On the other hand, “definitions we encounter” are “given” to students in the course of a reading, video, or other activity, often with a definition clearly stated in the text. Sometimes, definitions we encounter are helpful just in that lesson and need not be recorded in students’ Personal Glossaries. However, if a word we encounter will be frequently referred to throughout the unit, it should be added.

It is best for students if you create consensus definitions in the moment, using phrases and pictorial representations that the class develops together as they discuss their experiences in the lesson. When they co-create the meaning of the word, students “own” the word—it honors their use of language and connects their specific experiences to the vocabulary of science beyond their classroom. It is especially important for emergent multilingual students to have a reference for this important vocabulary, which includes an accessible definition and visual support. Sometimes defining a word is a challenge. The *Teacher Guide* provides a suggested definition for each term to support you in helping your class develop a student-friendly definition that is also scientifically accurate.

The definitions we co-construct and encounter in this unit are listed in this document and in each lesson to help prepare and to avoid introducing a word before students have earned it. They are not intended as a vocabulary list for students to study before a lesson, as that would undermine the authentic and lasting connection students can make with these words when they are allowed to experience them first as ideas they're trying to figure out.

Lesson	Definitions we co-construct	Definitions we encounter
L1		correlation, causation, p53
L2	hierarchical organization	tissue, organ, body system, organism, tumor, benign, malignant, and metastasis.
L3	cell cycle, mitosis	organelle, nutrient**, protein**, chromosome**, cell membrane**, nucleus, spindle, synthesis, relative
L4		

L5	mutation**, replication, complementary base pairs, DNA	
L6	gene expression	RNA, ribosome, amino acid, helicase, complementary base pairs
L7		
L8	meiosis, allele	inheritance**, crossing over
L9		melanoma
L10		
L11		chemotherapy, radiation, surgery, immunotherapy
L12		social determinants of health, health equity

*co-constructed or encountered in a previous OpenSciEd High School Biology Unit

**co-constructed or encountered in the middle school grade band of NGSS/OpenSciEd Middle School.

HOME COMMUNICATION

Dear Parents, Guardians, and Care-Givers,

Your child's high school biology class is starting a unit called *Who gets cancer and why? What can we do about it?* as part of the OpenSciEd high school science curriculum. Students will investigate the causes of and treatments for cancer. Specifically, they will investigate how cancer can be caused by mutations accumulated in our lifetime, mutations we inherit, and mutations caused by the environment. They will also hear from two young women, via video interviews about their personal experience with cancer.

Many students will have experiences with cancer, and those experiences may have been traumatic. Recalling past experiences or learning about others' experiences can be triggering. If your child or someone close to your child has had experiences with cancer, please contact me at _____ if you are comfortable doing so. You can also contact the school counselor at _____.

By knowing about these experiences in advance we can be sensitive to students' needs and provide support for students if they experience any strong emotions during this unit.

Adolescents will sometimes develop difficult behaviors after experiencing a loss or illness related to cancer. It is important for trusted adults to understand that these behaviors and emotions are common when children experience trauma. Students may be more aggressive or withdrawn and go through periods of sadness or anger or emotional "numbing." Contact a counselor if you see any of the following behaviors in your child:

- problems sleeping, nightmares,
- changes in school performance,
- truancy,
- risk-taking behavior,
- conflicts with peers,
- new or increasing psychosomatic complaints, including stomachaches and headaches,
- depression or suicidal thoughts.

Being able to talk to someone who is removed from the situation is often helpful to both adults and children after a traumatic event. After experiencing trauma, children are best supported when their parents or trusted caregivers accept their feelings and are open to listen and talk.

Reach out to a counselor or support center if you are concerned about trauma your child may have experienced related to cancer.

If you have any questions about the content of this unit or would like to discuss anything further, I encourage you to reach out to me at _____.

Best,

Estimados padres, guardianes y cuidadores:

La clase de biología de la escuela secundaria de su hijo está comenzando una unidad llamada *¿Quién padece cáncer y por qué? ¿Qué podemos hacer al respecto?* como parte del plan de estudios de ciencias de la escuela secundaria OpenSciEd. Los estudiantes investigarán las causas y los tratamientos del cáncer. En concreto, investigarán cómo el cáncer puede ser causado por mutaciones acumuladas a lo largo de nuestra vida, mutaciones que heredamos y mutaciones causadas por el medio ambiente. También escucharán a dos mujeres jóvenes, a través de entrevistas en video, sobre su experiencia personal con el cáncer.

Muchos estudiantes tienen experiencias con el cáncer. Y esas experiencias pueden haber sido traumáticas. Recordar experiencias pasadas o aprender sobre las experiencias de otros puede ser un desencadenante. Si su hijo o alguien cercano a su hijo ha tenido experiencias con cáncer, comuníquese conmigo al _____. Si se siente cómodo haciéndolo, podemos ser sensibles a las necesidades de los estudiantes y brindarles apoyo si experimentan emociones fuertes durante esta unidad.

En ocasiones, los adolescentes desarrollan comportamientos difíciles después de experimentar una pérdida o una enfermedad relacionada con el cáncer. Es importante que los adultos de confianza comprendan que estos comportamientos y emociones son comunes cuando los niños experimentan un trauma. Los estudiantes pueden ser más agresivos o retraídos. Y pasar por períodos de tristeza o ira o "adormecimiento" emocional. Comuníquese con un consejero si observa alguno de los siguientes comportamientos en su hijo:

- problemas para dormir, pesadillas,
- cambios en el rendimiento escolar,
- ausentismo escolar,
- comportamiento de riesgo,
- conflictos con sus compañeros,
- quejas psicósomáticas nuevas o en aumento, incluyendo dolores de estómago y de cabeza,
- depresión o pensamientos suicidas.

Poder hablar con alguien que está alejado de la situación suele ser útil tanto para adultos como para niños después de un evento traumático. Después de experimentar un trauma, los niños reciben mejor apoyo cuando sus padres o cuidadores de confianza aceptan sus sentimientos y están abiertos a escuchar y hablar.

Comuníquese con un consejero o un centro de apoyo si está preocupado por el trauma que su hijo pueda haber experimentado relacionado con cáncer.

Si tiene alguna pregunta sobre el contenido de esta unidad o desea discutir algo más, le invito a que se comuniqué conmigo al _____.

Sinceramente,

LESSON 1: Who gets cancer and why?

PREVIOUS LESSON *There is no previous lesson.*

THIS LESSON

ANCHORING PHENOMENON

3 days



Adapted from: National Cancer Institute, Unsplash

We hear that most of us will have some kind of experience with cancer in our lifetimes. We share our experiences and ideas and look at data about who gets cancer. We notice there are differences in who gets cancer based on factors like where we live. We also learn that the longer you live and the taller you are, the more likely you are to get cancer. We learn that scientists use animal models to study cancer, and we find out that not all animal species follow that pattern. Some of the biggest animals do not get a lot of cancer. We read about a gene that may protect them called p53. We develop a DQB and determine next steps for investigation.

NEXT LESSON *We will share our initial ideas about cells and investigate images of cancer and non-cancer cells. We will develop initial models to explain how cancer makes us sick and revise them after we obtain new information. We will update our Progress Trackers.*

BUILDING TOWARD NGSS

HS-LS1-1, HS-LS1-2, HS-LS1-4, HS-LS3-1, HS-LS3-2, HS-LS3-3, HS-ETS1-3



WHAT STUDENTS WILL DO

1.A Develop an initial model to explain and predict factors that cause cancer and the possible protective effects from p53. (SEP: 2.3; DCI: LS3.B.2; CCC: 2.2)

1.B Ask questions to clarify and seek additional information about the cause and effect of cancer based on genetic and environmental differences. (SEP: 1.1; DCI: LS1.A.1 & LS3.B.2; CCC: 2.2)

WHAT STUDENTS WILL FIGURE OUT

- Cancer affects all of us through our relationships.
- There are differences between the most commonly diagnosed and most commonly fatal cancers.
- Cancer incidence differs by geographic location.
- For humans, height and age are associated with higher rates of cancer.
- Scientists expected this to be true for other mammals, but it is not.
- There is a gene called p53 that protects some animals from cancer.

Lesson 1 • Learning Plan Snapshot

Part	Duration		Summary	Slide	Materials
1	10 min		NAVIGATE Introduce a new phenomenon and revisit norms.	A-C	
2	15 min		INITIAL IDEAS DISCUSSION Facilitate an Initial Ideas Discussion.	D	
3	15 min		INVESTIGATE CANCER DATA Investigate human cancer data.	E-H	<i>US Cancer Data</i>
4	5 min		NAVIGATE Give students time to complete an exit ticket.	I	
<i>End of day 1</i>					
5	2 min		NAVIGATE Share exit ticket data with students from the previous day's lesson.		
6	8 min		INVESTIGATE HUMAN DATA PATTERNS Share additional cancer data with students.	J-L	<i>Age and Height</i>
7	8 min		INTRODUCE ANIMAL MODELS Support students in obtaining and evaluating information in a reading about cancer in humans and nonhuman animals.	M-O	<i>Incidence of Cancer, Transcript: Dr. Battle</i>
8	12 min		MAKE SENSE OF A READING ABOUT CANCER Guide students as they make sense of new information about animals and incidence of cancer.	P-Q	<i>Incidence of Cancer</i>
9	10 min		DEVELOP INDIVIDUAL INITIAL MODELS Support student development of initial models.	R	
10	5 min		NAVIGATE Ask students to identify gaps in their initial models.	S	initial models
<i>End of day 2</i>					
11	3 min		NAVIGATE: SHARE INITIAL MODELS Ask students to share their initial models with a partner.	T	initial models
12	8 min		SMALL-GROUP MODELS Facilitate small-group model development.	U	whiteboard or chart paper, chart paper markers or dry erase markers

Part	Duration		Summary	Slide	Materials
13	8 min		DEVELOP INITIAL CONSENSUS MODEL AND IDENTIFY UNANSWERED QUESTIONS Support groups in sharing their models and coming to consensus on a class model and identifying unanswered questions.	V-W	small-group models
14	18 min		DEVELOP DRIVING QUESTION BOARD Prepare students to develop the DQB.	X	chart paper, chart paper markers, 3x3 sticky notes
15	5 min		CONSIDER IDEAS FOR INVESTIGATION Support students in generating ideas for investigation.	Y	
16	3 min		NAVIGATE: EXIT TICKET Ask students to complete an exit ticket about what question we should pursue next.	Z	

End of day 3

Lesson 1 • Materials List

	per student	per group	per class
Lesson materials	• science notebook • <i>US Cancer Data</i> • <i>Age and Height</i> • <i>Incidence of Cancer</i> • <i>Transcript: Dr. Battle</i> • initial models	• whiteboard or chart paper • chart paper markers or dry erase markers • small-group models	• chart paper • chart paper markers • 3x3 sticky notes

Materials preparation (30 minutes)

Review teacher guide, slides, and teacher references or keys (if applicable).

Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

Three-hole-punch all handouts so they can be added to student notebooks.

Gather chart paper, 3x3 sticky notes, and chart paper markers for the Driving Question Board.

Lesson 1 • Where We Are Going and NOT Going

Where We Are Going

In this lesson, students investigate data related to cancer to generate initial questions and models.

Their questions will allow them to seek additional information and clarify their ideas (SEP 1.1) about the cause and effect of cancer (CCC 2.2).

Student questions will set the stage for figuring out DCI

HS LS3.B.2 *Environmental factors also affect expression of traits, and hence affect the probability of occurrences of traits in a population. Thus the variation and distribution of traits observed depends on both genetic and environmental factors.* And HS LS 1.A.1 *Systems of specialized cells within organisms help them perform the essential functions of life.*

Student questions build on middle school level understanding of cells from MS LS1.A:

- *Within cells, special structures are responsible for particular functions, and the cell membrane forms the boundary that controls what enters and leaves the cell.*
- *In multicellular organisms, the body is a system of multiple interacting subsystems. These subsystems are groups of cells that work together to form tissues and organs that are specialized for particular body functions.*

As well as genetics from MS LA 1.B *Genetic factors, as well as local conditions affect the growth of the adult plant.*

In the middle school grade band, students use the crosscutting concept *cause and effect* to distinguish between causal and correlational relationships. Students build on this use as they note correlational relationships and ask questions that could produce empirical evidence to use in mechanistic explanations to support casual relationships.

Students encounter correlation and causation in this lesson and may add these definitions to their personal glossaries.

Where We Are NOT Going

We limited the demographic variables we investigate in the lesson to location by state. We will investigate other differences in cancer incidence or death by gender and identify race or ethnicity in later lessons. This will give students an opportunity to understand some of the biological basis of cancer before grappling with complicated social factors. This decision was made in an effort to avoid potentially harmful assumptions about race and/or ethnicity and genetics.

LEARNING PLAN for LESSON 1

1 · NAVIGATE

10 min

MATERIALS: science notebook

Introduce the phenomenon. Display **slide A**. Say, *If we have not already, each of us will likely have an experience with cancer in our lifetime. We have an opportunity to use our time in our science classes to talk about issues that affect us, like cancer, so we can better understand this human phenomenon.*

Revisit and add to our Community Agreements. Display **slide B**. Say, *Let's take a look at the Community Agreements we established earlier in the school year. Ask students to think about which of the agreements we might want to focus on as we discuss a potentially emotionally sensitive topic like cancer. Use *Example Community Agreements* as a resource. Students may share ideas about how focusing on the *respectful* and *committed to our community* agreements might help us when discussing difficult topics. Ask students to suggest specific ways they might draw on these agreements to support difficult conversations. Let students know that when the class discusses topics that feel emotionally challenging, they should feel comfortable asking to step out of the room.*

Stop and Jot. Display **slide C**. Ask students to take a few minutes to write about what they know about cancer in their science notebooks. This may include their personal experiences, events, and/or feelings. Let them know that while you are asking them to reflect on these experiences and feelings in writing, they will not be required to make those experiences and feelings public.

ADDITIONAL GUIDANCE

Before the start of the unit, consider letting students know that the class will be discussing cancer to give them time to process and raise any concerns they have. If a school counselor is available, consider reaching out for support and resources regarding trauma related to cancer or illness. See *Trauma-Informed SEL Supports* as a resource.

2 · INITIAL IDEAS DISCUSSION

15 min

MATERIALS: None

Turn and Talk. Display **slide D**. Ask students to turn and talk to a neighbor about what they know about cancer. Remind them that they may have written about personal stories and feelings in their science notebooks and it is up to them to decide if what they share includes this. Let students know they will participate in a whole-class discussion where they share a summary of their conversation with their partner and they should make sure not to share anything their partner would prefer to keep private.

Facilitate an Initial Ideas Discussion.* Call on a few student pairs and ask them to share their ideas. Record these ideas on the whiteboard. Encourage students to build on each others' ideas using prompts such as, *Did any pair discuss similar ideas?* or *Who can build on this idea?*

* STRATEGIES FOR THIS INITIAL IDEAS DISCUSSION

Reasons for eliciting students' initial ideas include:

- To get students' prior knowledge and experiences on the table.
- To provide a supportive opportunity for students to make sense of what may not be fully formed ideas (either their own ideas or those of others).
- To help students realize that there are gaps in our understanding in order to promote curiosity and

KEY IDEAS

Purpose of this discussion: To elicit student ideas related to cancer to make it possible for the unit to build on those ideas.

Listen for these ideas:

- There are different kinds of cancers.
- Some cancers are inherited, and some are related to the environment.
- Some cancers are treatable or curable, some are not.

Pay attention to students who may be experiencing trauma and connect them with additional resources and support as available.

consider what we could do next to figure something out.

Suggested prompt

Sample student response

What do you know about cancer?

I have had friends/family members with cancer.
They got really sick.
They had treatment (like chemo) and got better.
I know someone who died from cancer.

How have your experiences helped you learn more about cancer?

I learned about different types of cancer.
I learned about different kinds of treatment for cancer.

What don't you know about cancer that you want to understand better?

I do not really understand how cancer works.
Why do some people get cancer while others do not?
Why does it happen in certain parts of the body?

3 · INVESTIGATE CANCER DATA

15 min

MATERIALS: *US Cancer Data*

Elicit student ideas about how to begin their data investigation. Say, *It sounds like our class knows a lot about cancer from our personal experiences. We know that there are different types of cancer and many people are affected by cancer. How can we find out more about how our experiences compare with larger populations of people?* Listen for student responses related to looking at data. If they do not bring up data, ask them to think about what science practices we might engage in to investigate. Encourage students to think about the science practices they engaged in when they investigated wildebeest in the Serengeti and fires in the Arctic.

Share data related to cancer incidence and death. Display **slide E** and then **slide F**. Distribute *US Cancer Data* to each student. Ask students to take a minute to look at the graphs and stop and jot what they notice and wonder in their science notebooks. Then they should turn and talk to their neighbors about what they noticed and wondered. Call on a few students to share their thinking. Listen for ideas related to the difference between the types of cancers that are most frequently diagnosed and lead to death.

Share data related to cancer incidence and geographic location. Display slide G. Allow students to look at the map for a minute and stop and jot what they notice before asking them again to turn and talk with their partners. Encourage students to keep track of their thinking in their science notebooks. Call on a few pairs to share what they notice and wonder about the map. Listen for ideas related to differences in cancer rate based on geographic location. Students should notice that the incidence of cancer is not the same in all of the states and wonder why that is the case.

Whole-group discussion. Display **slide H**. Facilitate a whole-group discussion to capture what students noticed and wondered about the data. Make a three-column chart on the board and ask small groups to share what they notice and wonder. Head each column with the following: *Ideas We Agree On*, *Ideas We Disagree On*, and *New Ideas to Consider*.

ADDITIONAL GUIDANCE

Support students in building on each other's ideas. Encourage a group to share and then ask other groups to indicate whether their group also noticed this. If multiple groups notice the same idea, ask students if we should add it to the *Ideas We Agree On* column. When an idea comes up that students disagree on, remind students of the agreement related to respect and how we can respectfully disagree.

ADDITIONAL GUIDANCE

The data on slides E-G were generated from <https://gis.cdc.gov/Cancer/USCS/#/AtAGlance/>. Newer data may be available. The rates were of new cancers and cancer deaths were calculated per 100,000 people. Prompt students to think about whether or not the population of a state is a factor in the differences they see across states in the map.

4 • NAVIGATE

5 min

MATERIALS: science notebook



Exit Ticket. Display slide I. Ask students to turn to a new piece of loose-leaf paper in their science notebooks and answer the questions on the slide: *What is one question that you have whose answer will help us make progress on our lesson question: Who gets cancer and why?*

ASSESSMENT OPPORTUNITY

What to look for/listen for in the moment: Questions that relate to the cancer data on slides E-G that **clarify or seek additional information** such as: (SEP: 1.1)

- **Why** are some **cancers** more common than others? (DCI: LS3.B.2; CCC: 2.2)
- **Why** are some **cancers** more deadly than others? (DCI: LS3.B.2; CCC: 2.2)
- **How** can **where you live** affect **cancer** rate? (DCI: LS3.B.2; CCC: 2.2)

What to do:

Collect student exit tickets and look for questions related to the data as a formative assessment opportunity. Keep student questions until students are ready to develop the DQB. Provide written feedback to support question revision for DQB. Use *Supporting Questioning* to support students with question development.

Building toward 1.B Ask questions to **clarify and seek additional information** about the **cause and effect** of **cancer based on genetic and environmental** differences. (SEP: 1.1; DCI: LS3.B.2; CCC: 2.2)

End of day 1

5 • NAVIGATE

2 min

MATERIALS: science notebook

Share exit ticket data with students. Say, *I had a chance to look through your exit tickets from our last class. It seems like many of you noticed that people who live in different places have different rates of cancer and we do not really know why.* Adjust what you share with students based on the actual exit ticket data you collected and give students an opportunity to share any additional thoughts or questions with the class.

MATERIALS: science notebook, *Age and Height*

Share new human cancer data. Let students know that you also had similar wonderings. Say, *After we investigated some of the human cancer data by geographic region, I did a little research about other kinds of relationships we might see in human cancer data. I want to share with you what I found.*

Say, *I am going to share some data for you to make sense of in small groups. First, I want us to make sense of the kind of data the graphs include. Let's take a look.* Display **slide J**. Ask students to interpret what is on the x and y axes. Listen for students to identify the following:

- The x axis groups people by age group in 5-year intervals.
- Each bar represents a 5-year age group with the exception of <1 and 1-4 and 85+.
- The y axis shows a delay-adjusted rate per 100,000 persons.

Note that students can think of the y axis simply as rate per 100,000 persons. Delay-adjusted means data is submitted as much as 2 years after the end of a diagnosis year (a case diagnosed in 2019 is reported in 2021), so the accounts are adjusted to reflect that.

Display **slide K**. Explain to students that each point represents one country. The scientists collected data about the average height for adult males and females in many countries. They then plotted that against the incidence of cancer in that country.

Turn and Talk. Display **slide L**. Ask students to turn and talk to a partner about what kinds of claims they think they can make about the data and what evidence they have to support those claims. The graphs from the slides can also be found on *Age and Height* and can be distributed to students. They should write down their answers to the questions on the slide in their science notebooks. Call on a few students to share their thinking. *

* SUPPORTING STUDENTS IN DEVELOPING AND USING CAUSE AND EFFECT

Probe students to consider the difference between correlational and causal claims and to think about the evidence they need to support each type. If they want to make claims about how height and age *cause* cancer, they will need to identify *mechanisms* that could help them explain how height and age cause cancer. While these terms are used in the middle school grade band, students may need to build familiarity with and distinguish between them. Students can add these terms to their personal glossaries as *definitions we encounter*.

Suggested prompt	Sample student response
<i>What kinds of claims can you make about the data in Figure 1?</i>	Older people are more likely to be diagnosed with cancer. Very old people, over 85, are diagnosed less than people aged 75-84.
<i>Were all the people counted in the graph diagnosed with cancer? How do you know?</i>	Yes. The x axis says "age at diagnosis."
<i>What kinds of claims can you make about the data in Figure 2?</i>	In countries where the average height is higher, there is a higher incidence of cancer. Height is associated with incidence of cancer.
<i>Were all the people counted in the graph diagnosed with cancer? How do you know?</i>	No, it is just showing the average height of people in a county and the average rate of cancer for 100,000 people. It is showing the average of all people, not just those with cancer.

ADDITIONAL GUIDANCE

Additional information about the data in **slide J** can be found at <https://www.cancer.gov/about-cancer/causes-prevention/risk/age>. The data found in **slide K** was adapted from:

Jiang, Y., Marshall, R.J., Walpole, S.C. et al. An international ecological study of adult height in relation to cancer incidence for 24 anatomical sites. *Cancer Causes Control* 26, 493–499 (2015).

7 · INTRODUCE ANIMAL MODELS

8 min

MATERIALS: science notebook, *Incidence of Cancer*, *Transcript: Dr. Battle*

Introduce animal models for studying cancer. Say, *We have started to make progress on our lesson question, Who gets cancer?, but we have not yet discussed the why. Many scientists have been investigating why different people are diagnosed with, and die from, different cancers. Use the prompts below to guide a whole-class discussion.*

Suggested prompt	Sample student response
<i>How do scientists study cancer?</i>	They collect data. They make models. They do experiments.
<i>When they do these things, is it always with humans?</i>	They probably have data from hospitals and drug trials. They might use animals.
<i>What do they do when they want to learn more about how human bodies respond to illness?</i>	They study animals like mice. They might use animals to see how the disease makes them sick or to see how a treatment works.

Share a video interview with Dr. Stephanie Battle. Display **slide M**. Introduce students to Dr. Stephanie Battle, a cancer researcher to students. Distribute *Transcript: Dr. Battle* to each student and ask them to follow along as you play <https://youtu.be/Dmmju1Ju1Pk> on **slide N**.

Turn and Talk about the main ideas from the video. After watching the video, display **slide O** and ask students to discuss the questions on the slides. Then call on a few pairs to share their thinking. Using the prompts below as a guide.

Suggested prompt	Sample student response
<i>Why do scientists use animal models, such as mice?</i>	Cancer does not work the same in cells in a dish. To understand cancer you have to see it in a living system.

Suggested prompt	Sample student response
<i>Based on the claims you made about the relationships between height and age and incidence of cancer in humans, what kinds of mammals would you predict have the highest incidence of cancer?</i>	Mammals that are bigger and older. Giraffes, elephants, and whales.

8 · MAKE SENSE OF A READING ABOUT CANCER

12 min

MATERIALS: science notebook, *Incidence of Cancer*

Distribute cancer reading. Display **slide P**. Distribute *Incidence of Cancer* to each student and ask them to individually read the article and to mark it up using whatever literacy strategy is in place in your classroom. Encourage them to jot down notes in their science notebooks related to anything they notice and wonder.

Students answer questions individually then turn and talk. Display **slide Q** and ask students to record their answers to the Making Sense questions on the slide in their science notebooks. Next, ask them to turn and talk to a partner to compare answers. After they have had a few minutes to discuss their responses, call on a few pairs to share their thoughts.

Suggested prompt	Sample student response
<i>What is the relationship between height and age and cancer incidence in humans?</i>	The older you are, the more likely you are to be diagnosed with cancer. In countries where the average height is taller, the incidence of cancer is higher.
<i>What predictions did scientists make about cancer rates in nonhuman animals?</i>	Bigger, older animals would get more cancer.
<i>What did they observe?</i>	It is not true that the biggest and oldest mammals get cancer at a higher rate. Big animals like whales and elephants do not get a lot of cancer.
<i>What mechanisms did they propose that might explain their observations?</i>	For some big mammals, like elephants, there is a gene called p53 that protects them. Big animals like elephants have extra copies of p53, so maybe that is why they do not get cancer.

9 · DEVELOP INDIVIDUAL INITIAL MODELS

10 min

MATERIALS: science notebook



Develop individual models. Say, *We have figured out a lot about who gets cancer based on the data we investigated and in the article we just read. How can we begin to make sense of our developing ideas?* Listen for students to share ideas related to developing models. Prompt them to think about the practices they used in previous units if they do not suggest modeling. Display **slide R**. Ask students to take a few minutes to stop and jot their initial models in their science notebooks.

ASSESSMENT OPPORTUNITY

What to look for/listen for in the moment:

- Interactions between factors that might cause cancer, such as geographic location, size, and age in humans. (SEP: 2.3; DCI: LS3.B.2; CCC: 2.2)
- Interactions between nonhuman animals and p53 that prevent cancer. (SEP: 2.3; DCI: LS3.B.2)
- Questions about the mechanisms that both cause and protect from cancer. (SEP 2.3; CCC 2.2)

What to do:

- Support individual students by asking probing questions about how the components of the models are related.
- Focus on the language of cause and effect, such as *What do you think the cause of cancer is for taller or older people?* or *What effect might where you live have on incidence of cancer?*
- Probe them to think about and represent the smaller-scale mechanisms that they cannot see in their models.

Building toward 1.A Develop an initial model that helps explain and predict factors that cause cancer and the possible protective effects from p53. (SEP 2.3 ; DCI LS3.B.2; CCC 2.2)

10 · NAVIGATE

5 min

MATERIALS: science notebook, initial models

Identify gaps in initial models. Display slide S. Ask students to review their initial models and mark places on the model where they need more information to be able to answer the question *Who gets cancer and why?* Let them know that they will be sharing their models with their classmates in the next class.

End of day 2

11 · NAVIGATE: SHARE INITIAL MODELS

3 min

MATERIALS: science notebook, initial models

Turn and talk about initial models. Display slide T. Ask students to take out their initial models and turn and talk to a partner about what their model explains and what additional information they still need to answer the question *Who gets cancer and why?* Let students know when half the allotted time has passed so that they each have time to share.

12 · SMALL-GROUP MODELS

8 min

MATERIALS: whiteboard or chart paper, chart paper markers or dry erase markers

Develop small group models. Display slide U. Organize students into small groups of 3-4. Distribute whiteboards or chart paper and markers to each group and ask them to share their individual models one at a time. Students should look for the components and interaction that all or most of the models share as well as the unique features of the models. They should come to consensus on what to include and develop a

single group model. Revisit your classroom agreements and ask students to recall what equitable participation looks like in small groups.

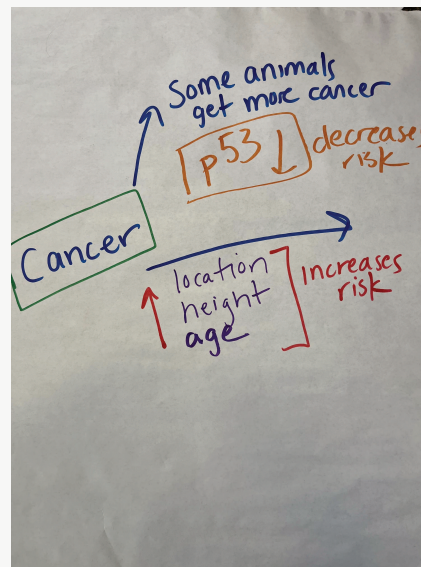
13 · DEVELOP INITIAL CONSENSUS MODEL AND IDENTIFY UNANSWERED QUESTIONS

8 min

MATERIALS: science notebook, small-group models

Develop a class consensus model. Display **slide V**. Call on one group to share their model with the class. Ask the rest of the class which parts of the model they agree with and want to include in the consensus model. Repeat this process until each group has shared or the class agrees that the model is complete.

Identify gaps that the model cannot yet explain. Say, *We have made great progress on our initial model to explain who gets cancer and why? We also have questions that we need to answer to make progress.* Display **slide W**. Ask students to brainstorm in small groups a list of as many questions as they can think of that they would need to answer to make additional progress on the question *Who gets cancer and why?* Pass back the questions students identified on day 1 to remind students of the questions they had after investigating the data. Encourage them to include any of their original questions that remain unanswered.



14 · DEVELOP DRIVING QUESTION BOARD

18 min

MATERIALS: chart paper, chart paper markers, 3x3 sticky notes

Write initial questions for the Driving Question Board. Pass out three sticky notes to each student. Display **slide X**. Say, *We have a lot of great questions about who gets cancer and why, and we are ready to create our Driving Question Board (DQB).* Remind students that the DQB will help keep the class organized and keep track of what we want to know and what we figure out throughout the unit. Instruct students to use the list of questions they generated to pick the most pressing questions to include on the Driving Question Board. They should write up to three questions each, one per sticky note, using their brainstormed list as a guide.

Gather in a Scientists Circle. Ask students to form a Scientists Circle, a horseshoe shape oriented toward the DQB, and to bring their sticky notes with them.



Support students in building the DQB. Build on the classroom norms you established in previous units when establishing the DQB. Support students in taking the lead. You might want to choose the first volunteer to begin the process and then step back. Step in when necessary to point students to some of the class norms to encourage equitable participation.

ASSESSMENT OPPORTUNITY

What to look for/listen for in the moment:

Questions based on observation to clarify and seek more information about: (SEP 1.1)

- What cancer is and how it can cause illness. (DCI: LS1.A.1; CCC: 2.2)
- What p53 is and how it can provide cancer protection. (DCI: LS3.B.2; CCC: 2.2)
- Effects of cancer treatment and prevention. (DCI: LS1.A.1; CCC: 2.2)
- Genetic and environmental factors that affect incidence of cancer. (DCI: LS3.B.2; CCC: 2.2)

What to do: Guide students to recognize the categories and group related questions together. Look for questions that group around the following:

- What is cancer?
- Who gets cancer?
- Why do people get cancer?
- How can cancer make us sick?
- How do cells become cancerous?
- Why is some cancer more common than others in older, taller people?
- What is p53 and how does it work?
- What are the genetics of cancer?
- Why does cancer seem to run in families?
- What does the environment have to do with cancer?
- Why do people in some places get more cancer than others?
- What treatments and prevention options are there?

If students need additional support in developing the practice of asking questions see *Supporting Questioning*.

Building toward 1.B Ask questions to clarify and seek additional information about the cause and effect of cancer based on genetic and environmental differences. (SEP 1.1; DCI: LS1.A.1 & LS3.B.2; CCC 2.2)

Choose a volunteer to go first, read their question, and put it on the DQB near the part of the graph to which it is related.

1. Raise your hand if you have a question that is related or the same.
2. The first volunteer selects the next student whose hand is raised. The student who is called on reads the related question, says why or how it relates, and then moves it onto the DQB with the original question.
3. That student selects the next student, who will read another related sticky note, move it, and then call on the next student.
4. Continue until the class agrees that all the related questions have been placed and everyone has shared at least one question.

15 · CONSIDER IDEAS FOR INVESTIGATION

5 min

MATERIALS: science notebook

Generate ideas for investigation. Congratulate students on generating a productive board full of great questions. Let them know that the next step is to brainstorm ideas that will help us figure out how to answer those questions. They should focus on one group of related questions at a time and generate ideas for how they could go about answering each question. Their first instinct may be to “do research.” Prompt them to be more specific and answer questions about what specific data they would need to answer each question. Consider modeling an example to get them started.

Display slide Y. Give students two minutes to generate ideas for investigation in their science notebooks. Encourage students to think about how we might generate the evidence we need to answer the questions that we have. If there is time, give them a minute to talk with a partner before sharing with the whole class. Record student ideas on the whiteboard or chart paper titled “Ideas for Investigation.”

Publicly display students' ideas for investigation. Ask individual students or pairs of students to share their ideas for investigation. Publicly display student ideas for investigation on the whiteboard or on a piece of chart paper for the class to have as a reference.

16 · NAVIGATE: EXIT TICKET

3 min

MATERIALS: science notebook

Prioritize next steps. Display **slide Z**. Ask students to tear a half sheet of notebook paper and write down which questions make sense to investigate first. Remind them that the unit questions are *Who gets cancer and why?* and *Where should we focus efforts on treatment and prevention?* Collect their exit tickets.

EXIT TICKET



Sort your exit tickets into categories based on common ideas. There should be a pile that is related to figuring out what cancer is. This is what students will investigate in Lesson 2. Use student exit tickets when you navigate at the beginning of Lesson 2.

Additional Lesson 1 Teacher Guidance

SUPPORTING STUDENTS IN MAKING CONNECTIONS IN MATH

CCSS.MATH.PRACTICE. MP2. Reason Abstractly and Quantitatively

When students investigate cancer data, they use quantitative representations (graphs) to identify patterns and ask questions about possible mechanisms.

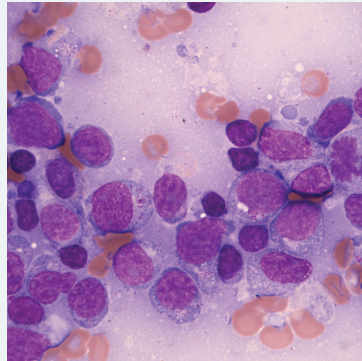
LESSON 2: What is cancer?

PREVIOUS LESSON We investigated data related to incidence of human cancer based on different variables such as geographic location, age, and size. We found out that scientists study animals to learn more about cancer. They predicted larger, older animals would follow the same pattern but found that was not true. We read about a gene called p53 that might protect some animals from cancer.

THIS LESSON

INVESTIGATION

2 days



William R. Geddie, CCO 1.0 Universal

We share our initial ideas about cells and investigate images of cancer and non-cancer cells. We notice that there are differences between them and that cancer cells have some common characteristics. We develop initial models to explain how cancer makes us sick and read new information to help us answer questions in our models. We revise our individual models and the class consensus model and update our Progress Trackers. We wonder how non-cancer cells turn into cancer cells.

NEXT LESSON We will play a game that models what happens in the cell as it grows and divides into non-cancer and cancer cells. We will compare our game model to a scientific model to fill in any gaps in our understanding.

BUILDING TOWARD NGSS

HS-LS1-1, HS-LS1-2, HS-LS1-4, HS-LS3-1, HS-LS3-2, HS-LS3-3, HS-ETS1-3



WHAT STUDENTS WILL DO

2.A Ask questions that will help identify patterns that explain the relationships between non-cancer and cancer cells. (SEP: 1.6; DCI: LS1.A.1 & LS1.A.3; CCC: 1.1)

2.B Develop and revise a model to illustrate the relationship between systems of specialized cells and cancer cells at the scales of the cells, the tissue, the organ, and the body. (SEP: 2.3; DCI: LS1.A.1 & LS1.A.3; CCC: 2.2)

WHAT STUDENTS WILL FIGURE OUT

- Cells have common characteristics.
- Cells are part of a hierarchical organization system of tissues, organs, and systems in organisms.
- Cancer cells look different from non-cancer cells.
- When cancer cells stick together, they can form tumors that can invade tissues, disrupt systems, and make us sick.

Lesson 2 • Learning Plan Snapshot

Part	Duration		Summary	Slide	Materials
1	5 min		NAVIGATE Review, generate and prioritize questions and next steps.	A	
2	10 min		INITIAL IDEAS DISCUSSION ABOUT CELLS Lead a discussion to elicit student ideas about cells.	B-C	
3	10 min		INVESTIGATE CELLS Guide students through an investigation of cell images on slides.	D-I	<i>Cell Images</i>
4	15 min		DEVELOP A MODEL TO EXPLAIN HOW CANCER CAUSES ILLNESS Facilitate individual and partner model development.	J-K	<i>Peer Feedback Protocol</i>
5	5 min		NAVIGATE Ask students to revise their initial models based on peer feedback.	L	
<i>End of day 1</i>					
6	5 min		NAVIGATE Review feedback on initial models and determine next steps.	M	initial models from day 1
7	10 min		READING ABOUT CANCER Facilitate a reading about cancer.	N-O	<i>Cancer</i>
8	min		REVISE INITIAL MODELS Students create models to explain how cancer makes us sick.	P	initial models from day 1
9	10 min		REVISE CLASS CONSENSUS MODEL Facilitate a whole-class discussion to add to the class consensus model.	Q	initial models from day 1
10	9 min		NAVIGATE Support students in completing the first two rows of their Progress Tracker.	R	<i>Progress Tracker</i>
<i>End of day 2</i>					

Lesson 2 • Materials List

	per student	per group	per class
Lesson materials	• science notebook • <i>Cell Images</i> • <i>Peer Feedback Protocol</i> • initial models from day 1 • <i>Cancer</i> • <i>Progress Tracker</i>		

Materials preparation (20 minutes)

Review teacher guide, slides, and teacher references or keys (if applicable).

Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

Three-hole-punch all handouts so they can be added to student notebooks.

Lesson 2 • Where We Are Going and NOT Going

Where We Are Going

In this lesson, students build toward understanding DCI related to the structure and function of organisms:

- HS LS1.A.1 *Systems of specialized cells within organisms help them perform the essential functions of life.*
- HS LS 1.A.3 *Multicellular organisms have a hierarchical structural organization, in which any one system is made up of numerous parts and is itself a component of the next level.*

These ideas build on middle school understanding of the structure and function of organisms including MS LS1.A:

- *Within cells, special structures are responsible for particular functions, and the cell membrane forms the boundary that controls what enters and leaves the cell.*
- *In multicellular organisms, the body is a system of multiple interacting subsystems. These subsystems are groups of cells that work together to form tissues and organs that are specialized for particular body functions.*

Students develop their use of the science practice of *asking questions*: Ask questions that can be investigated within the scope of the school laboratory, ~~research facilities, or field (e.g., outdoor environment)~~ with available resources and, ~~when appropriate, frame a hypothesis based on a model or theory~~. Students developed a similar element of the practice in middle school.

They continue to use the scientific practice of *developing and using models* and focus on both the development and revision of models based on evidence to explain interactions in systems.

Students use the crosscutting concept *patterns* as they make sense of the levels of organization in human cellular systems and use *cause and effect* as they explain interactions between cancer and non-cancer cells.

Students encounter the words: *tissue, organ, body system, organism, tumor, benign, malignant, and metastasis*. They will co-construct a definition of hierarchical organization.

Where We Are NOT Going

While students examine different cell types (lung, breast, skin, etc.), they will not investigate the functions of those cells and those body systems in depth. This exploration is beyond the scope of the unit. However, an extension for motivated students could include an in-depth exploration of a particular body system, how it functions, and how cancer disrupts that function. This exploration would support the development of HS LS 1.A.1.

LEARNING PLAN for LESSON 2

1 · NAVIGATE

5 min

MATERIALS: science notebook

Lead a discussion about what we figured out in the last class. Say, Yesterday, you all generated a lot of questions about who gets cancer and why. In your exit tickets, I noticed that some of you suggested we start our unit by figuring out what cancer is. Display slide A and use the prompts below as a guide.

Suggested prompt	Sample student response
What ideas do you have about how we can figure out what cancer is?	We could look at cells. We could watch a video or look at pictures. We could read about it.

2 · INITIAL IDEAS DISCUSSION ABOUT CELLS

10 min

MATERIALS: science notebook

Initial ideas discussion about cells. * Say, Some of you suggested that we look at cells to figure out what cancer is. I was able to find some images of cancer and non-cancer cells for us to look at. Before we do, let's take a minute to talk about what we already know about cells. Display slide B and use the prompts below as a guide.

Suggested prompts	Sample student responses	Follow-up questions
What do you know about cells?	They make up every living thing. They have parts inside them that do different jobs.	What is inside a cell? How do cells keep all their parts together?
Why are there different kinds of cells?	Different cells do different jobs. We need different cells for different things, like our brain cells do something different from our stomach cells.	
How are cell types different from each other?	Cells that have different functions might have different parts. Cells that do the same job might all make the same thing.	What is different about skin and lung cells?

*** STRATEGIES FOR THIS INITIAL IDEAS DISCUSSION**

The purpose of this discussion is to get student initial ideas and experience on the table. Provide a way for all students to share their ideas. Consider a think-pair-share where students first share their ideas with a partner before they share it with the whole class.

Suggested prompts	Sample student responses	Follow-up questions
<i>How are cells organized?</i>  <i>To figure out what cancer is, what questions do we need to answer about cells?</i>	Cells that are the same are together. We have systems like muscles or bones where all the cells that are like each other are together. What do cancer and non-cancer cells have in common? What differences are there between cancer and non-cancer cells across cell types? How do cancer cells look when they are in different cell types? Do cancer cells disrupt the cells in the different cell types?	<i>Are different kinds of cells all mixed up in the sample place like a bag of jelly beans?</i> <i>If we look at cancer and non-cancer cells, what should we look for?</i>

KEY IDEAS

Purpose of this discussion: To elicit student ideas to identify productive ideas that students can build on and areas where students may need additional support.

Listen for these ideas:

- All cells have common features like a cell membrane.
- In our bodies, cells are specialized for particular functions.
- Similar cells group together to form tissues or organs.

ASSESSMENT OPPORTUNITY

What to look for/listen for in the moment: Questions (SEP: 1.6) that will help students *investigate* patterns (SEP: 1.6) in cancer and non-cancer cells such as:

- What do **cancer and non-cancer cells** have in **common**? (DCI: LS1.A.1 & LS1.A.3; CCC: 1.1)
- What **differences** are there between **cancer and non-cancer** cells **across cell types**? (DCI: LS1.A.1 & LS1.A.3; CCC: 1.1)
- How do **cancer cells** look when they are in **different cell types**? (DCI: LS1.A.1 & LS1.A.3; CCC: 1.1)
- Do **cancer cells** **disrupt the cells** in the **different cell types**? (DCI: LS1.A.1 & LS1.A.3; CCC: 1.1)
- How does **cancer** disrupt the **cells and the system**? (DCI: LS1.A.1 & LS1.A.3; CCC: 1.1)

What to do:

If students are not ready to ask questions about cancer and non-cancer cells because they need more support building middle school ideas, see Lesson 6 from *OpenSciEd Unit 6.6: How do living things heal? (Healing Unit)* and <https://www.openscienced.org/general/microscope-body/>, where students can view skin, bone, and muscle cells to look for patterns within and between these cell types.

Building toward 2A Ask questions that will help identify **patterns** that explain the relationships between non-cancer and cancer cells. (SEP: 1.6; DCI: LS1.A.1 & LS1.A.3; CCC: 1.1)

Update personal glossaries. Display **slide C** and provide students with a few minutes to update their personal glossaries with definitions they encountered during the discussion and ideas they co-constructed.

ADDITIONAL GUIDANCE

As students voice prior understandings about cells they may use terms such as *tissue*, *organ*, and *body systems*. These terms can help students think about **hierarchical organization**, where cells make up tissues and tissue makes up organs and organ systems as part of an organism. When this happens, pause to let students know that they are describing what scientists call hierarchical organization and give them an opportunity to co-construct this definition. Once they come to consensus, give them an opportunity to add it to their personal glossary.

3 · INVESTIGATE CELLS

10 min

MATERIALS: science notebook, *Cell Images*

Introduce cell images. Display slide **D** and ask students to set up a two-column Notice and Wonder chart in their science notebooks. At the top of the chart they should write the question they want to investigate from the previous activity that will help them make progress on figuring out what cancer is. They should make a row for each of the cell types they will view: lung, breast, blood, and skin.

Review images on slides. Display each image on **slides E-H**, pausing for a moment on each slide to give students an opportunity to write down what they notice and wonder. Encourage students to note the differences they see between cancer and non-cancer cells. If students need a paper copy of the cell images, they can be found in *Cell Images*.

Turn and Talk. Organize students into pairs to share what they noticed and wondered about the cell images. Display **slide I** and ask students to discuss the questions on the slide. Call on a few pairs to share their ideas. Encourage volunteers to build on their classmates' ideas.

Suggested prompt	Sample student response
<i>What similarities and differences did you notice?</i>	Every cell has a part that is darker than the other. Each cell in the same type has a similar shape. There are a lot of tiny cells that make up tissue. The cells seem to be all smashed together in a tight space.
<i>What is the relationship between cancer cells and non-cancer cells in the different cell types?</i>	The cancer cells are clumped together. The cancer cells are different sizes from the non-cancer cells in the same space. The cancer cells are different colors than the non-cancer cells.
<i>At which levels of organization did we gain understanding about cancer?</i>	We understand more about what cancer cells look like and how they are different from non-cancer cells. We know what cancer looks like at the level of the cells.

Suggested prompt	Sample student response
<i>What levels do we still need more information about?</i>	We do not really know what cancer is in the body and how it makes people sick. We need to know more about how cancer affects an organ, system, or the whole body.

4 • DEVELOP A MODEL TO EXPLAIN HOW CANCER CAUSES ILLNESS

15 min

MATERIALS: science notebook, *Peer Feedback Protocol*

Motivate modeling as a way to make progress on the class's ideas. Say, *It sounds like you all have figured out a lot about what cancer looks like at the level of the cells, but we need to know more about how cancer interacts with other levels of organization like the organs, systems, or body. So far, we have investigated images and asked questions. What other science practices can we use to make sense of this?* Listen for students to suggest developing a model. If students do not suggest modeling, ask them to think about how we have made sense of ideas in the past.

Develop individual models. Display **slide J** and ask students to develop an initial model in their science notebooks to explain how cancer makes us sick.* Encourage them to choose a single cell type from the images previously investigated and to consider how the cancer cells will interact with the non-cancer cells in the system.

Turn and talk about initial models. Display **slide K**. Ask students to turn and talk to a partner to share their models and give and receive feedback. Consider setting a timer so that each student can give and receive feedback. Distribute *Peer Feedback Protocol* to any student that would benefit from a paper copy.

* ATTENDING TO EQUITY

Students should be encouraged to record their ideas using linguistic (e.g., written words) and nonlinguistic modes (e.g., photographs, drawings, tables, graphs, mathematical equations, measurements), especially as we develop these new ideas. This is particularly important for emerging multilingual students because making connections between written words and nonlinguistic representations helps students generate richer explanations of scientific phenomena.

5 • NAVIGATE

5 min

MATERIALS: science notebook



Revise initial models and identify questions. Display **slide L**. Ask students to consider the feedback they received from their peers and make revisions to their models. Then ask them to look for places they still have questions about how components interact or what mechanisms explain the interactions. Ask them to add a question mark anywhere they still have a question. Collect and review initial models before the next class.

ASSESSMENT OPPORTUNITY

What to look for/listen for in the moment: Models that explain: (SEP: 2.3)

- Cancer and non-cancer cells interact at the level of the cell, tissue, organ, body system, and organism. (DCI: LS1.A.3; CCC: 2.2)
- Those interactions may disrupt the typical function of the cells. (DCI: LS1.A.1; CCC: 2.2)
- If the typical function is disrupted, the person might feel sick because they do not get what they need from that organ or system. (DCI: LS1.A.1 & LS1.A.3; CCC: 2.2)

What to do: Provide written feedback on student models.

- If the student is missing the levels of organization, ask them what organ and organ system the cells are a part of.
- If the student is missing the idea that cancer cells disrupt non-cancer cells, ask them how they think the cancer cells interact with the non-cancer cells.
- If the student is missing the effect that the disruption might lead to illness, ask them to consider what those cells do and how a disruption might affect their function.

Building toward 2.B.1 Develop and revise a model to illustrate the relationship between systems of specialized cells and cancer cells at the scales of the cells, the tissue, the organ, and the body. (SEP: 2.3; DCI: LS1.A.1 & LS1.A.3; CCC: 2.2)

End of day 1

6 • NAVIGATE

5 min

MATERIALS: initial models from day 1

Review teacher feedback on initial models. Return student initial models. Display **slide M** and give students a few moments to review their feedback. Say, *You all made a lot of progress on figuring out what cancer is in your models, first on the level of the cells and then at the level of tissues, organs, and systems. I noticed that you have a lot of questions. What do you think we should do to make progress on the unanswered questions from your models?* Listen for students to suggest additional investigations into cancer, including looking at more cells, watching videos, or doing some reading.

7 • READING ABOUT CANCER

10 min

MATERIALS: *Cancer*, science notebook

Investigate cancer with a reading. Display **slide N**. Pass out *Cancer*. Say, *I have a reading that I think will help you answer many of the questions on your models.* Instruct students to read the article and mark it up using whatever strategy is in place in your classroom. *

Small-group sensemaking about the reading. Organize students into small groups of 3-4. Display **slide O** and ask students to answer the questions on the slide in their science notebooks as they discuss them with their small groups. Call on a few groups to share their responses.

* ATTENDING TO EQUITY

For students who need additional support with reading comprehension, consider having them read and annotate the article in pairs. Have them circle any unknown words, highlight important takeaways, and write

ADDITIONAL GUIDANCE

The reading introduces the terms *benign*, *malignant*, and *metastasize*. These terms are not essential to understanding or explaining the science ideas in the unit, but they are terms that students may have heard or will hear in the future. Encourage students to add these terms to their personal glossaries and words we encounter as needed. The reading also briefly addresses how people get sick and can sometimes die from cancer. Be aware that this could be upsetting to students who have experience with cancer and be ready to refer students to the appropriate resource in your school.

questions in the margins so that they have articulated their ideas before the whole-group discussion.

8 • REVISE INITIAL MODELS

min

MATERIALS: science notebook, initial models from day 1



Initial model revision. Display **slide P**. While they are in their small groups, ask students to turn to their initial models and determine what revisions they can make based on the reading. They should pay close attention to the places where they added question marks to identify which questions they can answer and which questions they still have. While each student is revising their own individual model, they should draw on resources from the group to help move everyone's thinking forward.

ASSESSMENT OPPORTUNITY

What to look for/listen for in the moment: **Models that explain:** (SEP: 2.3)

- Cancer and non-cancer **cells interact at the level of the cell, tissue, organ, body system, and organism.** (DCI: LS1.A.3; CCC: 2.2)
- Those **interactions may disrupt the typical function of the cells.** (DCI: LS1.A.1; CCC: 2.2)
- If the **typical function is disrupted, the person might feel sick** because they **do not get what they need from that organ or system.** (DCI: LS1.A.1 & LS1.A.3; CCC: 2.2)

What to do: Provide written feedback on student models.

- If the student is missing the levels of organization, ask them what organ and organ system the cells are a part of.
- If the student is missing the idea that cancer cells disrupt non-cancer cells, ask them how they think the cancer cells interact with the non-cancer cells.
- If the student is missing the effect that the disruption might lead to illness, ask them to consider what those cells do and how a disruption might affect their function.

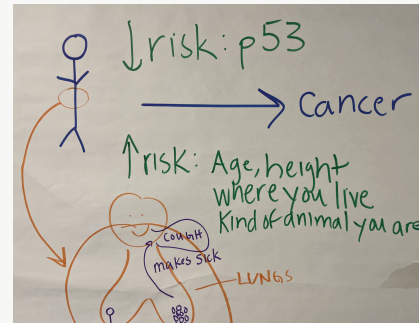
Building toward 2.B.2 **Develop and revise a model** to illustrate the relationship between **systems of specialized cells and cancer cells** at the **scales** of the cells, the tissue, the organ, and the body. (SEP: 2.3; DCI: LS1.A.1 & LS1.A.3; CCC: 2.2)

9 • REVISE CLASS CONSENSUS MODEL

10 min

MATERIALS: science notebook, initial models from day 1

Revise the class consensus model. Display **slide Q**. Say, *You all have made a lot of progress in figuring out answers to our lesson question: What is cancer? at multiple levels of organization. Let's take a moment to update our class consensus model.* Direct student attention to the class consensus model and call on a few students to suggest revisions to the model based on what they figured out in the lesson. After calling on each student, ask the rest of the class to accept or suggest changes to the revision before adding it to the model.



10 • NAVIGATE

9 min

MATERIALS: *Progress Tracker*, science notebook

Introduce the Progress Tracker. Say, *Before we move on, let's take a moment to capture what we figured out so we can track our progress over the course of the unit.* Distribute *Progress Tracker* to each student. Display **slide R**. Give students a few minutes to fill in the unit questions and the rows for Lesson 1 and 2.

Plan for next steps. Call on a few students to share their answers for the questions they still have. Guide students toward questions that will help the class make progress on the first unit question, *Who gets cancer and why?* Say, *How did what we figured out from the differences between non-cancer and cancer cells and how lung cancer makes us sick help us answer our lesson question What is cancer?*

See sample completed *Progress Tracker* below.

	What I figured out in pictures and/or words	Questions I have
Lesson 1 Who gets cancer and why?	Some cancers are more deadly and some are more common in people. Depending on where you live, there are different types of cancer. The taller and older you are, the more cancer you get. p53 keeps some animals from getting cancer.	What is cancer? How are cancer cells different from non cancer cells?
Lesson 2 What is cancer?	Cancer cells look different from non cancer cells. Cancer cells clump together. Cancer cells form tumors which take over the tissue, stop the system from working properly, and make us sick.	How do non cancer cells become cancer cells?

Additional Lesson 2 Teacher Guidance

SUPPORTING STUDENTS IN MAKING CONNECTIONS IN ELA

CCSS.ELA-Speaking and Listening.SL.11-12.5

Draw evidence from informational texts to support analysis, reflection, and research.

Students use images and a reading as informational text to analyze and reflect on the similarities and differences between various types of non-cancer human cells and cancerous cells and on how cancer cells cause disease.

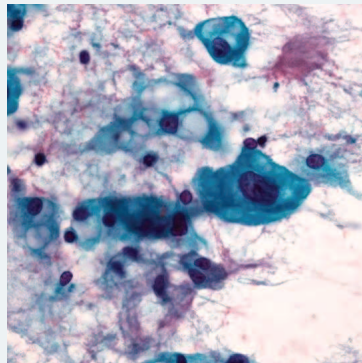
LESSON 3: How do non-cancer cells become cancer cells?

PREVIOUS LESSON We shared our initial ideas about cells and investigated images of cancer and non-cancer cells. We noticed that there are differences between them and that cancer cells have some common characteristics. We developed initial models to explain how cancer makes us sick and read new information to help us answer questions in our models. We revised our individual models and the class consensus model and updated our Progress Trackers. We wondered how non-cancer cells turn into cancer cells.

THIS LESSON

INVESTIGATION

3 days



Illustrations created by OpenSciEd in BioRender

We investigate how non-cancer cells become cancer cells by playing the Cell Game. We figure out that cells go through a cycle to get resources and are checked by p53 before they divide and make new cells. We play the game again and figure out how the cycle can be disrupted when p53 works differently to generate cancer cells. We recognize that our game model has limitations in its ability to explain everything that happens in the cell. We use a scientific model to help fill in gaps in our understanding. We figure out that when cells divide under typical conditions, mitosis results in two cells with identical genetic material. Cancer cells have differences in their chromosomes when compared to non-cancer cells. We wonder what makes those differences and decide to investigate that next.

NEXT LESSON We will make observations about cancer incidence in a computer simulation as we model the relationship between the rates of cellular division, mutation rate, age, height, and cancer. We wonder why some cancers seem to run in families.

BUILDING TOWARD NGSS

HS-LS1-1, HS-LS1-2, HS-LS1-4, HS-LS3-1, HS-LS3-2, HS-LS3-3, HS-ETS1-3



WHAT STUDENTS WILL DO

- 3.A** Use a model to illustrate the role of p53 in the cell cycle and new cell production. (SEP: 2.3; DCI: LS1.B.1; CCC: 2.2)
- 3.B** Use a model to explain how changes to the cell cycle can affect the system, resulting in non-cancer cells producing cancer cells. (SEP: 2.3; DCI: LS1.B.1; CCC: 2.2)
- 3.C** Identify the limits of the Cell Game model and use additional models to illustrate how the cell cycle produces two cells with identical chromosomes. (SEP: 2.4; DCI: LS1.B.1; CCC: 4.4)

WHAT STUDENTS WILL FIGURE OUT

- Cell division happens in all cells through a series of phases, ending with mitosis when one cell forms two new cells.
- The formation of new cells is typically regulated by p53, which provides feedback at specific checkpoints to ensure that a cell does not proceed until sufficient resources are acquired.
- When p53 fails to regulate cell division, non-cancer cells may form cancer cells.
- Cancer cells differ from non-cancer cells in that there are differences in their chromosomes.

Lesson 3 • Learning Plan Snapshot

Part	Duration		Summary	Slide	Materials
1	5 min		NAVIGATE Review, generate, and prioritize questions and next steps.	A	<i>Progress Tracker</i>
2	4 min		INTRODUCE THE CELL GAME, ROUND 1	C-E	<i>Round 1: Cell Game</i>
3	15 min		PLAY THE CELL GAME, ROUND 1 Facilitate game play of the Cell Game Round 1.		<i>Round 1: Cell Game</i> , 1 game board, 4 dice, 1 set of checkpoint cards, 1 Round 1 scorecard per person, 1 game piece per person, 1 non-cancer cell (blue chip) per person, at least 1 additional 1 non-cancer cell (blue chip) per person
4	8 min		COMPLETE MAKING SENSE QUESTIONS Guide students as they answer the Making Sense questions.	F	<i>Round 1: Cell Game</i>
5	8 min		BUILDING UNDERSTANDINGS DISCUSSION ABOUT THE CELL GAME Facilitate a Building Understandings Discussion about Round 1 of the Cell Game.	G-H	<i>Round 1: Cell Game</i>
6	4 min		UPDATE PERSONAL GLOSSARIES Guide a short discussion to update personal glossaries.	I-J	
7	2 min		NAVIGATE Prioritize next steps.	K	
<i>End of day 1</i>					
8	3 min		NAVIGATE Ask students to review their Stop and Jot from the end of last class.	L	
9	15 min		CELL GAME, ROUND 2 Explain the instructions for Round 2 and set students up to play the Cell Game.	M	<i>Round 2: Cell Game</i> , 1 game board, 4 dice, 1 set of checkpoint cards, 1 Round 2 scorecard per person, 1 game piece per person, 1 non-cancer cell (blue chip) per person, 1 set of Cellular Chance cards (13 cards), 15 cancer cells (red chips)
10	8 min		COMPLETE MAKING SENSE QUESTIONS, ROUND 2 Guide students as they answer the Making Sense questions.	N	<i>Round 2: Cell Game</i>

Part	Duration		Summary	Slide	Materials
11	10 min		BUILDING UNDERSTANDINGS DISCUSSION Facilitate a Building Understandings Discussion about Round 2 of the Cell Game.	O	Round 2: Cell Game
12	9 min		NAVIGATE Facilitate a discussion about limitations of models and next steps.	P	
End of day 2					
13	3 min		NAVIGATE Facilitate a discussion about takeaways from the previous class and motivate next steps.	Q	
14	10 min		INTERPRET DATA ABOUT THE CELL CYCLE Guide students in interpreting microscope and graphical data.	R-T	Cell Cycle Data
15	12 min		M PHASE CARD SORT Introduce and distribute mitosis card sort.	U-X	Mitosis Card Sort Key, M phase cards from classroom kit or https://docs.google.com/presentation/d/1ulijU1h5uNz9eISRZC-Y7yJ5OfgzLM7WUjdUS8YOcgs/edit?usp=drive_link
16	7 min		MAKE SENSE OF NON-CANCER AND CANCER CELLS Facilitate activity where students come to consensus about the differences between cancer and non-cancer cells.	Y	Multiple Models, blue and red chips
17	8 min		UPDATE CLASS CONSENSUS MODEL Lead a discussion about how to update class consensus model	Z	
18	5 min		NAVIGATE: UPDATE PROGRESS TRACKERS Ask students to update their Progress Trackers.	AA	
End of day 3					

Lesson 3 • Materials List

	per student	per group	per class
Lesson materials	• <i>Progress Tracker</i> • science notebook • <i>Round 1: Cell Game</i> • <i>Round 2: Cell Game</i> • <i>Cell Cycle Data</i> • <i>Multiple Models</i> • blue and red chips	• 1 game board • 4 dice • 1 set of checkpoint cards • 1 Round 1 scorecard per person • 1 game piece per person • 1 non-cancer cell (blue chip) per person • at least 1 additional 1 non-cancer cell (blue chip) per person • 1 Round 2 scorecard per person • 1 set of Cellular Chance cards (13 cards) • 15 cancer cells (red chips) • science notebook • <i>Mitosis Card Sort Key</i> • M phase cards from classroom kit or https://docs.google.com/presentation/d/1ulijU1h5uNz9eISRZC-Y7yJ5OfgzLM7WUjdUS8YOcgs/edit?usp=drive_link	

Materials preparation (30 minutes)

Review teacher guide, slides, and teacher references or keys (if applicable).

Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

If you purchased a classroom kit, it will come equipped with all the materials needed for students to play the game on days 1 and 2. If these materials are not available, you can print *Game Cards 1* for Round 1 and the *Game Cards 2* for Round 2. Cut along the solid line and fold on the dashed line to make the cards.

You can also print *Game Board* if needed. For best results, print in color on 11 by 17 paper and laminate.

Before class, place non-cancer cell stickers on the blue chips and cancer cell stickers on the red chips. Stickers are designed to fit standard 39 mm poker chips.

Be sure you have the following materials for each student group to play both rounds of the Cell Game:

- 1 game board
- 1 game piece per person
- 4 dice
- 1 Round 1 scorecard per person
- 1 Round 2 scorecard per person
- 1 non-cancer cell (blue chip) per person
- 15 cancer cells (red chips)
- 1 set of checkpoint cards (3 cards)
- 1 set of Cellular Chance cards (13 cards)

For day 3, make sure students have access to the Mitosis Card Sort. If you do not have a classroom kit, print and laminate the slides found at https://docs.google.com/presentation/d/1ulijU1h5uNz9eISRZC-Y7yJ5OfgzLM7WUjdUS8YOcgs/edit?usp=drive_link and *Multiple Models*

Make sure the Community Agreements (from Lesson 1) are accessible.

Lesson 3 • Where We Are Going and NOT Going

Where We Are Going

In this lesson, students investigate how non-cancer cells become cancer cells. Specifically, they look at how cells grow and then divide via mitosis (LS1.B.1). *In multicellular organisms individual cells grow and then divide via a process called mitosis, thereby allowing the organism to grow. The organism begins as a single cell (fertilized egg) that divides successively to produce many cells, with each parent cell passing identical genetic material (two variants of each chromosome pair) to both daughter cells. Cellular division and differentiation produce and maintain a complex organism, composed of systems of tissues and organs that work together to meet the needs of the whole organism.* This builds upon the middle school understanding that organisms reproduce and transfer their genetic information to their offspring (MS LS1.B). The portion of the DCI crossed out will be addressed in Lessons 7 and 8.

Students continue to engage with the focal practice of the unit— *developing and using models*—as they use the Cell Game model to illustrate the role of p53 in the cell cycle, identify limits to this model in terms of explaining the full mechanism responsible for the formation of cancer cells, and fill in some gaps in their understanding using a scientific model.

Students use the crosscutting concept *cause and effect* throughout the lesson by focusing on how p53 causes cell division to progress in a typical way and how, when it works differently, cancer cells can form. Students also use *systems and system models* by identifying the limits of the Cell Game model in predicting how cancer cells form.

Students co-construct definitions for cell cycle and mitosis.

Where We Are NOT Going

Although the game represents the processes of the cell cycle, including cell growth and division, students will not memorize the names of the phases of the cell cycle or mitosis. Knowing these names does not help them explain the anchoring phenomenon or support them in building conceptual understanding of how cells grow and divide (LS1.B). If students need more support in visualizing what cell division looks like, please see Lesson 9 in *OpenSciEd Unit 6.6: How do living things heal? (Healing Unit)*.

Students may have encountered nutrients (MS LS2.B), the idea of organelles as specialized structures within cells (MS LS1.A), and proteins (MS LS 1.A and 3.B) in their prior experiences in and out of school.

LEARNING PLAN for LESSON 3

1 · NAVIGATE

5 min

MATERIALS: *Progress Tracker*, science notebook

Review what we figured out in our last lesson. Display **slide A**. Ask students to turn and talk to a partner and then ask a few pairs to share their answers.

Prioritize next steps. Ask students to recall what questions they still had in *Progress Tracker* and what questions will help the class make progress on figuring out *Who gets cancer and why?* Listen for students to identify that although they figured out what cancer cells are and how they can make people sick, we still need to know how non-cancer cells become cancer cells or where cancer cells come from.

Suggested prompt	Sample student response
<i>What were some of the differences that we discovered between non-cancer and cancer cells?</i>	Non-cancer cells looked different from cancer cells. Cancer cells might form tumors. If a tumor is cancerous, it might invade other body parts and travel throughout the body to form additional tumors. Cancer cells and tumors can affect tissues and organs and make people sick.
<i>What did we decide to investigate next?</i>	How non-cancer cells turn into cancer cells. Where cancer cells come from.

Stop and jot about how cancer cells form. Display **slide B** and ask students to stop and jot in their science notebooks about how non-cancer cells can turn into cancer cells. Then ask students to turn and talk to a partner about their ideas. Call on a few pairs to share their responses.

Suggested prompt	Sample student response
<i>How do non-cancer cells turn into cancer cells?</i>	They get mutations. There is something wrong with them somehow.
<i>What could we do to figure out the answer to our question?</i>	We need to investigate what the cells are doing in our bodies. Maybe we could look at cells. Maybe we could simulate cells somehow.

ADDITIONAL GUIDANCE

If students have questions and/or ideas about how cancer gets into our bodies that are not related to cancer cells arising from non-cancer cells, consider pausing to allow students to work through these ideas. Students may have ideas that cancer is contagious, particularly since many middle and high school students are vaccinated against HPV and may have heard that HPV can cause cancer. While HPV can be contagious, the cancer that can sometimes result is not. Additional resources related to common ideas about what causes cancer can be found at <https://www.cancer.gov/about-cancer/causes-prevention/risk/myths>.

2 · INTRODUCE THE CELL GAME, ROUND 1

4 min

MATERIALS: science notebook, *Round 1: Cell Game*

Introduce the Cell Game, Round 1. Say, *We have a lot of ideas about how cancer cells form and become tumors, but we still have not figured out how this works. I have a model that is set up like a game that I think may help us answer some of our questions.* Display **slide C** and explain that students will play a board game where they roll the dice as they move around the board and earn various resources. Display **slide D**, which shows the game scorecard. Pause to point out the types of resources that students earn: nutrients, proteins, organelles, and chromosomes. Ask students to share their ideas about how each of these terms is defined. Encourage them to record them in their personal glossaries as definitions we encounter. Explain to students that they use the scorecards to track their progress throughout the game and should check off resources as they accumulate them. Distribute *Round 1: Cell Game* and ask students to read the directions with a shoulder partner.

Display **slide E**. Provide time for students to ask clarifying questions about the game directions, or call on students to summarize the steps of the directions out loud before they begin playing.

ADDITIONAL GUIDANCE

Students should be familiar with nutrients (MS LS2.B), the idea of organelles as specialized structures within cells (MS LS1.A), proteins (MS LS 1.A and 3.B), and chromosomes (MS LS3.A and 3.B) from their prior experiences in and out of school. While these terms are part of the middle school grade band of the NGSS, it is a good idea to pause and provide students with an opportunity to define these terms as they are encountered in the lesson to make sure the class has a common understanding.

If students need additional support developing middle school grade band ideas related to cells, see *OpenSciEd Unit 6.6: How do living things heal? (Healing Unit)*. Lessons 10 and 11 focus on how cells get what they need to grow and make more cells.

3 · PLAY THE CELL GAME, ROUND 1

15 min

MATERIALS: *Round 1: Cell Game*, 1 game board, 4 dice, 1 set of checkpoint cards, 1 Round 1 scorecard per person, 1 game piece per person, 1 non-cancer cell (blue chip) per person, at least 1 additional 1 non-cancer cell (blue chip) per person

Play the Cell Game, Round 1. Organize students into small groups of 3–5 students. * Distribute game materials to each group. Give students 15 minutes to complete Round 1 of the game. Circulate around the room as students play the game. Encourage students to begin completing the Making Sense questions in *Round 1: Cell Game* as game play progresses.

* ATTENDING TO EQUITY

As students prepare to play the Cell Game, review and discuss the class Community Agreements. Ask students to discuss which agreements they think may apply while playing the game. You could also ask

ADDITIONAL GUIDANCE

The Cell Game was adapted from materials created by the Fred Hutchinson Cancer Research Center. Fred Hutchinson Cancer Research Center. (2021, August 28) *Frontiers: Intro to Cancer Unit*.

students to focus on one agreement that they would like to improve upon personally during this lesson. Then at the end of the lesson, give students a moment to reflect on how they did with their selected agreement.

4 · COMPLETE MAKING SENSE QUESTIONS

8 min

MATERIALS: *Round 1: Cell Game*, science notebook

Complete the Making Sense questions. Display **slide F** and reflect on Round 1 results. While still in their groups, ask students to complete the Making Sense questions on the *Round 1: Cell Game*. Ask several groups to share their thinking with the class.

5 · BUILDING UNDERSTANDINGS DISCUSSION ABOUT THE CELL GAME

8 min

MATERIALS: *Round 1: Cell Game*, science notebook



Lead a Building Understandings Discussion.* Display **slide G**. Say, *As you completed the Making Sense questions, you summarized what the game modeled and started to relate it to what happens in an actual cell. Let's make sense of that.* Use the prompts below as a guide.

* STRATEGIES FOR THIS BUILDING UNDERSTANDINGS DISCUSSION

Asking students to restate what another student has said helps students listen carefully to each other so that they can work with others' ideas. This move can feel odd to students at first, so it will help if you let them know ahead of time that you will be asking this.

Suggested prompts	Sample student responses	Follow-up questions
<i>What happened in the cell in phases G1-G2?</i>	The cell was getting nutrients, proteins, and organelles during Phase G1 and Phase G2. The cell was getting (or making) chromosomes during Phase S. The cell was waiting for something/moving slowly during Phase M. The cell grows.	<i>What happens to the cell as it adds all of those resources?</i>
<i>What happened at the checkpoints?</i>	p53 is checking the cell to make sure it has what it needs. If the cell does not have what it needs, it gets sent back to fix it or it gets destroyed.	<i>What happens if the cell does not have enough resources?</i>
<i>What is p53's function in the cell?</i>	It checks everything and decides what the cell needs to do next based on what it has in it.	<i>What kinds of messages does p53 give to cells?</i>

Suggested prompts	Sample student responses	Follow-up questions
<i>What happened during phase M?</i> <i>What happened to the cell once it passed the final checkpoint?</i>	The cell is going through some specific steps, but we do not know exactly what. It makes a new cell.	<i>What does it mean that you had to roll a certain number to progress in this phase?</i> <i>What does it mean that you got a new blue chip?</i> <i>Is the new blue chip similar to or different from your original chip?</i>
KEY IDEAS Purpose of this discussion: To help students relate the steps in the game to the steps in the cell and to begin to build understanding about the role that p53 plays in controlling cell division. Listen for these ideas: - Cells acquire resources, such as nutrients, organelles, and chromosomes, which contribute to their growth. (DCI: LS1.B.1; CCC: 2.2) - Once a cell has adequate resources, it divides via mitosis. (DCI: LS1.B.1; CCC: 2.2) - At checkpoints, p53 regulates the cell cycle, making sure it has what it needs before it divides. (DCI: LS1.B.1; CCC: 2.2)		
ASSESSMENT OPPORTUNITY What to look for/listen for in the moment: See Key Ideas above. What to do: If students struggle to connect what happened in the game to what happens in a cell, they may need more time to discuss what each part of the game represents. Remix the student groups and give them additional time to discuss the Making Sense portion of <i>Round 1: Cell Game</i>. Provide students with an opportunity to revise the Making Sense chart following the discussion. Collect from each student and provide feedback using <i>Making Sense Key</i>. 3.A Use a model to illustrate the role of p53 in the cell cycle and new cell production. (SEP: 2.3; DCI: LS1.B.1; CCC: 2.2)		

6 · UPDATE PERSONAL GLOSSARIES

4 min

MATERIALS: science notebook

Introduce the cell cycle. Display **slide H** and say, *What you all have just described is what scientists call the cell cycle. Instead of the rectangle our model used in the game, a scientists' model is usually drawn as a circle.* Talk through the phases of the game and how they relate to the image on the slide.

Add *cell cycle* to personal glossaries. Display **slide I**. Pause and give students a moment to come to consensus on a definition. Definitions might be similar to: *The cycle cells go through to grow and divide into new cells.*

Share a video of cell division. Display **slide J**. Let students know that you have a video that shows what the process actually looks like in a cell and focus on the part where the cell divides. Play https://youtu.be/zDM4_ORbHZQ.

ADDITIONAL GUIDANCE

An additional term that students encounter here is *synthesis*. If students are not familiar with the definition, help them come to a consensus on a definition similar to, *making something from smaller parts*.

Students may also have heard the term *mitosis* and may bring it up here. They may notice it in the figure on **slide H**. When students bring this up, pause to co-construct an initial definition. Students will add to this definition later in the lesson. Definitions may look something like: *A series of steps that results in two cells [they may or may not have ideas about them being identical] from one*.

7 · NAVIGATE

2 min

MATERIALS: science notebook

Stop and Jot. Display **slide K**. Acknowledge that the class has figured out a lot about how cells grow and divide. Ask students to stop and jot in their notebooks about what we still need to know about *How do non-cancer cells become cancer cells?* Students should recognize that although they understand how non-cancer cells make more cells, they do not yet know how those cells could become cancer cells.

End of day 1

8 · NAVIGATE

3 min

MATERIALS: science notebook

Recall what was figured out in the previous class. Display **slide L**. Ask students to look at what they wrote down in their science notebooks at the end of the previous class to remember what the Cell Game helped us figure out about how non-cancer cells become cancer cells and what we still need to figure out. Listen for responses related to how the game helped us figure out how non-cancer cells make new cells and how it did NOT help us figure out how they turn into cancer cells.

9 · CELL GAME, ROUND 2

15 min

MATERIALS: *Round 2: Cell Game*, 1 game board, 4 dice, 1 set of checkpoint cards, 1 Round 2 scorecard per person, 1 game piece per person, 1 non-cancer cell (blue chip) per person, 1 set of Cellular Chance cards (13 cards), 15 cancer cells (red chips)

Introduce the Cell Game, Round 2. Let students know they will play the Cell Game one more time to try to figure out the answer to the questions they still have about how non-cancer cells become cancer cells. Display **slide M**. Say, *This round has some new features that I think will help us answer our questions*. Explain to students that the big difference between Round 1 and Round 2 is that each time they land on a light blue square, they will draw a Cellular Chance card, follow the directions on the card, and then place the card at the bottom of the pile.

Play the Cell Game, Round 2. Organize students into small groups of 3-5 students. Distribute *Round 2: Cell Game* to each student and game materials to each group.

10 · COMPLETE MAKING SENSE QUESTIONS, ROUND 2

8 min

MATERIALS: *Round 2: Cell Game*, science notebook

Reflect on Round 2 results. Display slide N. While still in their groups, ask students to complete the Making Sense questions on *Round 2: Cell Game*.

ADDITIONAL GUIDANCE

Making connections in math: Ask students to keep track of how many cancer and non-cancer cells they produce. At the end of Round 2, ask each group to add their results to a class data table. Then students determine the percentage of cancer cells produced compared to non-cancer cells. Students engage in mathematical modeling as they develop an understanding of the likelihood that cell division results in a cancer cell when p53 is functioning typically versus when p53 is functioning differently. Emphasize to students that these percentages may not reflect reality and that any percentages calculated are a result of game mechanics only. Should most students end up with cancer cells during the game, it is important that they do not come away thinking that developing cancer is inevitable in their lifetime.

This math extension supports CCSS.MATH.PRACTICE.MP.4, *model with mathematics*.

11 · BUILDING UNDERSTANDINGS DISCUSSION

10 min

MATERIALS: *Round 2: Cell Game*



Facilitate a Building Understandings Discussion.* Say, *Let's see if we can come to consensus on how non-cancer cells become cancer cells based on what happened in Round 2.* Display slide O. Ask students to refer to *Round 2: Cell Game* as they participate in the discussion. Use the prompts below as a guide.

* STRATEGIES FOR THIS BUILDING UNDERSTANDINGS DISCUSSION

As students participate in the discussion, encourage them to use evidence from the game to justify how the game helps us answer the question, *How do non-cancer cells become cancer cells?*

Suggested prompt

Sample student response

What happened in Round 2 that was different from in Round 1?

Some of us ended up with cancer cells (red chips).

Sometimes the Cellular Chance cards let us skip steps and move through the game board faster even when we did not have the right stuff.

We did not always need as many nutrients, organelles, or proteins to keep going in the game.

Sometimes p53 did not work properly.

Some of us could pass a checkpoint even if we did not have all the things the checkpoint required.

How did the differences change the outcome of the game?

In the end we made more cells, but some of them were cancer cells.

Suggested prompt	Sample student response
<i>How was the role of p53 different?</i> <i>How does this game help answer the question, How do non-cancer cells become cancer cells?</i>	It was still there at the checkpoints, but when it was not working properly, we could skip it and it did not check to make sure the cell had everything it needed. In Round 1, p53 always worked properly and provided feedback to the cell but not in Round 2. In Round 1, p53 made sure that only non-cancer cells were made. In Round 2, we got cancer cells when p53 didn't work properly. Non-cancer cells can become cancer cells when they pass a checkpoint without all the requirements. It seems like whether you end up with a cancer cell has something to do with whether p53 is working properly. When p53 checks the cell, we usually end up with non-cancer cells at the end of mitosis. But when p53 is not working, sometimes we end up with cancer cells.
KEY IDEAS	Purpose of this discussion: To help students relate the Cellular Chance cards in the game (SEP: 2.3) to a disruption to the cell cycle that can cause cancer cells to form. Listen for these ideas: - When p53 was working properly in the cell cycle, cells that did not have all of the requirements could not pass the checkpoints and divide. (DCI: LS1.B.1; CCC: 2.2) - When the cell cycle is not working properly, cells can pass checkpoints without meeting the requirements. (DCI: LS1.B.1; CCC: 2.2) - If a cell that does not have all the resources it needs and divides anyway, it can form a cancer cell. (DCI: LS1.B.1; CCC: 2.2)
ASSESSMENT OPPORTUNITY	What to look for/listen for: See Key Ideas above. What to do: If students have trouble relating what happened in the game to what happens in a real cell, provide them with a paper copy of <i>Game Board</i>. Ask them to mark up the gameboard by using pictures and/or words to explain what is happening at each step of the game. Building toward 3.B Use a model to explain how changes to the cell cycle can affect the system, resulting in non-cancer cells producing cancer cells. (SEP: 2.3; DCI: LS1.B.1; CCC: 2.2)

12 · NAVIGATE

9 min

MATERIALS: science notebook

Reflect on the limitations of the Cell Game model. Say, *Our model helped us figure out a lot, but it left us with some questions.* Display **slide P** and ask students to turn and talk with a partner about where the model helped us make progress and the limits of the model. Ask them to record their answers in their science notebooks. Once students have had a chance to discuss their responses, call on a few pairs to share. End the discussion by focusing on ideas for next steps.

Suggested prompt	Sample student response
<i>What did the model help us explain?</i>	How p53 regulates the cell cycle. What happens when p53 is not regulating the cell cycle. How non-cancer cells could divide and make cancer cells.
<i>What questions do we still have that the model COULD NOT help us answer?</i>	We do not really know what is happening with the organelles, nutrients, and proteins the cell is acquiring. We do not know how the cell makes or gets more chromosomes, where it comes from, or what the cell does with it. We really do not know anything about what is happening in phase M, where we had to roll a certain number to move forward. We know that when p53 is working differently, we make cancer cells, but we do not know how those cells are different.
<i>How can we make progress on those questions?</i>	We could do more research. We could look at more cells. We could ask a scientist.

End of day 2

13 · NAVIGATE

3 min

MATERIALS: science notebook

Recall takeaways from the previous class. Display **slide Q**. Ask students to turn to their notes from the end of the last class period to review what the Cell Game model could and could not help them explain. Call on a few students to share their ideas.

Motivate next steps. Say, *One of the things you mentioned in our last class and now was that our Cell Game model was limited in its ability to help us understand what was happening in the different phases and how cancer cells are different from non-cancer cells. You all also suggested that we could do more research, look at more cells, or ask a scientist. I think those are great ideas. Let's do more research! I have collected some data and some models that might help.*

14 · INTERPRET DATA ABOUT THE CELL CYCLE

10 min

MATERIALS: science notebook, *Cell Cycle Data*

Prepare science notebooks. Display slide R. Say, *We are going to look at three different pieces of evidence for non-cancerous cells to see if we can better understand the Cell Game model. For each piece, I would like you to briefly record what you think the evidence is showing and how this might be related to the Cell Game.* Ask students to create a T-chart to record their thinking. *

Interpret cell growth data. Display slide S. Say, *The first piece of data includes images of the same set of cells over different periods of time during the cell cycle. Look at the figure and the caption. Record your thoughts in your science notebook.* Ask students to share their thoughts with a partner and then with the class using the prompts below as a guide. The image found on the slide is also available in *Cell Cycle Data*.

ADDITIONAL GUIDANCE

Students might not recognize the units μm^2 . They do not need to understand the units beyond that a cell with a size of $45 \mu\text{m}^2$ is larger than a cell with the size of $15 \mu\text{m}^2$. Students should connect the cell colors to the colors in the key (red = larger, blue = smaller).

This is an opportunity for students to think about scale (e.g., millimeters vs. micrometers, etc.). $1 \mu\text{m}$ (micrometer) = .001 mm. In the figure, μm^2 is referring to the outer cell surface area which is correlated to cell volume.

For more information see:

Jones, A. R., Forero-Vargas, M., Withers, S. P., Smith, R. D., Traas, J., Dewitte, W., & Murray, J. L. (2017). Cell-size dependent progression of the cell cycle creates homeostasis and flexibility of plant cell size. *Nature Communications*, 8(1). <https://doi.org/10.1038/ncomms15060>

* ATTENDING TO EQUITY

Consider adding or removing scaffolding for your students to support them as they use the data to provide evidence of mechanistic accounts. Some examples of scaffolding may include metacognitive techniques to think about how we interpret figures and/or discussing as a class different parts of the figures like legends, keys, axes, and labels before students interpret figures. Some examples of less scaffolding may include removing visual cues like arrows from the slides for Figure 1 or the cell diagrams from Figure 2, or separating images like the microscope images from the model images in the M Phase Card Sort.

Suggested prompt	Sample student response
<i>What do you notice about this image?</i>	The arrow is pointing at the same cell at different time points. The cell seems to be getting bigger. It starts blue, then goes to green, and then to yellow. According to the colored bar, yellow means a bigger size than blue. At 80 hr time point, the arrow is now pointing at two cells. The cell seems to have split.
<i>How do you think this figure is related to the Cell Game?</i>	The figure shows the cell getting larger before dividing. In the Cell Game, we had to collect things like organelles, proteins, nutrients, and genetic material. Adding those things to the cell could make it bigger. During G1, S, and G2, the cell probably needs space for all this extra material and gets bigger. In the Cell Game, the cell splits. We see one cell and then it becomes two cells at 80 hours.
<i>Based on this image, why do you think a cell needs to gather all this stuff before dividing?</i>	The cell split into two. Maybe these new cells need stuff to survive.

Interpret genetic material data. Display **slide T**. Say, *Our next figure is a graph about the relative amount of genetic material in a cell during different phases of the cell cycle. Look at the figure and the caption and record your thoughts in your science notebook. Ask students to share their thoughts with a partner and then with the class. The image found on the slide is also available in *Cell Cycle Data*.*

ADDITIONAL GUIDANCE

The y-axis is a measure of the relative amount of genetic material in the cell. The class may need to come to consensus about what the word relative means. Consider using the term relative in a sentence to compare something in the classroom, such as different numbers of pencils in your hands. The number in one hand is more or less relative to the other. In the game, students considered genetic material in the form of chromosomes. DNA will be introduced in Lesson 4.

Suggested prompts	Sample student responses	Follow-up questions
<i>What do you notice in the figure?</i>	The relative amount of genetic material starts at one and then increases to two (doubles). There are images of cells at G1 and G2. There are more squiggly lines/genetic material in the G2 phase.	<i>What do you think the squiggly lines/genetic material are? Think about your game.</i>
<i>How do you think this figure relates to the Cell Game?</i>	In the game, we added chromosomes during the S phase. In the graph, this is when the genetic material is increasing.	<i>In the cell game, you added four chromosomes to a cell during the S phase. Based on this figure, how many chromosomes do you think were in the cell during G1?</i>
<i>How do the chromosomes being added to the cell compare to the original chromosomes?</i>	The cell is adding chromosomes that look like the chromosomes that already exist in the cell. There were two yellow and two purple chromosomes, and then there were four yellow and four purple chromosomes. The chromosomes look doubled, like they have two squiggly lines.	
<i>Which phases of the cell cycle did the data help us better explain? Which phases do we still need more information about?</i>	We saw the cells growing, which gives us evidence related to G1 and G2. We saw the genetic material doubling, which gives us evidence related to S. We do not have any evidence about M.	<i>What did you see in the pictures of the cells?</i> <i>What did you see in the graph of genetic material?</i>

15 • M PHASE CARD SORT

12 min

MATERIALS: science notebook, *Mitosis Card Sort Key*, M phase cards from classroom kit or https://docs.google.com/presentation/d/1ulijU1h5uNz9eISRZC-Y7yJ50fgzLM7WUjdUS8YOcgs/edit?usp=drive_link

Review the M phase from the Cell Game. Display **slide U**. Say, *You all noticed that we need additional evidence to support our understanding of the M phase.* Use the prompts below to generate student ideas about what they already know about the M phase and what questions they have.

Suggested prompts	Sample student responses	Follow-up questions
<i>What happened during the M spaces in the game?</i>	We started the game with one cell. After the M phase, we had two cells. We made another cell.	<i>What about the dice? Were there rules? Do you think they meant anything?</i>
<i>What were the rules about the dice? Why were they there?</i>	To get through the M spaces, we had to roll 1, 2, 3, 4, and 5 in that order. Maybe the order is important. We could not roll a 3 first.	<i>Why might the order matter?</i>

 **Introduce M phase card sort.** Display **slide V**. Say, *I have some data about the M phase that I think will help answer your questions. The data consists of actual cell photos and drawings from a scientific model of a cell during the M phase.* Ask students to work with a partner to 1) use the scientific model to identify the blue- and green-colored structures in the photos, 2) sequence the photos from start to end, and 3) describe what they think is happening during the M phase. Distribute one set of M phase cards to each pair. Display **slide W** and ask them to record their thinking in their T-charts in their science notebooks.

*** ATTENDING TO EQUITY**

The NGSS refers to the cell at the beginning of the cell cycle as the parent cell and the two cells at the end as daughter cells. This language could reinforce gender binary thinking and you may want to consider how to best represent these relationships. For more resources see:

<https://www.genderinclusivebiology.com/>

White, Peter, et al. "Ditch gendered terminology for cell division." *Nature*, vol. 599, no. 7886, 25 Nov. 2021, p. 556. Gale In Context: Environmental Studies, link.gale.com/apps/doc/A683612168/GRNR?u=coloboulder&sid=ebsco&xid=d3ec1cf3.

ASSESSMENT OPPORTUNITY

What to look for/listen for in the moment:

- The Cell Game model helps us see that we start with one cell and end with two but not what goes in between. (SEP: 2.4; DCI: LS1.B.1; CCC: 4.4)
- The cards show that the cells each get half of the chromosomes because they doubled in the S phase. (SEP: 2.4; DCI: LS1.B.1)
- The cells end up with identical chromosomes. (DCI: LS1.B.1)

Key to the card sort is available in *Mitosis Card Sort Key*.

What to do: Circulate around the room to support student thinking. If students struggle to order the cards, consider asking them to focus on one structure and then check if that sequence of cards makes sense for other structures. Ask clarifying questions as needed, such as:

- What structures do you see in the scientific model that you did not see in the game?
- What structures do you think are colored blue and green in the cell photos? How did you figure it out?
- How are you figuring out how to sequence the cards? What does the Cell Game model tell you about the order?
- What structures do you see in the scientific model that you do not see in the photos?
- How do the new cells compare to the starting cell?
- What do you think happens to these new cells?

For students who quickly grasp the ideas in the card sort, consider showing a still from the mitosis video (from slide J). Ask students to identify a cell in M phase and to explain their thinking. Replay video to give students a chance to apply their knowledge.

Building toward 3.C Identify the limits of the Cell Game model and use additional models to predict changes to the cell cycle resulting in differences in the chromosomes in the cells produced by cell division. (SEP: 2.4; DCI: LS1.B.1; CCC: 4.4)

ADDITIONAL GUIDANCE

Only certain cell structures are visible in the cell images. The chromosomes (DNA) are blue, spindle fibers (microtubules) are green, and centromeres are red. Students will not see a cell membrane or nuclear envelope even though they are in the scientific model.

The drawings show chromatin condensing into chromosomes; both are labeled as chromosomes. DNA organization is further discussed in Lessons 4 and 5).

Update personal glossaries. Display *slide X*. If students have not yet brought up *mitosis*, let them know that the process they just described with the card sort is called mitosis. Support them in coming to a consensus on the definition and adding to their personal glossaries. For students who had already added mitosis, give them a chance to revise and add to their definition. If students did not add *nucleus*, *cell membrane*, and *spindle* to their personal glossaries as they worked on the card sort, encourage them to add these definitions now. *

ADDITIONAL GUIDANCE

A definition for *mitosis* may look like: *Part of the cell cycle where one cell divides into two cells with identical chromosomes/genetic material*. They may include the differences in mitosis for cancer and non-cancer cells.

16 · MAKE SENSE OF NON-CANCER AND CANCER CELLS

7 min

MATERIALS: science notebook, *Multiple Models*, blue and red chips

Make sense of cancer and non-cancer cell models using the Cell Game. Display *slide Y*. Quickly assess class on how they are feeling about what was happening during the different phases of the Cell Game (e.g., fist-to-five). Acknowledge responses. Say, *In the Cell Game, we saw cancer and non-cancer cells. Have we looked at anything today that helped us understand the differences in these cells better?* Acknowledge responses. Say, *I have scientific models of day 1 and day 2 of the Cell Game. Work with a partner to place the chips on the models to show whether the cell is cancerous or non-cancerous.* Distribute chips and *Multiple Models*.

ADDITIONAL GUIDANCE

This is an opportunity to circulate and gauge what students remember about the Cell Game and possibly pre-assess their ideas about chromosomes, inheritance, and phenotypes (Lesson 8).

If students struggle getting started with the activity, ask them what happened on day 1 and emphasize answers about there being only non-cancerous cells.

If students struggle with identifying the cancer cell on the day 2 model, ask students to compare the cells to the other non-cancer cells they have already identified.

Suggested prompts	Sample student responses	Follow-up questions
<i>What did you notice about cancer and noncancerous cells?</i>	The cancer cell has a chromosome that looks different: it is red and yellow. The non-cancer cells all have the same chromosomes as the starting cell, which was a non-cancer.	<i>How did you figure that out?</i>

Suggested prompts	Sample student responses	Follow-up questions
Based on the Cell Game, how do you think this change might have occurred? (Hint: what was the difference between day 1 and day 2 of the Cell Game?)	On day 1, cells stopped at checkpoints and could only go on if it had stuff it needed. On day 2, some cells could go past checkpoints without being ready or having what it needed. On day 2, cells passed checkpoints when there was a 'bad'/non-functioning p53. Maybe it's related to p53 because that was what was not working when a cancer cell was produced.	If students only talk about checkpoints and not p53, ask: Why did cells skip checkpoints?

17 · UPDATE CLASS CONSENSUS MODEL

8 min

MATERIALS: None

Update class consensus model. Display slide Z. Say, *Wow! You have all processed a lot about the cell cycle and the Cell Game. Let's add some of our new ideas to our consensus model. What should we add?*

KEY IDEAS

Purpose of this discussion: To come to consensus on the idea that cancer cells have a chromosomal difference compared to non-cancer cells and elevate that we think p53 is somehow involved.

Listen for these ideas:

- Cells go through a cell cycle.
- A lot happens during the cell cycle: cells grow, chromosomes double, and the cell divides during mitosis.
- When a non-cancer cell divides into non-cancer cells, the new cells are identical: their chromosomes are the same.
- When a non-cancer cell divides into a cancer cell, something is different about the chromosomes.
- The cell cycle has checkpoints.
- When a cell skips a checkpoint, it becomes cancerous.
- Checkpoints work when there is a functioning/working p53.
- Cells skip checkpoints when there is a non-functioning/non-working p53.

Listen for these uncertainties:

- How does p53 work?
- Is p53 involved in making a different chromosome?
- When/Where in the cell cycle do the chromosomes change?
- How are chromosomes different? What is a chromosome made of?

* STRATEGIES FOR THIS CONSENSUS DISCUSSION

There are two goals of this discussion: (1) to continue to help students build the habit of sharing their ideas publicly and (2) to determine the sets of ideas that all students in the class agree with vs. the set of ideas that there is disagreement with or we are more uncertain about. It is important to accept all student responses and to encourage students to share their ideas. Further, it is important to highlight areas of disagreement and help students clearly explicate their thinking in these areas. Be careful not to favorably respond to any one idea over others so as not to "give away" what might be going on in the phenomenon.

MATERIALS: None

Update Progress Trackers. Display slide AA. Ask students to turn to their *Progress Tracker* to update them with the progress they have made on their thinking related to our unit question, *Who gets cancer and why?*

One possible representation of a completed Progress Tracker is shown below.

	What I figured out in pictures and/or words	Questions I have
Lesson 3 How do non-cancer cells become cancer cells?	Cancer cells form when p53 is not working in the cell cycle. Normally, cells grow, make new chromosomes, and divide, and p53 checks to make sure it has everything it needs before it divides. If it is not working correctly, the cells that get made do not have everything they need but get made anyway. They are different because they have different chromosomes.	What does it mean that the chromosomes are different? How did they get to be different?

Additional Lesson 3 Teacher Guidance

SUPPORTING STUDENTS IN MAKING CONNECTIONS IN ELA

CCSS.ELA-Speaking and Listening.SL.11-12.5

Make strategic use of digital media (e.g., textual, graphical, audio, visual, and interactive elements) in presentations to enhance understanding of findings, reasoning, and evidence and to add interest.

Teachers present a visual element, (video, images), and guide students as they engage with an interactive element (Cell Game) in order to collect evidence and develop a model to explain how non-cancer cells can sometimes form cancer cells when p53 functions differently.

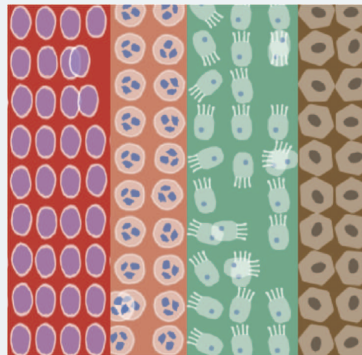
LESSON 4: Why are some kinds of cancer more common than others in older and taller people?

PREVIOUS LESSON We investigated how non-cancer cells become cancer cells by playing the Cell Game. We figured out that cells go through a cycle to get resources and are checked by p53 before they divide and make new cells. We played the game again and figured out how the cycle can be disrupted when p53 works differently to generate cancer cells. We recognized that our game model had limitations in its ability to explain everything that happens in the cell. We used a scientific model to help fill in gaps in our understanding. We figured out that when cells divide under typical conditions, mitosis results in two cells with identical genetic material. Cancer cells have differences in their chromosomes when compared to non-cancer cells. We wondered what made those differences and decided to investigate that next.

THIS LESSON

INVESTIGATION

1 day



We decide to investigate how cell division could lead to different rates of cancer for older and taller people. We use a computer simulation to model these mutation rates in different cell types from different systems and to collect evidence. We figure out that there is a relationship between mutation rates, rates of cellular division, age, and height. We wonder why it seems that some cancers run in families.

NEXT LESSON We will investigate how chromosome differences happen in cancer cells through a computer simulation and reading. We will construct an explanation about the role of DNA replication, mutations, and p53 in chromosome differences. We will give and receive peer feedback and revise our explanations.

BUILDING TOWARD NGSS

HS-LS1-1, HS-LS1-2, HS-LS1-4, HS-LS3-1, HS-LS3-2, HS-LS3-3, HS-ETS1-3



WHAT STUDENTS WILL DO

7.A Use a computer simulation as evidence to develop and revise a model that predicts how the rate of cell division affects the likelihood of cancer. (SEP: 2.3; DCI: LS3.B.1 & LS1.B.1; CCC: 4.4)

WHAT STUDENTS WILL FIGURE OUT

- Some cell types divide more than others.
- The longer you live, the more your cells divide.
- The taller you are, the more your cells divide.
- The more cellular divisions there are, the more chances there are for mutations to happen.

Lesson 4 • Learning Plan Snapshot

Part	Duration		Summary	Slide	Materials
1	3 min		NAVIGATE Facilitate discussion about what we figured out in our consensus model and what questions we decided to prioritize.	A	Driving Question Board, classroom consensus model
2	8 min		DEVELOP INITIAL MODELS Guide students to construct an initial model that explains how the cell cycle and cell division lead to different cancer rates for different cancer types and older and taller people.	B-E	<i>Age and Height</i>
3	13 min		CELL GROWTH AND CANCER COMPUTER SIMULATION Demonstrate use of the Cell Growth and Cancer computer simulation and direct student exploration.	F-H	<i>Cell Growth Simulation</i> , one computer for each pair with access to https://www.openscienced.org/simulation/b3-l4-cell-growth-cancer/
4	8 min		BUILDING UNDERSTANDINGS DISCUSSION ABOUT THE SIMULATION Lead a Building Understandings Discussion about cell division, mutation rate, cell type, and cancer.	I-J	<i>Cell Growth Simulation</i>
5	11 min		SHARE PEER FEEDBACK AND REVISE INITIAL MODELS Encourage students to revise their initial models, adding what they figured out in the Cell Growth and Cancer computer simulation.	K-L	<i>Peer Feedback Protocol, Progress Tracker</i>
6	2 min		NAVIGATE	M	

End of day 1

Lesson 4 • Materials List

	per student	per group	per class
Lesson materials	• science notebook • <i>Age and Height</i> • <i>Cell Growth Simulation</i> • <i>Peer Feedback Protocol</i> • <i>Progress Tracker</i>	• one computer for each pair with access to https://www.openscienced.org/simulation/b3-l4-cell-growth-cancer/	• Driving Question Board • classroom consensus model

Materials preparation (20 minutes)

Review teacher guide, slides, and teacher references or keys (if applicable).

Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

Three-hole-punch all handouts to be added to student notebooks.

One computer per pair of students with access to <https://www.openscienced.org/simulation/b3-l4-cell-growth-cancer/>

Lesson 4 • Where We Are Going and NOT Going

Where We Are Going

The goal of this lesson is for students to gather evidence from the computer simulation that different cells have different rates of division and, therefore, different rates of mutation. They will be able to adjust the variables of height and age to discover that the more times a cell divides, the more chances there are for mutation and, therefore, cancer. They will also see that it takes a long time for cancer to occur through random mutation, which usually happens for much older people.

This lesson continues to develop an understanding of HS-LS3.B.1 from previous lessons and MS-LS3.B.2, which names mutations as a source for genetic variation, but whose effects will be varied. Students will see that mutation rates differ depending on cell type, and the accumulation of mutations is a cause of cancer. Students build on ideas related to the following disciplinary core idea:

- ~~LS3.B.1: 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)

This lesson also begins to develop an understanding of HS-LS1.B.1 from previous lessons and MS-LS1.A which supports students in understanding the hierarchy of organization of complex organisms from cells to body systems. Students develop initial ideas of how cells differentiate from the generic cells they had been engaging with in previous lessons to the different cell types in the computer simulation. Students build on ideas related to the following disciplinary core idea:

- ~~LS.1.B.1: In multicellular organisms individual cells grow and then divide via a process called mitosis, thereby allowing the organism to grow. The organism begins as a single cell (fertilized egg) that divides successively to produce many cells, with each parent cell passing identical genetic material (two variants of each chromosome pair) to both daughter cells.~~ Cellular division and differentiation produce and maintain a complex organism composed of systems of tissues and organs that work together to meet the needs of the whole organism. (HS-LS1-4)

In the computer simulation, students use the crosscutting concept *systems and system models* to investigate the unequal results caused by cell division. Different cell types divided at different rates caused the variability of mutation rates. They saw that cancer incidence resulted from the accumulation of mutations in the other cell types. They build on their use of this element of the crosscutting concept from Lesson 3 and in *OpenSciEd Unit B.1: How do ecosystems work, and how can understanding them help us protect them? (Serengeti Unit)* and *OpenSciEd Unit B.2: What causes fires in ecosystems to burn and how should we manage them? (Fires Unit)*.

Students use the science practice *developing and using models* to explore the relationship between being older and taller by developing models to visualize their initial ideas about how differences in cell types could cause different results in rates of cancer. Students then use a computer simulation to investigate these ideas. They build on the use of this practice throughout the unit and from *Fires Unit*.

Where We Are NOT Going

Although the simulation compares cellular division across different cell types, details about the different cell types and their specific functions are not investigated. If students are interested in learning more about cell division and cancer in different cell types this can serve as an extension.

LEARNING PLAN for LESSON 4

1 · NAVIGATE

3 min

MATERIALS: science notebook, Driving Question Board, classroom consensus model

Review classroom consensus model. Display **slide A**. Ask students to recall the big ideas they figured out in Lesson Set 1 and included in their consensus models in the last lesson. Ask students to recall what they decided to investigate next when they revisited their DQB in the previous lesson. Call on a few students to share. Help students remember that we are still figuring out the genetic basis of cancer based on a single gene and still have questions about why taller and older people get cancer more than others.

Suggested prompt

What were the big ideas we figured out in Lesson Set 1 and included in our consensus model?

What questions did we decide to investigate next on the DQB?

Sample student response

We figured out the genetic basis of cancer.

Why does being older/taller increase your risk of getting cancer?

2 · DEVELOP INITIAL MODELS

8 min

MATERIALS: science notebook, *Age and Height*

Turn and Talk. Display **slide B**. Ask students to turn and talk about how what we figured out in our consensus model can help us think about higher cancer rates in older and taller people. Ask students to record their ideas in their science notebooks. Refer students to *Age and Height* to help them recall the data they investigated in Lesson 1.

Initial model construction. Display **slide C**. Have students individually develop initial models in their science notebooks that explain our lesson question: *Why are some kinds of cancer more common than others in older and taller people?*

Remind students that models include components, interactions, and mechanisms. Let students know that since these are initial models, we are still determining all components and how they are related. Suggest adding question marks where they know something is happening but do not know what. Encourage them to refer back to their science notebook for ideas.

Turn and Talk. Display **slide D**. Ask students to turn and talk to their neighbor to share their initial models. Each partner should share their thinking for 1 minute and then listen while their partner shares. Encourage students to look for similarities and differences and to ask questions of each other.

3 · CELL GROWTH AND CANCER COMPUTER SIMULATION

13 min

MATERIALS: *Cell Growth Simulation*, one computer for each pair with access to <https://www.openscienced.org/simulation/b3-l4-cell-growth-cancer/>

Introduce the Cell Growth and Cancer computer simulation. Display **slide E**. Share that you have a computer simulation that can help them continue to make progress on their questions. Share that the simulation has five different cell types: two different kinds of blood, colon, skin, and brain.

Turn and Talk. Ask students to turn and talk to their partners about how what we figured out about the cell cycle and mitosis is related to these different cell types. Display **slide F**. Once students have had a chance to share their ideas, ask them to update their initial models and add anything new that they discussed.

Demonstrate how to use the computer simulation. Display **slide G**. Play <https://www.youtube.com/watch?v=XVbX8yuinxY> Pass out computers to pairs of students if possible and *Cell Growth Simulation* to each student. Ask students to follow the directions on their handout. While the last stage of the simulation is running, they should answer the Making Sense questions that follow. Let students know they will share their thinking in a whole-class discussion.

ADDITIONAL GUIDANCE

The “Adult-Height” slider in the simulation provides height measurements in centimeters. If students struggle to equate a person’s height to this unit of measurement, choose a few heights from the simulation and convert them to a more familiar unit, like feet and inches. Then, ask students to visualize two people of those heights standing beside each other. For example, visualizing 180 cm as a person who is 5’11” and 220 cm as a person who is 7’2” may help students conceptualize the changes made when moving the “Adult-Height” slider up and down.

Set up a class data table. Display **slide H**. On the whiteboard (or digitally), set up a data table for students to share their age and biopsy results data at the end of the simulation. Encourage small groups to run the simulation several times for a more significant class data set.

4 · BUILDING UNDERSTANDINGS DISCUSSION ABOUT THE SIMULATION

8 min

MATERIALS: science notebook, *Cell Growth Simulation*

Facilitate a Building Understandings Discussion. Display **slides I-J**. Ask students to have their science notebooks and handouts nearby to reference during the discussion. Use the prompts below to help students make sense of what they experienced in the computer simulation.

Suggested prompt	Sample student response
<i>What did you notice about cell division in different types of cells?</i>	Certain cells divide more than others.
<i>What did you notice about the mutation rate of different types of cells?</i>	The cells that divided more frequently had more mutations, and the cells that divided less frequently had fewer mutations.
<i>How does this relate to age?</i>	Cells divide as you grow, so the longer you live, the more your cells have divided. So the older you get, the more mutations you will accumulate.
<i>How does this relate to height?</i>	Taller people have more cells than shorter people, so there are more divisions happening in the same amount of time. So taller people accumulate mutations more frequently than shorter people.

Suggested prompt	Sample student response
<i>How do these mutations relate to cancer?</i>	After the cells had a lot of mutations, they sometimes got cancer. This happened more frequently in tall, older people. Most of our positive cancer results happened in older people. As they got older, they accumulated more mutations per cell.
<i>What do the slopes of the lines tell us about the relationship between cell division and mutations?</i>	As the number of cell divisions increases, the number of mutations also increases.
KEY IDEAS	Purpose of this discussion: Prompt students to share what they figured out from the Cell Growth and Cancer computer simulation. Students should notice and wonder about how cell division leads to cancer. This will provide students with the ideas they need to revise their models from earlier in the lesson. Listen for these ideas: • Colon cells and both types of blood cells divided more frequently than skin and brain cells. • Cells that divided more often had more mutations than those that divided less often. • Changing the height changed the number of cells. The person had more blood, colon, and skin cells when they were taller. • Cancer happened more frequently in older people. • Cancer happened more frequently in cells that divided a lot, like colon cells and both types of blood cells.

5 • SHARE PEER FEEDBACK AND REVISE INITIAL MODELS

11 min

MATERIALS: science notebook, *Peer Feedback Protocol*, *Progress Tracker*

Engage in peer feedback. Display *slide K*. Share *Peer Feedback Protocol* with them and give them time to review another classmate's initial model.



Revise initial models. Display *slide L*. Ask students to update the initial models they developed in their science notebooks. They should update their models based on what they figured out by interacting with the Cell Growth and Cancer computer simulation and the feedback they received on *Peer Feedback Protocol*. Say, *Our model was supposed to help us progress toward our lesson question, Why are some kinds of cancer more common than others in older and taller people? Which questions were answered by the simulation? Are there mechanisms we now understand? Are there new questions to add?*

ASSESSMENT OPPORTUNITY

What to look for/listen for in the moment: Revised **initial models** (SEP 2.3) explaining how getting older and taller affects mutation rates and its relationship to cancer.

- Different **cell types** form after mitosis. (DCI LS1.B.1)
- Different **cell types divide** at **different rates**. (DCI LS1.B.1 & LS3.A.1; CCC 4.4)
- The more **cells divide**, the **more chances** for **mutations** to happen. (DCI: LS3.B.1; CCC: 4.4)
- The more **mutations** a person has, the higher their likelihood of getting **cancer**. (DCI: LS3.B.1; CCC: 4.4)
- **Cells divide** as you **grow**, so an older person has more **cell divisions** than a younger person. Because of this, **the older person will likely have more mutations** than the younger person. (DCI: LS3.B.1; CCC: 4.4)
- Taller people have more **cells** than shorter people, so there are more **divisions** happening in the same amount of time for the taller person. Because of this, **taller people will accumulate mutations more frequently** than shorter people. (DCI: LS3.B.1; CCC: 4.4)

What to do: As students revise their models, prompt them to use evidence from the computer simulation, discussion, notes, and peer feedback to inform their revisions. Remind students they observed different types of cells, manipulated conditions like height and age, and collected data about the relationships between cell division rate, number of mutations per cell, and cancer diagnoses. Encourage students to revisit the simulation if needed.

7.A Use a **computer simulation** as evidence to **develop and revise a model that predicts** how the **rate of cell division** affects the likelihood of cancer. (SEP: 2.3; DCI: LS3.B.1 & LS1.B.1; CCC: 4.4)

6 • NAVIGATE

2 min

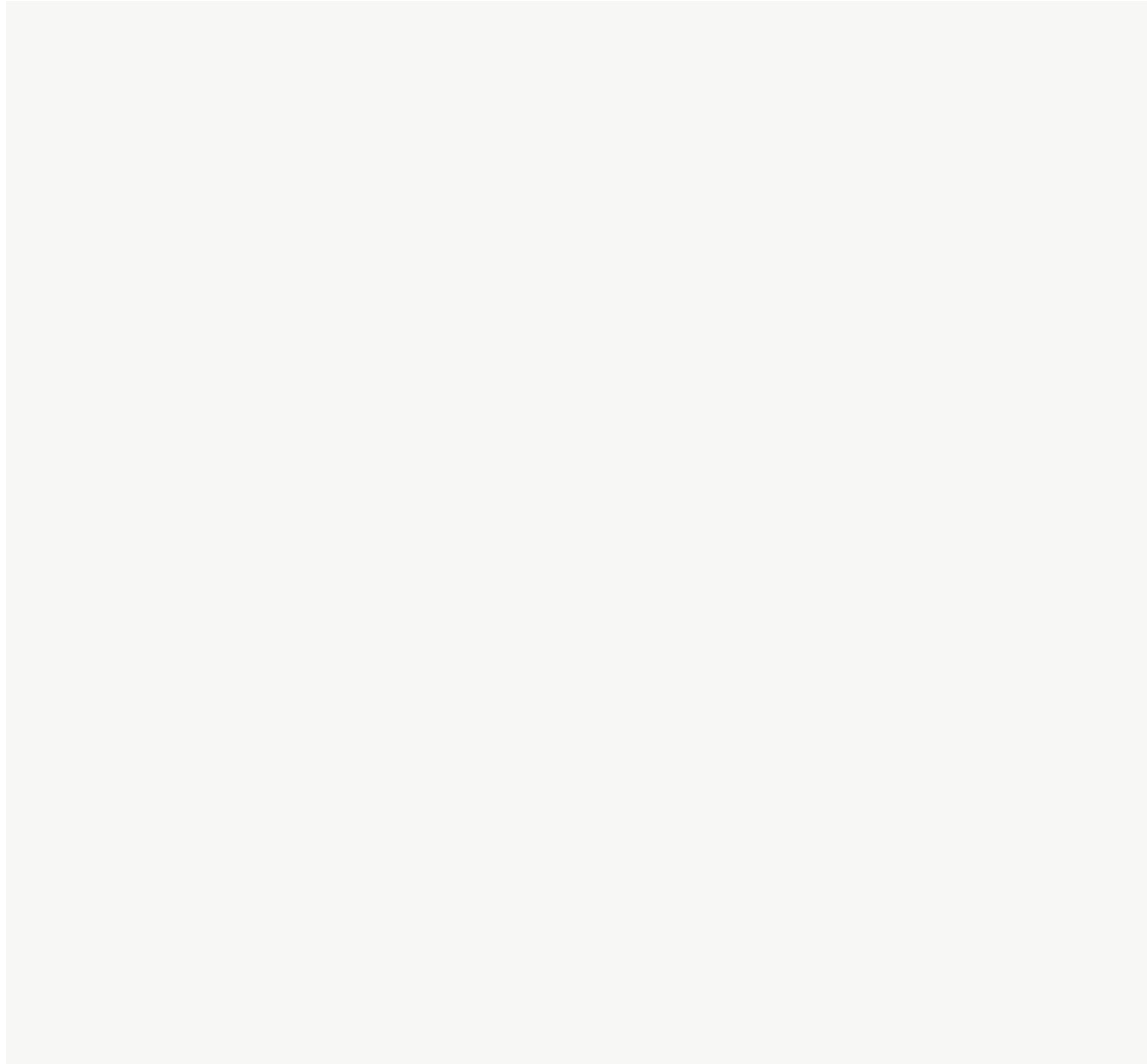
MATERIALS: science notebook

Update Progress Trackers. Celebrate with students how much progress they have made, not only on *Why are some kinds of cancer more common than others?* but also on the unit question, *Who gets cancer and why?* Display **slide M**. Ask students to turn to the Progress Trackers in the science notebooks to update them on their progress in their thinking related to our unit question: *Who gets cancer and why?*

Ask students to take a minute and think about what questions they still need to answer to make progress and what new questions have come up for them.

One possible representation of a completed Progress Tracker is shown below.

	What I figured out in pictures and/or words	Questions I have
Lesson 4: Why are some kinds of cancer more common than others in older and taller people?	Different types of cells divide at different rates. The more a cell divides, the more mutations it can get. The more mutations a cell accumulates, cancer will result. Taller people and older people have more cellular division than shorter or younger people.	Why does it seem that cancer runs in families? How does a person's environment affect whether or not they get cancer?



Additional Lesson 4 Teacher Guidance

SUPPORTING STUDENTS IN MAKING CONNECTIONS IN MATH

HSF-IF.C.7 Graph functions expressed symbolically show the key features of the graph, by hand in simple cases and using technology for more complicated cases.

As students interact with the Cell Growth and Cancer computer simulation, they will graph the relationship between the number of cell divisions and the average number of mutations per cell.

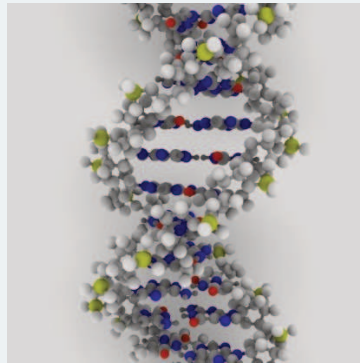
LESSON 5: How do cancer cells end up with differences in their chromosomes and what is the role of p53 in preventing the differences?

PREVIOUS LESSON We made observations about how cell division led to increased cancer rates in older and taller people. We noticed in a computer simulation that as different types of cells divided, they accumulated mutations, which increased the likelihood that the person got cancer. We wonder why some cancers seem to run in families.

THIS LESSON

INVESTIGATION

2 days



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We decide to investigate how chromosome differences happen in cancer cells. We share our initial ideas about chromosomes and then use a computer simulation and reading to find answers to our questions. We figure out that during the S phase, chromosomes duplicate through DNA replication. During this process, mutations can occur, which can cause differences in the DNA and chromosomes. p53 can correct those mutations, but not all versions of p53 do that work. We construct an explanation, give and receive peer feedback, and revise our explanations. We wonder why there are different versions of p53 and why they work differently.

NEXT LESSON We will participate in a kinesthetic model to figure out how DNA codes for proteins and will see how we can make different versions of p53 with different functions. We will use a reading to fill in gaps that the model could not help us with. We will complete an electronic exit ticket to check our understanding.

BUILDING TOWARD NGSS

HS-LS1-1, HS-LS1-2, HS-LS1-4, HS-LS3-1, HS-LS3-2, HS-LS3-3, HS-ETS1-3



WHAT STUDENTS WILL DO

5.A Construct an explanation based on evidence about how mutations can occur during DNA replication, resulting in differences in chromosomes, and the role of p53 in their repair. (SEP: 6.2; DCI: LS3.B.1; CCC: 2.2)

WHAT STUDENTS WILL FIGURE OUT

- Chromosomes are duplicated through DNA replication.
- During DNA replication, mutations can occur.
- p53 can correct those errors, but not all versions of p53 work the same.
- Non-cancer cells have identical chromosomes, but the chromosomes in cancer cells have differences.

Lesson 5 • Learning Plan Snapshot

Part	Duration		Summary	Slide	Materials
1	3 min		NAVIGATE Review what we figured out in the last lesson and prioritize next steps.	A	
2	7 min		INITIAL IDEAS DISCUSSION Facilitate an Initial Ideas Discussion about DNA and chromosomes.	B-E	
3	13 min		INTRODUCE A COMPUTER SIMULATION Demonstrate use of the DNA computer simulation and direct student exploration.	F-H	<i>Simulation Guidance</i> , internet connected device able to run https://www.openscienced.org/simulation/b3-l5-dna-fork/
4	12 min		BUILDING UNDERSTANDINGS DISCUSSION ABOUT DNA REPLICATION Facilitate a Building Understandings Discussion about DNA replication based on the simulation.	I-J	<i>Simulation Guidance</i>
5	10 min		BRAINSTORM GOTTA-HAVE-IT CHECKLIST FOR EXPLANATIONS Support students in brainstorming Gotta-Have-It Checklists for explanations.	K-M	<i>Simulation Guidance</i> , loose-leaf paper
<i>End of day 1</i>					
6	5 min		NAVIGATE Ask students to generate the Gotta-Have-It Checklist.	N	<i>Checklist Explanation Template</i>
7	8 min		INTRODUCE A READING Facilitate a student reading to support finding additional evidence.	O-P	<i>DNA and Chromosomes, Checklist Explanation Template</i>
8	10 min		CONSTRUCT EXPLANATIONS Facilitate students in constructing individual explanations to answer the lesson question.	Q	loose-leaf paper
9	10 min		PEER FEEDBACK ON EXPLANATION Organize students to give peer feedback on explanations.	R	<i>Peer Feedback Rubric</i>
10	10 min		REVISE EXPLANATIONS Facilitation student revision of explanations.	S	student explanations, <i>Peer Feedback Rubric</i>
11	2 min		NAVIGATE Generated ideas for next steps.	T	
<i>End of day 2</i>					

Lesson 5 • Materials List

	per student	per group	per class
Lesson materials	• science notebook • <i>Simulation Guidance</i> • loose-leaf paper • <i>Checklist Explanation Template</i> • <i>DNA and Chromosomes</i> • <i>Peer Feedback Rubric</i> • student explanations	• internet connected device able to run https://www.openscienced.org/simulation/b3-l5-dna-fork/	

Materials preparation (20 minutes)

Review teacher guide, slides, and teacher references or keys (if applicable).

Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

Three-hole-punch all handouts so they can be added to student notebooks.

Make sure there are enough working computers to run the simulation <https://www.openscienced.org/simulation/b3-l5-dna-fork/>.

Lesson 5 • Where We Are Going and NOT Going

Where We Are Going

The goal of this lesson is for students to use evidence from multiple sources to explain the cause of differences in the chromosomes of cancer cells.

This lesson builds on an understanding of HS LS1.B.1 from Lesson 3 and MS LS3.A, which identifies mutations as changes to genes. Here students investigate the role of DNA replication in generating mutations in the form of substitutions. Students build new ideas related to the following disciplinary core idea:

- ~~LS3.B.1: 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)

Students use the crosscutting concept of *cause and effect* to investigate the small-scale mechanisms, such as complementary base pairing, that can lead to mutations. They build on their use of this element of the crosscutting concept from Lessons 1-3 and in *OpenSciEd Unit B.1: How do ecosystems work, and how can understanding them help us protect them? (Serengeti Unit)* and *OpenSciEd Unit B.2: What causes fires in ecosystems to burn and how should we manage them? (Fires Unit)*.

Students use the science practice of *constructing explanations* to construct and revise an explanation of the lesson question. They build on the use of this practice from *Fires Unit*.

In this lesson, students will co-construct definitions for the following words, which they should add to their personal glossaries: *DNA replication and mutation*. Students will also encounter definitions including: *helicase and complementary base pairs*. Words should be defined and recorded AFTER your class has developed a shared understanding of their meaning.

Where We Are NOT Going

Although this lesson focuses on DNA replication and mutation, names of the specific enzymes involved and specific details relating to the directionality of the DNA and leading and lagging strands are beyond the scope of the high school grade band of the NGSS and are not necessary to explain the lesson or unit phenomenon.

This lesson does not address the chemical reactions that occur as nucleotides are added during DNA replication or the hydrogen bonding in double-stranded DNA. In the middle school grade band of the NGSS, students work with ideas related to molecular interactions, such as: *Substances are made from different types of atoms, which combine with one another in various ways. Atoms form molecules that range in size from two to thousands of atoms* (MS PS1.A), and students use this understanding of molecules in this lesson. Chemical reactions will be explored in more depth in OpenSciEd High School Chemistry.

While this lesson does not explore the discovery of the structure and function of DNA, some students may benefit from an investigation that extends their learning to include topics such as the discovery of the structure of DNA in the 1950s by scientists, including James Watson, Francis Crick, and Rosalind Franklin. Today, historians wonder about the cancer that ended Rosalind Franklin's short life and the repeated exposure to the X-rays she used to determine the structure of DNA.

LEARNING PLAN for LESSON 5

1 · NAVIGATE

3 min

MATERIALS: science notebook

Review what we figured out and what new questions we have. Display **slide A**. Use the following prompts to guide the discussion.

Suggested prompt	Sample student response
<i>What did we figure out in our last class?</i>	We figured out that when p53 is not working, non-cancer cells can divide into cancer cells. When non-cancer cells divide, their chromosomes are the same. Cancer cells have differences in their chromosomes.
<i>What question do we still need to answer?</i>	We need to figure out how/why those chromosomes are different. We want to know how those differences get in those cancer cells. Why is p53 helping the cell sometimes but not other times?

2 · INITIAL IDEAS DISCUSSION

7 min

MATERIALS: science notebook

Stop and Jot. Display **slide B**. Ask students to take out their science notebooks and say, *We want to explore more about those chromosomes and the differences we saw between the chromosomes of cancer and non-cancer cells. What do you already know about chromosomes?*

Turn and Talk. Display **slide C**. Ask students to share their answers with a partner and to record new ideas they hear in their science notebooks. Listen for students to identify chromosomes as genetic material or DNA.

Facilitate an Initial Ideas Discussion. Display **slide D**. Use the prompts below to facilitate an Initial Ideas Discussion. *

Suggested prompt	Sample student response
<i>What are chromosomes? What do you know about them?</i>	They are made of DNA. They are genetic materials. They have genes.
<i>How did the chromosomes of non-cancer cells compare to each other at the end of the game/mitosis?</i>	The chromosomes in the non-cancer cells were the same.

* STRATEGIES FOR THIS INITIAL IDEAS DISCUSSION

Reasons for eliciting students' initial ideas include:

- To get students' prior knowledge and experiences on the table.
- To provide a supportive opportunity for students to make sense of what may not be fully formed ideas (either their own ideas or those of others).
- To help students realize that there are gaps in our understanding to promote curiosity and what we could do next to figure something out.

Suggested prompt	Sample student response
<i>How did the chromosomes of the cancer cells compare to the non-cancer cells at the end of the game/mitosis?</i> <i>What do you think makes those chromosomes different?</i>	The chromosomes of the cancer cells had differences. Maybe they have a mistake (mutation). Maybe something happened when they doubled/got more DNA to make them different. p53 was not checking them.
KEY IDEAS	Purpose of this discussion: Elicit student ideas about the relationship between DNA and what happens during the S phase of mitosis. Listen for these ideas: • Chromosomes are made of DNA. • Chromosomes/DNA get made or copied during the S phase of mitosis. • Non-cancer cells have identical chromosomes at the end of mitosis. • Cancer cells have differences in their chromosomes. • Some kind of mistake (mutation) happens that makes them different. Update personal glossaries. Display slide E. If students bring up new vocabulary during the discussion, pause to give them a moment to add definitions to their personal glossaries.
ADDITIONAL GUIDANCE	This Initial Ideas Discussion will leverage vocabulary from NGSS MS LS3.A, which identifies mutations as changes to genes. If students bring up mutations during this discussion, pause to give them an opportunity to add them to their personal glossaries. They will revise this definition later in the lesson. The NGSS middle school grade band focuses on <i>genetic material</i>. Some students will be familiar with DNA and will bring it up here. When this happens, pause and give students an opportunity to add a definition for DNA to their personal glossaries. At this point, the definition may be general, such as <i>genetic material</i>. Students will revise this definition later in the lesson.

3 · INTRODUCE A COMPUTER SIMULATION

13 min

MATERIALS: *Simulation Guidance*, internet connected device able to run <https://www.openscienced.org/simulation/b3-l5-dna-fork/>

Introduce the computer simulation. Let students know that they have a lot of great ideas about chromosomes and how/why they have differences in cancer cells, but they still have questions they need to answer. Let them know that you have a computer simulation that will help them continue to make progress on their questions.

Demonstrate how to use the computer simulation. Display **slide F**. Play <https://youtu.be/pmRluwP8il4> Organize students into small groups of 2-3. Pass out internet-connected devices to each group and *Simulation Guidance* to each student. If possible, provide each student with an internet-connected device. Ask students to follow the directions on their handout. If some students need additional support, you can project

the simulation, have students read the steps, and model the simulation on the board. Give students time to engage with the simulation and record their data.

After completing the simulation, they should answer the Making Sense questions that follow. Display **slide G**. Let students know they will share their thinking in a Building Understandings Discussion.

Update personal glossaries. During the simulation, students will interact with a model of DNA replication and will explain that process during the discussion. Display **slide H**. Once students have described the idea that the DNA is making a copy of itself, pause to let them know that they have just described a process scientists call *DNA replication*. Give students time to co-construct and add a definition to their personal glossaries. Definitions may be similar to *the process of DNA making a copy of itself*. If students share new ideas about DNA and mutations, give them time to revise these definitions as well.

4 · BUILDING UNDERSTANDINGS DISCUSSION ABOUT DNA REPLICATION

12 min

MATERIALS: *Simulation Guidance*

Building Understandings Discussion about the simulation. Use the prompts below to facilitate a Building Understandings Discussion about what students figured out in the simulation. Display **slide I**.

Suggested prompt	Sample student response
<i>What happened in the simulation?</i>	DNA unwound, unzipped, and then a new DNA strand was made by pairing up the letters.
<i>How did the letters fit together?</i>	The shapes fit together in a special way. The As went with the Ts, and the Cs went with the Gs.
<i>Did the correct letters always go together? How did you know?</i>	Sometimes the wrong letter got put in, and those turned red.
<i>What did you do when there was an incorrect pairing?</i>	We added p53 to the strand, which took out the wrong letter. There were different kinds of p53s, and only one of them worked.
<i>At the end of the simulation, what was the result?</i>	The simulation started with one strand of DNA, and we had two strands when it finished.

Update personal glossaries. If *DNA replication* has not been named at this point in the lesson, this is a good time to connect this idea to what they experienced in the simulation. Display **slide J**. Again, as students describe that DNA is making a copy of itself, name that they have described what scientists call *DNA replication*. Give students time to co-construct a definition and add it to their personal glossaries. Create space for sharing any new ideas about DNA, chromosomes, and mutations, and give them time to revise these definitions as well.

5 · BRAINSTORM GOTTA-HAVE-IT CHECKLIST FOR EXPLANATIONS

10 min

MATERIALS: *Simulation Guidance*, science notebook, loose-leaf paper

Check in on progress toward answering the lesson question. Display slide K. Say, *We have figured out a lot about DNA replication and mutations. Let's check in to see what kind of progress we have made in answering our lesson question: How do cancer cells end up with differences in their chromosomes, and what is the role of p53 in preventing the differences?*

Turn and Talk. Display slide L. Ask students to turn and talk to a partner about what evidence they have so far that could help them answer the lesson question and what additional evidence they need.



Generate ideas for Gotta-Have-It Checklists. Display slide M. Ask students to turn to a clean sheet of loose-leaf paper in their science notebooks and generate ideas for what to include on a checklist that will help them construct an explanation that answers the lesson question. Students should turn this in before they leave class.

ASSESSMENT OPPORTUNITY

What to look for/listen for in the moment: Ideas that will support [student explanations](#) (SEP: 6.2):

- The relationship between DNA and chromosomes.
- Why/how/when is the **DNA replicating**. (DCI: LS3.B.1)
- Where/how/why **errors occur during replication**. (DCI: LS3.B.1; CCC: 2.2)
- Where/how/why **errors are corrected**. (DCI: LS3.B.1; CCC: 2.2)
- What happens to the DNA after replication.
- How the DNA with **mutations** relates to **cancer cells with differences in their chromosomes**. (DCI: LS3.B.1; CCC: 2.2)

What to do: Collect student exit tickets. Look for ideas that relate to the checklist on *Checklist Explanation Template* and consider editing the checklist to include ideas generated by students in your classes. If students do not suggest similar ideas in *Checklist Explanation Template*, plan to start day 2 by sharing an example from the populated checklist and asking students to review *Simulation Guidance* and the lesson question with a partner to generate such relevant criteria. Alternatively, consider handing back some of the ideas on the exit tickets to pairs of students for them to revise based on an example.

Building toward 5.A.1 [Construct an explanation based on evidence](#) about **how mutations can occur during DNA replication, resulting in differences in chromosomes** and the role of p53 in their repair. (SEP: 6.2; DCI: LS3.B.1; CCC: 2.2)

End of day 1

6 • NAVIGATE

5 min

MATERIALS: science notebook, *Checklist Explanation Template*

Introduce the Gotta-Have-It Checklist. Display slide N. Say, *I reviewed your exit tickets, and you all had some productive ideas for what evidence we need to answer our lesson question: How do cancer cells end up with differences in their chromosomes, and what is the role of p53 in preventing the differences? I put your ideas together with some additional ideas in a Gotta-Have-It Checklist.* Distribute *Checklist Explanation Template* to each student.

Pairs complete Gotta-Have-It Checklist. Organize students into pairs and ask them to complete the Gotta-Have-It Checklist by identifying the evidence they have and the evidence they need to be able to explain the lesson question.

Whole-class discussion. Call on a few pairs to share their ideas. Ask students to share the ideas they identified as places where they need additional evidence. Use *Checklist and Explanation Key* to guide the discussion.

7 • INTRODUCE A READING

8 min

MATERIALS: *DNA and Chromosomes*, *Checklist Explanation Template*, science notebook

Introduce the reading. Say, *We have a lot of great evidence from our simulation and other activities from the unit. I heard you identify places where you need additional information, and I have a reading that I think will help you fill in some of the gaps in evidence that you identified on the checklist.* Display **slide O** and distribute *DNA and Chromosomes* to each student. Give students time to read individually using whatever reading strategy is in place in your classroom.*

Add evidence from the reading to the Gotta-Have-It Checklist. Display **slide P**. Organize students into small groups of 3-4. Challenge each student to choose a piece of evidence from the reading that they think will address the needs they identified on the checklist. They should discuss that evidence with the group, get feedback, and revise what they include in the checklist based on the small-group discussion.

* ATTENDING TO EQUITY

DNA and Chromosomes contains challenging concepts and vocabulary. Many students, including students who read below grade level, will benefit from additional reading support. The Coherent Reading Protocol is well suited for this text. When using this protocol, students pause after each chunk of text to monitor their understanding and identify the main ideas. This will prepare them directly for the next part of the lesson, in which they use evidence from *DNA and Chromosomes* to construct explanations.

Another strategy that can be used instead of (or in conjunction with) the Coherent Reading Protocol is a teacher read-aloud. In a read-aloud, the teacher models critical thinking strategies, including visualizing, asking questions, and synthesizing information. The Coherent Reading Protocol and more information about teacher read-alouds can be found in the *OpenSciEd Teacher Handbook: High School Science*.

8 • CONSTRUCT EXPLANATIONS

10 min

MATERIALS: loose-leaf paper

Construct individual explanations. Say, *Now that you have completed your checklists, you have all the evidence you need to explain our lesson question.* *Display **slide Q**. Ask students to take out a blank sheet of loose-leaf paper. They should use *Checklist Explanation Template* and additional materials in their science notebooks to explain the lesson question.

* SUPPORTING STUDENTS IN ENGAGING IN CONSTRUCTING EXPLANATIONS AND DESIGNING SOLUTIONS

If your students need more support in constructing their explanations, distribute *Explanation Writing Support* to each student. You can use the *Student Explanation Key* as a

rubric as support for feedback. Make sure to tell students that you will be collecting this and providing feedback using the rubric.

10 min

9 • PEER FEEDBACK ON EXPLANATION

MATERIALS: *Peer Feedback Rubric*

Facilitate peer feedback. Display slide R. Distribute *Peer Feedback Rubric* to each student. Say, *Now that you have constructed explanations, you will have a chance to give and receive peer feedback to help you revise your explanations.* Organize students to exchange explanations with a peer. Give them time to read the explanation and record their feedback.

10 • REVISE EXPLANATIONS

10 min

MATERIALS: student explanations, *Peer Feedback Rubric*

Return peer feedback and explanations. Instruct students to return their peer's explanation along with the rubric. Give students a few moments to review the feedback and ask their peer reviewer any questions they may have.



Revise explanations using peer feedback. *Display slide S. Then provide students with time to revise their explanations using the feedback from their peers. Some students may have minor revisions that can be completed on their original explanation, while others may need a new piece of loose-leaf paper to rewrite their explanation. When students are finished, collect their peer feedback, initial draft (if on separate loose-leaf), and their revised explanation.

ASSESSMENT OPPORTUNITY

What to look for/listen for: Explanations based on evidence, including: (SEP: 6.2)

- DNA must be unzipped and unwound for DNA replication to begin. (DCI LS3.B.1)
- When non-cancer cells divide, the new cells, including chromosomes, are identical to the parent cell; cancer cells have differences in their chromosomes. (DCI LS3.B.1)
- Mutations occur during cell division and cause the differences in the chromosomes. (DCI:LS3.B.1; CCC: 2.2)
- One version of p53 was able to attach to the DNA strand to break the bonds of the mutation to repair it. (DCI:LS3.B.1; CCC: 2.2)
- There were versions of p53 that did not help correct mutations.

What to do: Collect student explanations and provide feedback using *Student Explanation Key*. Provide students with an opportunity to revise their explanations based on your feedback. This is also an opportunity to support student growth in providing and acting on peer feedback. Review the peer feedback and provide written feedback. Use the prompts on slide S. Consider how the receiving student acted on the feedback. Look for examples of places where students acted on or missed an opportunity to act on peer feedback in their revisions.

Building toward 5.A.2 Construct an explanation based on evidence collected from a simulation about how mutations can occur during DNA replication and the role of p53 in repairing mutations. (SEP 6.2; DCI LS3.B.1; CCC 2.2)

* ATTENDING TO EQUITY

Support students with learning differences and/or emerging multilingual students by providing opportunities for students to complete the explanations in multiple modalities. You may consider allowing some students to present their answers verbally with you or with another student acting as a scribe to record their thinking on paper or through a voice recording. Some students may benefit from using gestures, images, or manipulatives to support their explanations instead of written text. In each case, encouraging students to use multiple modalities to show their thinking creates a clear, accessible, equitable pathway for all students to demonstrate proficiency.

11 · NAVIGATE

2 min

MATERIALS: None

Generate ideas for next steps. Display **slide T**. Ask students to record their ideas for what questions the class should pursue next.

Additional Lesson 4 Teacher Guidance

SUPPORTING STUDENTS IN MAKING CONNECTIONS IN ELA

RST 11-12.9 Synthesize information from a range of sources.

Students synthesize information from a range of sources (computer simulation, reading, game) in order to construct their explanations.

LESSON 6: How do we make p53, and why is it different sometimes?

PREVIOUS LESSON We decided to investigate how chromosome differences happen in cancer cells. We shared our initial ideas about chromosomes and then used a computer simulation and reading to find answers to our questions. We figured out that during the S phase, chromosomes duplicate through DNA replication. During this process, mutations can occur, which can cause differences in the DNA and chromosomes. p53 can correct those mutations, but not all versions of p53 do that work. We constructed an explanation, gave and received peer feedback, and revised our explanations. We wondered why there are different versions of p53 and why they work differently.

THIS LESSON

INVESTIGATION

2 days



Photo by Braño on Unsplash

We decide to investigate how we make p53 and why sometimes it looks different. We participate in a kinesthetic model where we set the classroom up as a cell and figure out how DNA codes for proteins. We see how we can make different versions of p53 and how those versions might have different functions. We recognize that our model is limited in what it can help us understand about the real cell, and we read about gene expression to obtain additional information to answer our questions. We complete an electronic exit ticket to check our understanding.

NEXT LESSON We will develop our class consensus model to connect the ideas that we figured out throughout the first lesson set. We will pause and take inventory of all we have figured out so far. We will return to our Driving Question Board to update our questions and prioritize next steps.

BUILDING TOWARD NGSS

HS-LS1-1, HS-LS1-2, HS-LS1-4, HS-LS3-1, HS-LS3-2, HS-LS3-3, HS-ETS1-3



WHAT STUDENTS WILL DO

- 6.A** Use a model to illustrate the relationships between DNA structure and the structure and function of p53. (SEP: 2.3; DCI: LS1.A.2; CCC: 6.2)
- 6.B** Integrate information from multiple sources to answer questions about how changes to the structure of the DNA in the p53 gene relates to protein function. (SEP: 8.2 ; DCI: LS1.A.2 & LS3.A.1; CCC: 6.2)

WHAT STUDENTS WILL FIGURE OUT

- DNA is organized into genes in chromosomes.
- Each gene codes for a protein through a process called gene expression.
- Mutations in genes can lead to different structures and functions in proteins.
- If the code in DNA is different, the sequence of amino acids and the protein may be different.
- Additional mutations can occur during gene expression.
- Not all DNA codes for proteins.

Lesson 6 • Learning Plan Snapshot

Part	Duration		Summary	Slide	Materials
1	6 min		UPDATE PROGRESS TRACKER Guide students in updating their Progress Trackers.	A	<i>Progress Tracker</i>
2	5 min		REVIEW COMMUNITY AGREEMENTS Review the Community Agreements to decide which one(s) to focus on in our lesson today.	B	Community Agreements (from Lesson 1)
3	5 min		INTRODUCE A KINESTHETIC MODEL Review directions and organize students around the model.	C	
4	15 min		USE A KINESTHETIC MODEL Organize students in pairs to carry out a kinesthetic model.	D-F	<i>Kinesthetic Model, DNA Sequences, Amino Acid Cards</i>
5	10 min		MAKE SENSE OF THE KINESTHETIC MODEL Support pairs in making sense of what they did in the kinesthetic model.	G-I	<i>Kinesthetic Model</i>
6	2 min		NAVIGATE Ask students to revise ideas based on peer discussion and submit.	J	<i>Kinesthetic Model</i>
<i>End of day 1</i>					
7	5 min		NAVIGATE Review what we figured out in class yesterday and what we still need to figure out.	K	
8	15 min		INTRODUCE A READING Introduce a reading to support students in filling in the gaps in their understanding.	L-M	<i>DNA and p53</i>
9	10 min		BUILDING UNDERSTANDINGS DISCUSSION ABOUT GENE EXPRESSION Facilitate a Building Understandings Discussion to make sense of what we figured out in the simulation and the reading.	N-O	<i>Kinesthetic Model</i>
10	12 min		COMPLETE AN ELECTRONIC EXIT TICKET Students complete an electronic exit ticket to sum up learning and apply it to a new situation.	P	<i>Progress Tracker, https://docs.google.com/forms/d/1WgO8ZwktlMP-s1PVRp99vhwD1vXaS5rSAHHpcQhkAxQ/copy</i>
<i>End of day 2</i>					

Lesson 6 • Materials List

	per student	per group	per class
Lesson materials	• <i>Progress Tracker</i> • science notebook • <i>Kinesthetic Model</i> • <i>DNA and p53</i> • https://docs.google.com/forms/d/1WgO8ZwktlMP-s1PVRp99vhwD1vXaS5rSAHHpcQhkAxQ/copy		• Community Agreements (from Lesson 1) • <i>DNA Sequences</i> • <i>Amino Acid Cards</i>

Materials preparation (40 minutes)

Review teacher guide, slides, and teacher references or keys (if applicable).

Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

Three-hole-punch all handouts so they can be added to student notebooks.

Make sure the classroom Community Agreements (from Lesson 1) are accessible.

Make enough copies of *DNA Sequences* and *Amino Acid Cards* for each pair of students. Each copy of *DNA Sequences* has enough DNA for three pairs of students. Each copy of *Amino Acid Cards* has enough amino acids for 1 pair of students. Cut the DNA strands into strips and cut out the amino acid cards. Set out the materials at Location 1 (nucleus) and Location 2 (ribosome) prior to the kinesthetic model. To avoid crowding, designate multiple areas for Location 2.

You can print *Amino Acid Cards* on cardstock and laminate it as a class set to protect them for future use.

Lesson 6 • Where We Are Going and NOT Going

Where We Are Going

In this lesson, students develop a conceptual understanding of gene expression. They build on their understanding of DNA from Lesson 4 as well as a middle school level understanding of the following ideas:

MS-LS3.A: . . . *Each distinct gene chiefly controls the production of specific proteins, which in turn affects the traits of the individual. Changes (mutations) to genes can result in changes to proteins, which can affect the structures and function of the organism and thereby change traits.*

MS-LS3.B: . . . *genetic information can be altered because of mutations. Though rare, these mutations may result in changes to the structure and function of proteins . . .*

To support development of high school grade band ideas, students build understanding of the role of DNA in genes, including the nucleotides that make up the genetic code, how they can be altered through mutation (HS-LS3.A.1), and how those changes affect the resulting protein (HS-LS1.A.2).

Students build on their middle school use of the crosscutting concept *structure and function* by investigating the substructures' (i.e., nucleotides and amino acids) shape and use in gene expression.

Students co-construct the definition of gene expression and encounter definitions for *RNA*, *ribosome*, and *amino acid*. Words should be defined and recorded in personal glossaries AFTER your class has developed a shared understanding of their meaning.

Where We Are NOT Going

While this lesson introduces students to gene expression, memorization of the specific steps of and molecules involved in transcription and translation are beyond the scope of the NGSS high school grade band. In the kinesthetic model structures such as RNA and the ribosome are introduced to give students terminology to talk about what actually happens in the cell. However, they are not the focus of the learning in this lesson.

While not required for the standards or the phenomenon, students may be familiar with the terms *transcription* and *translation* from their everyday lives. These terms have the potential to help them understand the process of gene expression (transcribing from DNA to RNA and translating from RNA to amino acid/protein) by relating these new processes to something familiar.

LEARNING PLAN for LESSON 6

1 · UPDATE PROGRESS TRACKER

6 min

MATERIALS: *Progress Tracker*, science notebook

Update Progress Trackers. Ask students to take out *Progress Tracker*. Display **slide A**. Say, *In Lesson 4 we figured out a lot of big ideas about DNA replication, mutations, p53, and how cells can end up with differences in their chromosomes. Let's take a few minutes to track our progress.* Give students a few minutes to record their thinking, including the questions they still need to answer. Call on a few students to share their thinking. Use the sample *Progress Tracker* below as a guide.

	What I figured out in pictures and/or words	Questions I have
Lesson 4 How do cancer cells end up with differences in their chromosomes, and what is the role of p53 in preventing the differences?	DNA makes up chromosomes. When DNA gets copied, sometimes there are errors called mutations. Mutations happen when the letters/bases do not pair with their match. p53 can correct mutations. Some of the p53s did not correct mutations.	<i>How do we get p53?</i> <i>Why did some of the p53 fix mutations and some did not?</i> <i>Why did the p53 have different shapes?</i>

2 · REVIEW COMMUNITY AGREEMENTS

5 min

MATERIALS: *Community Agreements* (from Lesson 1)

Turn and Talk to review the Community Agreements. Display **slide B**. Say, *Before we begin our investigation today, let's revisit our Community Agreements to see which one we should focus on.* Give students a minute to review them individually and turn to their elbow partners to discuss which agreements they want to focus on in today's lesson. Call on a few volunteers to share their ideas. Take note to remind students of these agreements as the lesson progresses.

ADDITIONAL GUIDANCE

The simulation in this lesson supports students in figuring out a lot of big science ideas. While all of the sample agreements apply, *Moving Our Science Thinking Forward* is a good agreement to elevate. Students will engage in some productive struggle as they work through big ideas. Support them in identifying ways that they can help each other as they work together to figure things out.

3 · INTRODUCE A KINESTHETIC MODEL

5 min

MATERIALS: science notebook

Turn and Talk. Say, *You all had some questions about p53, where it comes from, and why there are different versions. Display slide C and ask students to turn and talk to an elbow partner about their ideas. Then, call on a few pairs to share their ideas. Listen for responses such as:*

- We make p53.
- We get p53 from our food.
- The differences are from mutations.
- The differences are from the environment.

Introduce the kinesthetic model. Say, *You all have a lot of great ideas about where p53 comes from and why there are different versions. I have a way we can investigate and figure out the answers to these questions. Let students know that you have a kinesthetic model that can help us figure it out, where they will get up and move around just like they did with the wildebeest and grass in *OpenSciEd Unit B.1: How do ecosystems work, and how can understanding them help us protect them?* (Serengeti Unit).*

4 • USE A KINESTHETIC MODEL

15 min

MATERIALS: *Kinesthetic Model*, science notebook, *DNA Sequences*, *Amino Acid Cards*

Review the instructions for the kinesthetic simulation. Display **slide D**. Distribute *Kinesthetic Model* to each student. Review the directions on slides D-F.

ADDITIONAL GUIDANCE

At this point, there are several parts of the model that the students may not be able to identify. This is expected. Encourage students to record their questions. Over the course of the lesson, they will have the opportunity to fill in these gaps.

Simulate the model. Let students know where location 1 and 2 are in the classroom. Organize them into pairs. Each pair should be responsible for one strand of DNA.

5 • MAKE SENSE OF THE KINESTHETIC MODEL

10 min

MATERIALS: *Kinesthetic Model*, science notebook

Complete Part 2: Making Sense. Display **slide G**. As students complete the activity, ask them to return to their seats to complete Part 2 of *Kinesthetic Model* with their partner.

Compare results. Display **slide H**. Have students share their response with another pair. They should discuss similarities and differences they see and mark up their own ideas to indicate where they heard new ideas they might want to add. Display **slide I** when students are ready to see the key to the sentences.

6 • NAVIGATE

2 min

MATERIALS: science notebook, *Kinesthetic Model*



Revise responses. Display **slide J**. Give students a few moments to revise their ideas in the table and to the lesson question in *Kinesthetic Model*. Collect student responses before the end of class.

ASSESSMENT OPPORTUNITY

What to look for/listen for: See *Gene Expression Simulation* for guidance.

What to do: Provide written feedback to students on *Kinesthetic Model*. Pay attention to the following:

If students do not identify the connection between the code in the DNA and the protein they made, prompt them with questions such as:

- What is the **relationship** between the **DNA** and the **p53 protein**? (SEP 2.3; DCI LS1.A.2; CCC 6.2)
- How did the **structure** of the **DNA** affect the **structure** of the **protein**? (SEP 2.3; DCI LS1.A.2; CCC 6.2)

If students do not identify that differences in DNA were responsible for differences in proteins (sentences), prompt them with questions such as:

- What other **differences** were there in **parts of the model** for groups that had different **sentences (proteins)**? (SEP 2.3; DCI LS1.A.2; CCC 6.2)

If they do recognize that there were differences in DNA, ask them:

- How did the **differences** in **DNA** get there? (SEP 2.3; DCI LS1.A.2; CCC 6.2)

Building toward 5.A Use a model to illustrate and predict the **relationships** between **DNA** and **protein structure** and the **function** of p53. (SEP 2.3; DCI LS1.A.2 & LS3.A.1; CCC 6.2)

End of day 1

7 • NAVIGATE

5 min

MATERIALS: None

Review our progress with the kinesthetic model. Display slide K. Return *Kinesthetic Model* to each student. Give students a few moments to individually review the feedback. Then ask them to turn and talk to a partner and talk about what questions they still have. Call on a few students to share their thinking. Listen for students to point out places where they need more information to answer their questions.

8 • INTRODUCE A READING

15 min

MATERIALS: *DNA and p53*

Introduce a reading. Display slide L. Pass out *DNA and p53*. Say, *I have a reading that can help you answer some of your questions*. Give students several minutes to read and annotate individually using whatever reading strategy is in place in your classroom.

Small group sensemaking about the reading. Say, *Based on the reading, what would you like to add to our mapping tool?* Organize students into small groups of 3–4 and give them time to fill in the last two columns of the mapping tool in *Kinesthetic Model* using the heading from slide M as a guide. * *

Component of the model	What it represents.	Additional information from the reading.	Ways the model differs from the real world.
Location 1	Where the DNA is in the cell.	Nucleus	

* SUPPORTING STUDENTS IN ENGAGING IN OBTAINING, EVALUATING, AND COMMUNICATING INFORMATION

Use this opportunity to make explicit the benefits and limitations of using physical/kinesthetic representations and informational text as sources of information for answering questions. Ask students to think of the benefits and limitations as you are mapping the model to the system. Benefits of the kinesthetic model might

Paper DNA strand at location 1	DNA that has the code for p53.	p53 gene	There are 18,000 base pairs in the p53 gene. The model had 36-39.
Copy and edited copy in your handout	The message from the DNA that travels around the cell.	RNA	
Location 2	Where the protein gets made in the cell	Ribosome	
Cards with codes and words	How the DNA gets turned into proteins.	amino acids	There are 375 amino acids in the p53 protein. The model had 8 or 9.
Sentence you wrote down in your handout.	p53 protein.		

include being able to simulate cellular processes without microscopes and other technology. A limitation might include that other factors are not accounted for in the simulation or that we are not using real cells. The informational text may provide information about how the components of the model function in the real world.

* ATTENDING TO EQUITY

For students who demonstrated mastery of the standard at an earlier stage, consider an extension activity that requires them to consider the structure and function of the protein based on the charge of the amino acids. For more information see *Optional Extension*

9 • BUILDING UNDERSTANDINGS DISCUSSION ABOUT GENE EXPRESSION

10 min

MATERIALS: *Kinesthetic Model*

Building Understandings Discussion. Display slide N. Facilitate a Building Understandings Discussion about gene expression. *

Suggested prompts	Sample student responses	Follow-up questions
<i>Why were there different versions of the DNA? What did each different version code for?</i>	There were mutations in the original sequences of the p53 gene that gave us the other versions of p53.	<i>What were the differences between the three different strips of paper that represented DNA?</i>
<i>How did the structure of each of the different versions of p53 affect the function?</i>	Only p53a was able to attach to the DNA strand and repair the mutations.	<i>What did that sequence of DNA represent?</i>
<i>What happened in places where the sentence did not match the key? What did that represent in the cell?</i>	People made mistakes somewhere in the copying process that was like a mutation. The mistakes represented new mutations.	<i>In Lesson 4, what did you notice about the different shapes of the p53 protein?</i>
<i>What do you think the shape of the p53 protein would look like in the case where the sentence did not match the key?</i>	It might have a totally different shape that did not work at all to repair DNA.	<i>What caused the sentence not to match the key?</i>
		<i>When your sentence had errors, did it make sense?</i>

* STRATEGIES FOR THIS BUILDING UNDERSTANDINGS DISCUSSION

Asking students to restate what another student has said helps students listen carefully to each other so that they can work with others' ideas. This move can feel odd to students at first, so it will help if you let them know ahead of time that you will be asking this.

KEY IDEAS

Purpose of this discussion: To support students in building an understanding about how DNA codes for protein and how mutations can impact the structure and function of proteins.

Listen for these ideas:

- The differences in DNA sequences created the different forms of p53.
- The words (amino acid sequences) were sometimes different, even when the DNA sequence was the same.
- There were mistakes in the process that represent mutations.

Update personal glossaries. Display slide O. Say, *You figured out some really big ideas about this process of making proteins from the code in DNA. Scientists call this process gene expression. Let's pause and add this to our personal glossaries.* Support students in coming to consensus on a definition for gene expression. Record this definition in a public space and give students time to record in their science notebooks.

10 · COMPLETE AN ELECTRONIC EXIT TICKET

12 min

MATERIALS: *Progress Tracker*, science notebook, <https://docs.google.com/forms/d/1WgO8ZwktlMP-s1PVRp99vhwD1vXaS5rSAHHpcQhkAxQ/copy>

Complete an exit ticket. Display slide P. Have students complete <https://docs.google.com/forms/d/1WgO8ZwktlMP-s1PVRp99vhwD1vXaS5rSAHHpcQhkAxQ/copy>. Encourage students to use their notes and models to help them answer the questions on the electronic exit ticket. See *Exit Ticket Guidance* for instructions on how to make the electronic exit ticket.

ASSESSMENT OPPORTUNITY

What to look/listen for in the moment: See *Electronic Exit Ticket Key* for guidance.

What to do: See *Electronic Exit Ticket Key* for guidance.

Building Toward 5.B Integrate information from multiple sources to answer questions about how changes to the structure of the DNA in the p53 gene relate to protein function. (SEP 8.2 ; DCI LS1.A.2 & LS3.A.1; CCC 6.2)

Additional Lesson 5 Teacher Guidance

SUPPORTING STUDENTS IN MAKING CONNECTIONS IN ELA

WHST.9-12.9 Draw evidence from informational texts to support analysis, reflection, and research.

When students answer questions, they will use evidence from informational texts to support their answers.

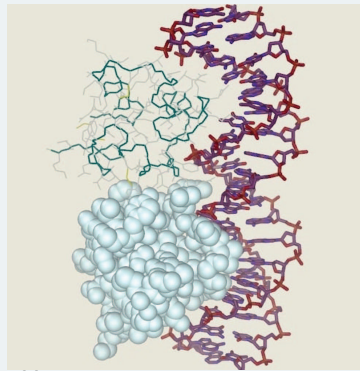
LESSON 7: What is the genetic basis of cancer?

PREVIOUS LESSON We participated in a kinesthetic model where we set the classroom up as a cell and figured out how DNA codes for proteins. We saw how we can make different versions of p53 and how those versions might have different functions. We recognized that our model was limited in what it could help us understand about the real cell, and we read about gene expression to obtain additional information to answer our questions. We completed an electronic exit ticket to check our understanding.

THIS LESSON

PUTTING PIECES TOGETHER

1 day



P99am

We develop our class consensus model to connect the ideas that we figured out throughout the first lesson set. We acknowledge that we have made progress on a lot of ideas and decide to pause and take inventory of all we have figured out so far. We return to our Driving Question Board to update our questions and prioritize next steps. We decide that we need to figure out the relationship between being taller and older and getting cancer.

NEXT LESSON We will investigate other reasons why someone might get cancer by watching and modeling families to see how mutations that increase the risk of cancer can be inherited.

BUILDING TOWARD NGSS

HS-LS1-1, HS-LS1-2, HS-LS1-4, HS-LS3-1, HS-LS3-2, HS-LS3-3, HS-ETS1-3



WHAT STUDENTS WILL DO

6.A Develop and use a model based on evidence to explain the genetic cause and effect of cancer. (SEP: 2.3 ; DCI: LS1.A.1, LS1.A.2, LS1.A.3, LS1.B.1 ; CCC: 2.2)

WHAT STUDENTS WILL FIGURE OUT

- Cells are part of a hierarchical organization system of tissues, organs, and systems in organisms.
- When cancer cells stick together, they can form tumors that can invade tissues, disrupt systems, and make us sick.
- Cancer cells form when p53 is not working.
- Cell division happens in all cells through a series of phases, ending with mitosis when one cell forms two new cells with identical chromosomes.
- Cancer cells have differences in their chromosomes.
- Chromosomes are made of DNA that is copied during DNA replication when mutations can occur.
- p53 can correct those errors, but not all versions of p53 work the same.
- Each gene codes for a protein through a process called gene expression.
- p53 is a protein coded for by a gene.
- Mutations in genes can lead to different structures and functions in proteins.

Lesson 7 • Learning Plan Snapshot

Part	Duration		Summary	Slide	Materials
1	5 min		NAVIGATE Summarize what we have figured out so far and motivate pausing to make sense of it all.	A	
2	10 min		REVISIT PROGRESS TRACKERS Guide students in revisiting their Progress Trackers.	B	<i>Progress Tracker</i>
3	5 min		BRAINSTORM COMPONENTS FOR GOTTA-HAVE-IT CHECKLIST Guide students in brainstorming a list of components needed in our consensus models.	C-D	
4	5 min		SELF-ASSESSMENT Have students complete a self-assessment of their decisions on their Gotta-Have-It Checklist.	E	colored pen (any color other than the main color)
5	15 min		DEVELOP CLASS CONSENSUS MODEL Develop a class consensus model to explain the genetic basis of cancer.	F-J	chart paper and chart paper markers (optional), 3x3 sticky notes
6	5 min		NAVIGATE Revisit our Driving Question Board to guide our investigations in Lesson Set 2.	K	Driving Question Board, 3x3 sticky notes, colored markers

End of day 1

Lesson 7 • Materials List

	per student	per group	per class
Lesson materials	• <i>Progress Tracker</i> • science notebook • colored pen (any color other than the main color)		• chart paper and chart paper markers (optional) • 3x3 sticky notes • Driving Question Board • colored markers

Materials preparation (5 minutes)

Review teacher guide, slides, and teacher references or keys (if applicable).

Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

Make sure chart paper and chart paper markers, or an alternative way to capture the consensus model, are available.

Lesson 7 • Where We Are Going and NOT Going

Where We Are Going

During this culminating lesson of Lesson Set 1, students put the pieces together to model and explain the genetic basis for cancer. Students use the evidence collected in the first 5 lessons to support their explanations.

Students use the science practices of *developing and using models* by developing a consensus model as a class where they establish connections between all of the components, interactions, and mechanisms they had been investigating up to that point. Students review the ideas they figured out from their Progress Trackers, where they have to gather evidence from several different types of models they have engaged in up to this point. Then they create a Gotta-Have-It Checklist as a way to include the necessary components, interactions, and mechanisms.

Students use the crosscutting concept of *cause and effect* throughout the lesson as they explain mutations in DNA and the structure and function of proteins by looking at small-scale changes, such as substitutions in bases in DNA and how that leads to changes in amino acids, which affect the shape of the p53 protein and its role in repairing DNA. They build on the initial use of examining small-scale mechanisms from Lessons 1 through 3 in this unit and *OpenSciEd Unit B.2: What causes fires in ecosystems to burn and how should we manage them? (Fires Unit)* to achieve this goal.

Where We Are NOT Going

Although students investigated mutations in Lesson Set 1, they have not yet figured out how mutations can be inherited or caused by environmental factors. In Lesson Set 2, students will investigate how different factors affect cancer incidence.

LEARNING PLAN for LESSON 7

1 · NAVIGATE

5 min

MATERIALS: None

Lead a discussion about what we have figured out so far. Display slide A. Say, *We have figured out a lot of big science ideas over the past week or two! What are some of the ways that we make sense of a lot of ideas? How do we make connections between ideas that we have?* Pause to give students an opportunity to share their ideas about what practices they might engage in.

Listen for ideas such as:

- We develop written explanations.
- We create models to explain relationships between components and ideas.
- We communicate our ideas with others.

Say, *Today, we are going to take what we have learned to develop a class model that tells the story of what we have figured out.*

2 · REVISIT PROGRESS TRACKERS

10 min

MATERIALS: Progress Tracker

Revisit the Progress Tracker. Display slide B. Say, *Since we have figured out many great ideas, let's review the Progress Tracker to build our Gotta-Have-It Checklist. Let's look back at the consensus model we started in Lesson 2. Since we have many huge ideas, we need to make a new one, but it is a good place to start. What are some of the biggest ideas we have figured out since Lesson 2?*

Call on volunteers to review the ideas on the Progress Tracker and the Gotta-Have-It Checklist.

	What I figured out in pictures and/or words	Questions I have
Lesson 5 How do we make p53, and why is it different sometimes?	DNA is in genes on chromosomes. Each gene codes for an amino acid which codes for a protein. If you change the DNA, then you may also change the shape of the protein, which may change how it works. This is called gene expression.	How much have we figured out already?

3 · BRAINSTORM COMPONENTS FOR GOTTA-HAVE-IT CHECKLIST

5 min

MATERIALS: science notebook

Develop a Gotta-Have-It Checklist. Display slide C. Say, *If we are going to make a detailed model to explain the genetic basis of cancer, we need to revisit what we have figured out.*

Have students title a new page *Gotta-Have-It Checklist* in their science notebooks. Say, *In your notebook, you will need a wide column on the left and 2 thinner columns on the right. The wide column should be titled "What is the genetic basis of cancer?" The two right columns are "Used" and "Not Used." You can check off which of these items were actually used in the model so that you can have them for updating the model later.*

Turn and Talk. Display slide D. Say, *Working with your partner, go through your science notebooks, use your Progress Trackers and handouts, and complete the first column on the Gotta-Have-It Checklist. We will complete the rest of this checklist later. The row for Lesson 2 is filled out for you.* Give students a few minutes to complete the first column of their Gotta-Have-It Checklist. Please see the sample checklist below.

What is the genetic basis for cancer?	Used	Not Used
Lesson 2: Non-cancer cells turn into cancer cells. Cancer cells clump together and form tumors that invade surrounding tissues, disrupt systems, and cause disease.		
Lesson 3: Cells grow and repair in the cell cycle when one cell forms two new cells. p53 maintains the checkpoints in the cell cycle by checking to make sure that the cell has enough nutrients and resources. If cells skip checkpoints, they will develop cancer. Cancer cells have differences in their chromosomes.		
Lesson 4: Mutations can result from errors made during DNA replication. The more mutations there are, the more likely cancer will result. p53 attaches to the DNA strand and repairs mutations, but not all versions of p53 work the same.		
Lesson 5: A mutation in DNA causes changes in protein structure, which could change the function of the protein. A mutation in p53 DNA causes a change in the p53 protein, which changes the function of p53. If p53 fails, then cancer will result.		

4 • SELF-ASSESSMENT

5 min

MATERIALS: science notebook, colored pen (any color other than the main color)

Lead students in a self-assessment opportunity. Display slide E. Students will explain their evidence for the genetic basis for cancer. They will also explain why they included some ideas and not others on their Gotta-Have-It Checklist. Remind students that they are to annotate their Gotta-Have-It Checklist with their colored pen so that they can see the results of their self-assessment and the additional ideas that they believe need to be added.

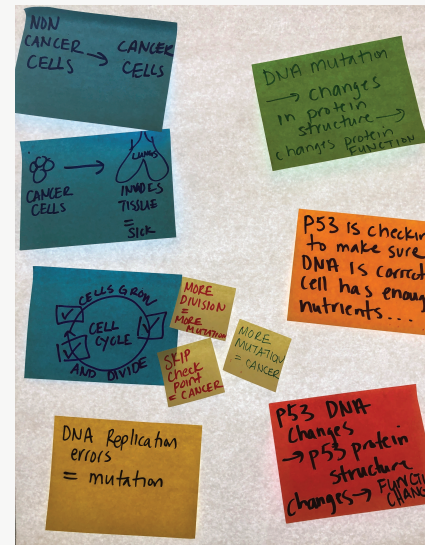
5 · DEVELOP CLASS CONSENSUS MODEL

15 min

MATERIALS: science notebook, chart paper and chart paper markers (optional), 3x3 sticky notes



Brainstorm model components to develop a consensus model. ** Display slide F. Ask students to gather in a Scientists Circle. Have students bring their science notebooks and completed Gotta-Have-It Checklists. Say, *What components from our Gotta-Have-It Checklists do we need in our model to explain the genetic basis of cancer? Which ideas interact with each other? These ideas are the components.* As students share their ideas, write a component on a sticky note and add it to the poster.



* SUPPORTING STUDENTS IN ENGAGING IN DEVELOPING AND USING MODELS

Students will participate in developing the class consensus model based on evidence they have collected in Lesson Set 1 to illustrate the genetic basis of cancer. The evidence they have collected is from multiple types of models, including computer simulations, kinesthetic simulations, and a game model. Ask students to consider the merits and limitations of each of these types of models.

* SUPPORTING STUDENTS IN DEVELOPING AND USING CAUSE AND EFFECT

Although students are working with cause and effect elements related to small-scale mechanisms in this lesson, encourage them to recognize that we identified the need to establish empirical evidence to support our claims. Ask them to revisit their definition of empirical evidence from Lesson 1 and look for examples of the use of empirical evidence in the class consensus model.

* SUPPORTING STUDENTS IN DEVELOPING AND USING CAUSE AND EFFECT

Students will explain the cause-and-effect relationship between mutations in DNA and the structure and function of proteins by looking at small-scale changes such as changes in bases in DNA leading to changes in amino acids, which change the structure and function of the protein. In this case, if

ASSESSMENT OPPORTUNITY

What to look for/listen for in the moment:

Students making connections explaining the genetic basis for cancer, including the following to be included in the [class consensus model](#):

- The [cell cycle](#) has [p53 checkpoints](#) to reduce the likelihood that cancer cells will form.
- A [mutation in p53 DNA](#) causes [changes](#) in the [shape](#) of the [protein](#), which does not allow it to repair [mutations](#). (DCI LS.1.A.2; CCC2.2)
- [Cancer cells](#) have differences in their chromosomes compared to [non-cancer cells](#). (DCI LS.1.A.1)
- When [cancer cells](#) form, they [clump together](#), becoming [tumors](#), which can invade surrounding tissue, divert resources, and [cause disease](#). (DCI LS.1.B.1; CCC 2.2)
- [Cells](#) go through the [cell cycle](#) ending in [mitosis](#), when they [divide](#) for [growth or repair](#). (DCI LS.1.B.1)
- p53 tightly regulates new cell formation at checkpoints during the [cell cycle](#) (DCI LS.1.B.1)
- [Mutations are errors](#) that occur in [DNA replication](#) during the cell cycle because there is an error in the DNA.
- If p53 fails, non-cancer cells can become cancer cells.
- Most [DNA codes](#) for [proteins](#); therefore [mutations in DNA](#) can [cause](#) the [proteins](#) to have [different shapes](#). (DCI LS.1.A.2; CCC2.2)
- The [structure of proteins](#) is [related to their function](#), so when the [structure changes due to a mutation](#), [so does the function](#). (DCI LS.1.A.2; CCC2.2).

What to do: Guide students to return to the sensemaking they have done throughout Lessons 1-5. Prompt students with questions such as:

- How can you use cause and effect to think about what is happening here?
- What evidence do you have to support that relationship?
- How will your model illustrate this?

Building toward 6.A [Develop and use a model based on evidence](#) to explain the [genetic cause and effect](#) of cancer. (SEP 2.3 ; DCI LS.1.A.1, LS1.A.2, LS1.A.3, LS1.B.1 ; CCC 2.2)

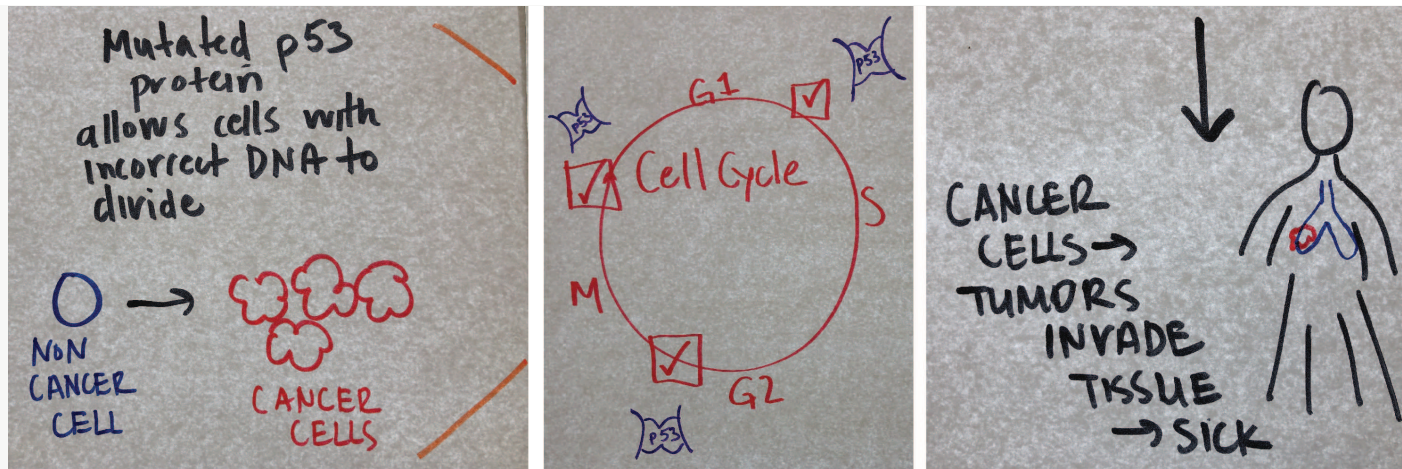
Discuss moving components around. Display slide G. Say, *Now that we have some components on the poster, we may need to move them around to organize this story to develop a more complete model of this system. As we review our past lessons, think of how these ideas are related to help us do this.*

Review Lessons 2 and 3. Display slide H. Say, *Let's go back to the beginning to see what we figured out and make sure that we have all of our components and we can show interactions and mechanisms in our model of this system. Feel free to use your notebooks to help us remember where we have been as we do this.*

Say, *Let's start at the beginning. What did we figure out in Lessons 2 and 3, and how can we represent it in our model?* Listen for responses related to how non-cancer cells become cancer cells through the cell cycle. Prompt students to consider the role of p53 in the cell cycle.

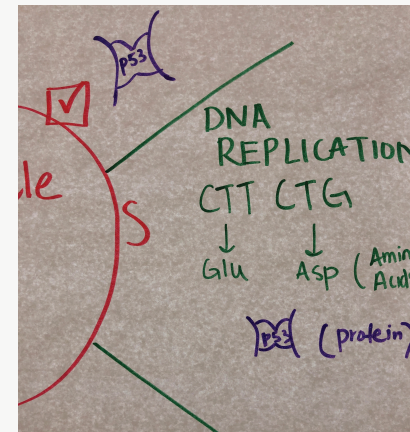
Say, *Do we all agree with what we have here? Thumbs up if you agree, thumbs down if you do not.* If students disagree, be sure to address their concerns before moving on.

p53 cannot attach to the DNA strand because of a change in shape, then it can not repair the DNA, leading to cancer.

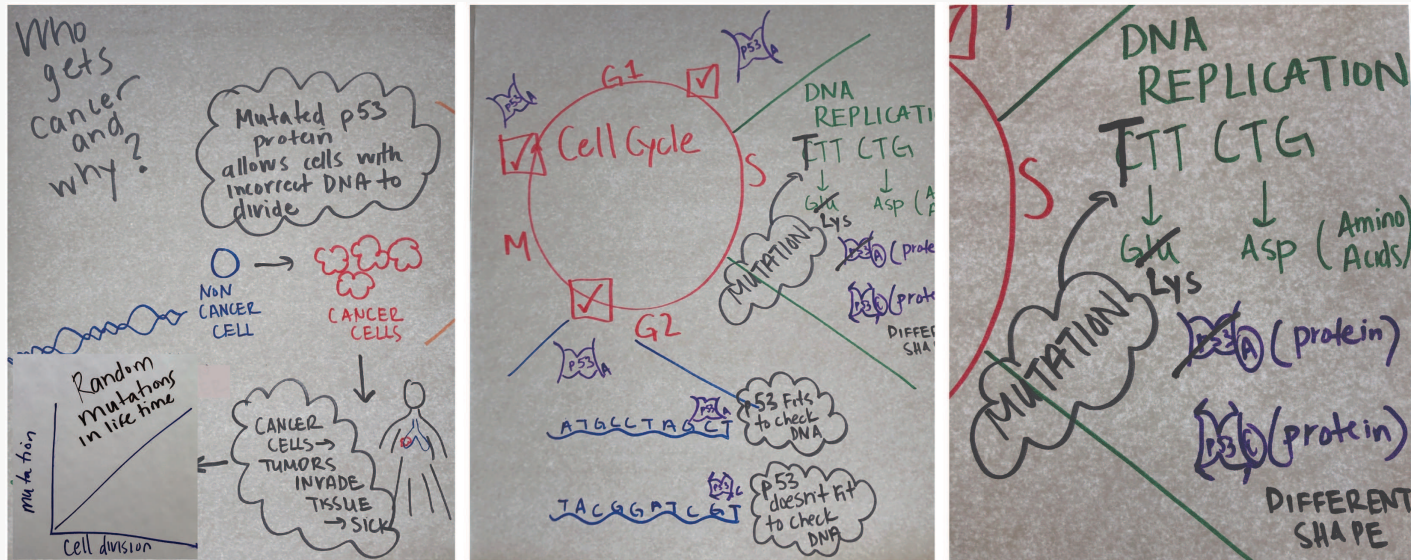


Review Lesson 4. Say, All right, so what was the key takeaway from the computer simulation that needs to be added to this model? How do mutations impact DNA and cancer? How would we show it on the model? Listen for responses about the fact that chromosomes in non-cancer cells are identical but different in cancer cells. Students may also share ideas about how mutations form during DNA replication and the relationship between mutation and cancer.

Review Lesson 5. Say, Great work, everybody! How do we feel about our model so far? Thumbs up if you agree with what you see. Thumbs down if you want to move something or don't agree with something up there. Pause to ensure all students agree and have an opportunity to offer suggestions and share ideas.



Ask students to recall what they figured out in Lesson 5. Listen for responses related to gene expression and how mutations in DNA lead to differently shaped proteins that do not have the same function. Say, *How could this be represented in our model?* Prompt students to explain their thinking in the context of p53. Listen for ideas about how p53 in the A or butterfly shape can attach to DNA and repair errors. Other versions of p53, which result from mutation, cannot perform this function. Add new components to the model. *



Review the model with students. Say, *Now that we have developed this model, does it tell the story of the genetic basis of cancer? What is missing that we need up here?* Display slide I. Call on a few volunteers to talk through the model. Say, *As we review the model, let's go back to the Gotta-Have-It Checklist to complete columns 2 and 3. If we used that idea in the model, put a check in the "Used" column (column 2). If the idea is not in the model, put a check in the "Not Used" column.* Display slide J. Guide students to consider how to add the elements that were in the "Not Used" column.

ADDITIONAL GUIDANCE

The learning plan suggests walking through the lessons chronologically. However, students may make sense of the ideas in a different order as they put the pieces together. For example, students might start with the cell cycle or DNA replication if these are bigger ideas they are confident in understanding. The sequence is unimportant – support students in making sense in ways that make sense to them.

6 · NAVIGATE

5 min

MATERIALS: Driving Question Board, 3x3 sticky notes, colored markers

Revisit the Driving Question Board. Display slide K. Say, *Now that we have reviewed the ideas we have learned, it is an excellent time to look back at the Driving Question Board. Let's review the questions that we have answered so far.* Ask students to scan the questions silently for 1 minute. Have them share the questions they believe we have answered so far with their partners. Call volunteers to read the questions you have answered to share with the whole class. When students identify questions that have been answered, mark the sticky note with a star or move the answered questions to one side of the board.

Say, *It sounds like we understand the genetic basis of cancer. What are the questions that we have left to answer? Can any of those questions help us make progress on filling in what our model does not explain?* Give students a moment to identify critical questions and share them in their small groups. In addition, challenge students to add new questions that have come up for them. Consider asking students to nominate questions we could investigate next to continue making progress on the question *Who gets cancer and why?* Call on volunteers to share their questions and ideas for investigation with the class.

Listen for ideas such as:

- We saw data about being older and taller giving you cancer too. Our model does not show us how that happens.
- Our model does not show anything about how cancer gets passed on in families.
- Our model also does not show how the environment could cause cancer, like lung cancer from smoking.

Additional Lesson 6 Teacher Guidance

SUPPORTING STUDENTS IN MAKING CONNECTIONS IN ELA

RI. 3.3 Describe the relationship between a series of scientific ideas or concepts and cause-effect.

The class consensus model explains how mutations in genes can lead to cancer.

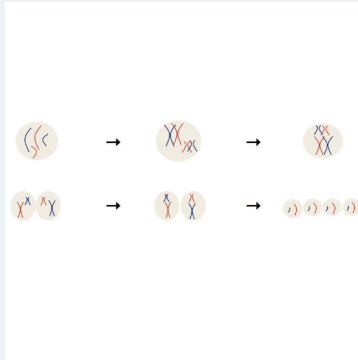
LESSON 8: Why do some cancers appear to run in families?

PREVIOUS LESSON We developed our class consensus model to connect the ideas that we figured out throughout the first lesson set. We took inventory of our new ideas. We returned to our Driving Question Board to update our questions and prioritize next steps. We decided that we need to figure out the relationship between being taller and older and getting cancer.

THIS LESSON

INVESTIGATION

2 days



We decide to investigate other reasons why someone might get cancer. We watch videos about two young individuals, Lakita and Lauren, who survived multiple cancers. We model Lakita's family in a pedigree and use a second model to try to understand more about Lauren's family. We figure out how mutations that increase the risk of cancer can be inherited in families. We decide to investigate mutations due to the environment next.

NEXT LESSON We will investigate scientific data related to the incidence of skin cancer and design and carry out our own investigations. We will read about the mechanism of UV radiation causing mutations in our cells and about a protective mechanism in our skin.

BUILDING TOWARD NGSS

HS-LS1-1, HS-LS1-2, HS-LS1-4, HS-LS3-1, HS-LS3-2, HS-LS3-3, HS-ETS1-3



WHAT STUDENTS WILL DO

8.A Develop and use multiple models to explain how the inheritance of p53 alleles and other gene alleles can cause cancer in multiple generations of a family through new combinations of alleles. (SEP: 2.4; DCI: LS3.B.1; CCC: 2.2)

WHAT STUDENTS WILL FIGURE OUT

- People with Li-Fraumeni syndrome have an increased risk of developing cancer because of an inherited p53 allele.
- Pedigrees show the occurrence of traits in families and can help model inheritance.
- During meiosis, chromosome pairs can swap regions of DNA in a process called *crossing over*.
- Crossing over can result in new combinations of alleles along a chromosome and thus more genetic variation.

Lesson 8 • Learning Plan Snapshot

Part	Duration		Summary	Slide	Materials
1	3 min		NAVIGATE Guide a brief class discussion about what we figured out and decided to investigate next.	A	
2	10 min		INTRODUCE A CASE STUDY Introduce Lakita and Lauren, young cancer survivors.	B-F	<i>Transcript: Lauren Family History, Transcript: Lakita Family History., Community Agreements</i>
3	10 min		INVESTIGATE A PEDIGREE Introduce a pedigree chart of Lakita's family for students to investigate.	G-J	<i>Lakita's Family Pedigree</i>
4	10 min		CLASS DISCUSSION ABOUT LAKITA'S PEDIGREE Guide students in a discussion about how p53 alleles in Lakita's family.	K	<i>Lakita's Family Pedigree</i>
5	9 min		INTRODUCE A NEW PEDIGREE Attempt to make sense of a new pedigree.	L-O	<i>p53 BRCA1 Pedigree, laminated color copy of p53 BRCA1 Pedigree</i>
6	3 min		NAVIGATE Elicit student ideas for what we need to figure out to explain the pedigree.	P	
<i>End of day 1</i>					
7	3 min		NAVIGATE Review what the class decided to investigate today.	Q	
8	4 min		INITIAL IDEAS DISCUSSION ABOUT HOW ALLELES ARE PASSED ON Lead a brief discussion about how traits are inherited.	R	
9	8 min		MODEL THE PEDIGREE WITH PIPE CLEANERS AND BEADS Support students in using the pipe cleaners and beads to model the chromosomes and alleles in this family.	S	<i>p53 BRCA1 Pedigree, laminated color copy of p53 BRCA1 Pedigree</i>
10	8 min		READ ABOUT HOW ALLELES ARE PASSED ON Distribute reading for students to find additional information about how alleles are passed on.	T	<i>Passing on Alleles</i>
11	8 min		REVISE PIPE CLEANER AND BEAD MODELS Support students as they revise their models to incorporate what they figured out from the reading.	U	scissors

Part	Duration		Summary	Slide	Materials
12	8 min		BUILDING UNDERSTANDINGS DISCUSSION ABOUT INHERITANCE Lead a Building Understandings Discussion to synthesize what students have figured out about inheritance.	V-W	
13	6 min		NAVIGATE: ELECTRONIC EXIT TICKET Distribute exit ticket.	X	https://docs.google.com/forms/d/1MKGi-g_VGjflx7slyFqUoKgiSxSaKkX_RFqcSILO_QE/copy

End of day 2

Lesson 8 • Materials List

	per student	per group	per class
Lesson materials	• science notebook • <i>Transcript: Lauren Family History</i> • <i>Transcript: Lakita Family History.</i> • <i>Lakita's Family Pedigree</i> • <i>p53 BRCA1 Pedigree</i> • <i>Passing on Alleles</i> • https://docs.google.com/forms/d/1MKGi-g_VGjflx7slyFqUoKgjSxSaKkX_RFqcSIL_O_QE/copy	• laminated color copy of <i>p53 BRCA1 Pedigree</i> • scissors	• Community Agreements

Materials preparation (30 minutes)

Review teacher guide, slides, and teacher references or keys (if applicable).

Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

Three-hole-punch all handouts so they can be added to student notebooks.

Preview the videos <https://youtu.be/ux7obpTlkbU> and <https://youtu.be/U1ZifbvvIOQ> prior to class.

Day 1: Organize per pair:

- 18 same-colored 6" pipe cleaners (chromosomes) per pair.
- Two colors of pony beads, 18 of one color and 18 of the other color (36 total; p53 alleles).
- Extra pipe cleaners and beads as needed.

Day 2: Organize per group:

- 20 same-colored 6" pipe cleaners (chromosomes) per pair.
- Four colors* of pony beads, 20 each (80 total; p53 and BRCA1 alleles). Example from slide:
 - 20 dark blue beads
 - 20 red beads
 - 20 light blue beads
 - 20 yellow beads
- Scissors (not needed until after the reading).

*Note: The colors do not matter, but be sure to come to consensus with the students about which colors represent which alleles.

Lesson 8 • Where We Are Going and NOT Going

Where We Are Going

In this lesson, students review and build on middle school level ideas about how traits are inherited through sexual reproduction. In middle school, students developed ideas about the mechanism by which parents contribute half of their genetic materials to their offspring (MS LS3.B). Here, students revisit sexual reproduction in the context of meiosis and add the idea of crossing over as a means to increasing the genetic combinations possible during sexual reproduction as specified in HS LS3.B.1: *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)

Students began to develop their use of the science practice *developing and using models* at the high school grade band in *OpenSciEd Unit B.1: How do ecosystems work, and how can understanding them help us protect them? (Serengeti Unit)* and in earlier lessons in this unit. Here, they move flexibly between pedigree and physical models and consider their merits and limitations.

Students began to develop their use of the crosscutting concept *cause and effect* at the high school grade band in *OpenSciEd Unit B.1: How do ecosystems work, and how can understanding them help us protect them? (Serengeti Unit)* and in earlier lessons in this unit. Here they use smaller-scale mechanisms including meiosis and crossing over to explain inheritance.

Students will co-construct definitions for *inheritance* and *meiosis*. Students will encounter words and definitions from earlier in the unit or middle school as well, such as *chromosomes*, *generations*, *offspring*, *gametes*, *sperm*, *eggs*, *allele*, *crossing over*, and *pedigree*. They will also encounter new words in the case studies, such as *Li-Fraumeni syndrome*, *osteosarcoma*, and *MDS*.

Where We Are NOT Going

The specific steps of meiosis are beyond the scope of the NGSS high school grade band and are not necessary for students to explain the phenomenon of p53 inheritance and Li-Fraumeni syndrome.

The terms *dominant* and *recessive* are not introduced in this lesson. These terms oversimplify the relationship between gene and protein. The goal is for students to understand that each allele is coding for protein. If they are homozygous for the LFS mutation, 100% of the protein they make does not fix mutations. If they are heterozygous, 50% of the protein they make does not fix mutations and 50% of the protein they make does fix mutations.

LEARNING PLAN for LESSON 8

1 · NAVIGATE

3 min

MATERIALS: science notebook

Stop and Jot. Display **slide A**. Ask students to stop and jot about what the class figured out in the last lesson and what questions they still have. Call on a few students to share their thoughts. Use the prompts below as a guide.

Suggested prompt	Sample student response
<i>What did we figure out in the last class?</i>	The more your cells divide, the more chances you have for a mutation, so older and taller people have more cancer.
<i>What questions do we still have?</i>	The mutations you accumulate in your lifetime only account for 66% of cancer. What else causes cancer?

2 · INTRODUCE A CASE STUDY

10 min

MATERIALS: science notebook, *Transcript: Lauren Family History*, *Transcript: Lakita Family History*., Community Agreements

Introduce the cases of Lakita and Lauren, cancer survivors. Display **slide B**. Say, *I have an interview with two cancer survivors that I want to share with you. I think it will help us answer some of our questions about what else could cause cancer. Let's revisit our Community Agreements and think about how they can help us as we listen to these young women describe their experiences with cancer.*

Revisit Community Agreements. Display **slide C** and direct students to the Community Agreements your class has been working with. Ask students to consider which agreement might help us work with potentially difficult content about young people who have experienced cancer. Encourage students to share their ideas. If students are unsure, ask them to consider how the agreement *Respectful: Our classroom is a safe place to share* could help the class.

ADDITIONAL GUIDANCE

Supporting empathy and emotions: Revisiting class Community Agreements before viewing this video will be helpful, as it may elicit some strong emotions among students. In the video, Lakita describes losing multiple family members to cancer and describes her experience having had multiple rounds of screening, cancer diagnosis, and treatment from age 10. Be aware that students may be thinking of loved ones who have experienced cancer in their families and communities. In addition, students may be thinking about how cancer can be inherited and may start worrying about the risk of their loved ones or themselves developing cancer. Please be mindful of these and provide safety and support by sharing awareness. See the teacher references materials in Lesson 1 for more support.

Consider saying: *As we work through this lesson, be mindful of any impact that you notice within yourself based on your own personal experiences. If you need to talk, process, or regain some grounding in the here and now, please let me or the school counselor know.* Be aware that students who are struggling may demonstrate a variety of behaviors, including but not limited to: fidgeting, withdrawal, disruption or distraction, rapid breathing, holding their breath, and/or a change in body language or tonation. If you notice a student might be struggling, share what you are observing and ask if they need some help.

Set up a Notice, Wonder, Feel chart. Display **slide D**. Ask students to set up a Notice, Wonder, Feel chart in their science notebooks to capture their ideas as they watch the video. Invite students to add an additional column to capture their feelings about what they see and hear in the video. Play the videos <https://youtu.be/ux7obpTlkbU> and <https://youtu.be/U1Zifbvvl0Q> found on **slide E** and give students several minutes to capture their ideas. For transcripts of both videos, see *Transcript: Lauren Family History* and *Transcript: Lakita Family History*.

Share notice/wonder/feel about Lakita and Lauren's stories. Ask students to share some of their thoughts with a partner and then with the class. See some possible student responses in the table below.

Notice	Wonder	Feel
Lakita is 16, lives in Kenya, and has had cancer 3 times. The osteosarcoma cancer was in her tibia and fibula, and then it came back to her hip. Lauren got cancer at age 3. Li-Fraumeni caused both of their cancers at a young age. They both got a genetic test that showed she inherited Li-Fraumeni syndrome from her dad. Lakita's dad and many of his family members died from cancer caused by Li-Fraumeni. Lauren's dad had skin cancer.	What is Li-Fraumeni syndrome? What is MDS? Why did her cancer come back? Why did it take so long to get a genetic test? Why did they need to send it to Germany? What treatment options are available? Why did so many relatives get cancer? If a parent has Li-Fraumeni syndrome, what are the chances it will be passed down to their children?	I wonder how Lakita/Lauren deal emotionally with getting cancer so often and at a young age. If they had identified LFS earlier, maybe more of Lakita's family would have survived. It must be difficult for Lakita and Lauren to share their family's cancer history with us. How would I react if I found out I had an inherited genetic mutation that led to cancer at a younger age? Should I get a genetic test if one of my parents died of cancer?

Update Personal Glossaries. Display **slide F**. Pause to give students a moment to record the new definitions for the Li-Fraumeni (lee-FRAH-meh-nee) syndrome and additional terms they encountered in their Personal Glossaries. Encourage students to add any term that is unfamiliar to them and encourage the class to share their ideas about what they mean.

ADDITIONAL GUIDANCE

Students will encounter unfamiliar terms in the video and should add definitions to their Personal Glossaries after they identify and discuss their ideas about what they might mean.

- Li-Fraumeni syndrome: a condition that increases the risk of cancer. It has something to do with p53 and families (students can revise this definition later in the lesson).
- Osteosarcoma: a type of bone cancer.
- MDS: rare blood cancer.

3 · INVESTIGATE A PEDIGREE

10 min

MATERIALS: *Lakita's Family Pedigree*

Introduce Lakita's family pedigree. Say, *We heard that Lakita and Lauren's family had something called Li-Fraumeni syndrome, and Lauren told us it has something to do with the p53 gene. Since Lakita shared more about her family, let's take a look at a model of her family and see if we can figure out what is going on.* Display **slide G**. Explain that scientists that study genetics in families use family trees called *pedigrees*. Explain that pedigrees show traits in families over generations. Review how pedigrees are organized and give students time to add a definition to their Personal Glossaries. *

- Squares represent sperm parents.
- Circles represent egg parents.
- Individuals that are shaded in had cancer related to a p53 mutation.
- A slash through the symbol indicates that the individual is deceased.

Clarify components of the model. Let students know that they will develop a model using pipe cleaners and two different-colored beads to make sense of Lakita's pedigree. Explain that although humans have 46 chromosomes (23 pairs), we are only going to model chromosome 17 that has the p53 gene. Say, *What do you think the beads will represent if we use pipe cleaners to represent the chromosomes?* Listen for students to recognize that the beads represent different versions of the p53 gene. As students are using the word *versions*, let them know that scientists use the word *allele* to represent this idea and ask them to add a definition to their Personal Glossaries.

Decide on how to represent alleles. Display **slide H**. Acknowledge that there are multiple alleles of the p53 gene, but to simplify our model, one color represents a version that corrects mutations, and the other color represents a version that does not correct mutations. As a class, choose 1 color to represent each version. Ask students to turn and talk about the possibilities for each individual using the prompts below as a guide.

Suggested prompt	Sample student response
<i>If each person has two copies of chromosome 17 (two pipe cleaners), what possible combinations of beads can they have?</i>	Two of color 1. Two of color 2. One of each color.
<i>If color 1 represents the allele that corrects mutations and color 2 represents the allele that does not correct mutations, what are the possible allele combinations for someone that has LFS?</i>	Two copies of color 2. One of each color.
<i>Genetic testing showed that Lakita's grandfather and her mother DO NOT have genes that lead to LFS. That means they only have versions that DO correct mutations. What are their possible allele combinations?</i>	Two copies of color 1.

Update Personal Glossaries. Display **slide I**. Pause and give students a moment to add definitions for the ideas they have just discussed to their Personal Glossaries. These include *genotype*, *phenotype*, *heterozygous*, and *homozygous*.*

*** ATTENDING TO EQUITY**

Biological sex is usually considered to be genetically determined, typically by the X and Y chromosomes. While the XX and XY combinations are the most common, other combinations exist and should be recognized. Gender is a social construct and is not the same as biological sex. Gender refers to how individuals position themselves and are positioned by others. Gender definitions, identities, expectations, and roles vary in different cultures, with some cultures embracing multiple gender definitions. In this unit, it is more scientifically accurate to refer to biological sex rather than gender. For that reason, we recommend the terms *egg parent* and *sperm parent* when discussing meiosis and fertilization instead of mother and father. In addition, families may be made up of individuals who do not conform to gender binaries. Lakita's family tree uses terms such as mother and father because that is how her family chose to be represented.

*** ATTENDING TO EQUITY**

Supporting emergent multilinguals: When developing new vocabulary, strategies that may benefit emergent multilingual learners are to use student-friendly definitions, make connections to cognate words when possible, and include a visual representation of the word. Use these strategies throughout the unit for both “words we earn” and “words we encounter.”

ADDITIONAL GUIDANCE

Without knowing any of the genotypes in the pedigree, an individual with LFS could be either homozygous (two copies) or heterozygous (one copy). Asking students to draw on what they have already figured out about the p53 allele will help scaffold their models and their answers to the Making Sense questions.

While the p53 mutation inheritance pattern shown in the pedigrees can be described as dominant, the lesson does not use the term in an effort to help students understand the relationship between gene and protein without oversimplifying. The goal is for them to understand that each allele is coding for protein. If they are homozygous for the LFS mutation, 100% of the protein they make does not fix mutations. If they are heterozygous, 50% of the protein they make does not fix mutations and 50% of the protein they make does fix mutations.

While not necessary to explain the phenomenon, if you would like to introduce the terms *genotype*, *phenotype*, *homozygous* and *heterozygous*, a good time to have students add these definitions to their Personal Glossaries is after they determine the possible combinations in the discussion above.

 **Investigate Lakita's family pedigree.** Distribute *Lakita's Family Pedigree* to each student. Display **slide J**. Let students know that you are going to organize them into pairs and you will provide each pair with 18 pipe cleaners and a set of beads of 2 different colors. As students finish their models, ask them to work on the Making Sense questions on *Lakita's Family Pedigree*. Student models may look like:



ASSESSMENT OPPORTUNITY

What to look for/listen for in the moment: Using pipe cleaners and beads to illustrate genotypes for Lakita's family pedigree. (SEP: 2.4)

- Correctly identifying **genotypes** based on phenotypes and **inheritance** for **different individuals over multiple generations**. (DCI: LS3.B.1; CCC: 2.2)
 - Lakita's grandfather and mother will be homozygous for the p53 allele that corrects mutations.
 - Lakita and her father, aunts, and uncles will be heterozygous for the p53 allele that does not correct mutations.
 - Lakita's aunts that have not been tested could be homozygous for the p53 allele that corrects mutation or heterozygous for the p53 allele that does not correct mutations.
 - Lakita's grandmother could be homozygous or heterozygous for the p53 allele that does not correct for mutations.

What to do:

- If students struggle with the aunts who are unknown or in determining whether shaded individuals are homozygous or heterozygous, explain that it's okay for models to show uncertainties and help students figure out how to show this. One way is by including a pipe cleaner without a bead.
- Collect and review student responses on *Lakita's Family Pedigree*. See *Lakita's Pedigree Key* for guidance. Consider waiting to collect the handout until after the discussion so students have a chance to revise their responses.

Building toward 8.A.1 Develop and use multiple models to explain how the inheritance of p53 alleles and other gene alleles can cause cancer in multiple generations of a family through new combinations of alleles. (SEP: 2.4; DCI: LS3.B.1; CCC: 2.2)

ADDITIONAL GUIDANCE

The middle school grade band of NGSS exposes students to ideas about inheritance, including MS LS3.B *In sexually reproducing organisms, each parent contributes half of the genes acquired at random by the offspring. Individuals have two of each chromosome and hence two alleles of each gene, one acquired from each parent. These versions may be identical or may differ from each other.* If students experienced OpenSciEd in middle school, they may recall *OpenSciEd Unit 8.5: Why are living things different from one another? (Muscles Unit)*, where in Lesson 5, they used pedigrees to figure out where babies with extra-big muscles get that trait variation. If students need additional support with middle school grade band ideas, use this lesson as a resource.

4 • CLASS DISCUSSION ABOUT LAKITA'S PEDIGREE

10 min

MATERIALS: science notebook, *Lakita's Family Pedigree*

Facilitate a whole-class discussion. Display slide K. Use the following prompts as a guide. *

Suggested prompts	Sample student responses	Follow-up questions
<i>How did you represent chromosome 17 and the p53 gene in Lakita's family?</i>	Each person got two pipe cleaners for each copy of the chromosome and two beads, one for each copy of the p53 gene.	<i>How did you represent alleles you were uncertain about?</i>

Suggested prompts	Sample student responses	Follow-up questions
<i>Where did the differences in the alleles of the p53 genes come from?</i>	They got passed down from the parents to the offspring. The first person who had it must have had a mutation.	<i>In our previous lessons, where did we see different versions of p53?</i>
<i>How did Lakita get the p53 allele that caused her cancer?</i>	She most likely got a copy of the p53 gene from her dad.	<i>What information do we have about Lakita's parents?</i>
<i>Do you think Lakita's dad had accumulated a mutation in his lifetime that gave him an allele for p53 that does not correct mutations, or did he have it when he was born? Explain.</i>	He probably already had it because it was in his whole body since he had cancer. Since he passed it on to Lakita, we know it was in his sperm cells.	<i>Which cells transfer genetic information from parent to offspring?</i>
<i>How did the p53 gene that Lakita got lead to her cancer?</i>	The p53 gene coded for a p53 protein that did not correct mutations, so when there were mutations, they sometimes made tumors and gave her cancer.	<i>What kind of function did p53 proteins with different shapes have?</i>

KEY IDEAS

Purpose of this discussion: To elicit student ideas from middle school and earlier lessons in this unit about chromosome pairs, genes, alleles, and mutations. Students likely came into modeling with an understanding that offspring get half their genetic material/chromosomes from each parent. They are synthesizing this information with their understanding of the p53 gene to provide a mechanism for the prevalence of Li-Fraumeni syndrome in Lakita's family.

Listen for these ideas:

- Individuals have two chromosome 17s.
- Each chromosome had a p53 gene, resulting in each person having 2 alleles (sometimes the same and sometimes different).
- Individuals get one chromosome/allele from each parent.
- Lakita most likely got a p53 allele that does not correct mutations from her dad and the copy that does correct mutations from her mom.
- Lakita's dad has this mutation in all of his cells and also inherited this mutation (at this point, students may be unsure about this idea).
- If a p53 allele cannot fix mutations, cells can grow unregulated and can become cancer.

5 · INTRODUCE A NEW PEDIGREE

9 min

MATERIALS: p53 BRCA1 Pedigree, laminated color copy of p53 BRCA1 Pedigree

Consider multiple kinds of cancers and hear more from Lauren. Say, *Lakita and Lauren both talked about having multiple different kinds of cancer. Lakita had osteosarcoma and MDS. Lauren did not share what kind of cancer she had, but she did share that her dad, who also has Li-Fraumeni syndrome, had skin cancer. Lauren was concerned that she could be at risk for breast cancer, and she had a prophylactic mastectomy; a surgery to remove the breasts and prevent cancer.* Display **slide L**. Let students know you have another clip from Lauren's video and play <https://youtu.be/-NhqJRlJsw>. After watching the video, ask students to consider why people with LFS might get so many different types of cancer. Accept all student responses.

Examine chromosome 17. Display **slide M**. Say, *p53 is on chromosome 17. I have an image of chromosome 17 that I would like to share with you.* Ask students to discuss with a partner and then the class what they notice about chromosome 17.

Suggested prompt	Sample student response
What do you notice about chromosome 17?	It has more genes than just p53. These genes also have alleles that can increase your risk of cancer.
What do you wonder?	What does it mean to "increase your risk of cancer?"

Introduce pedigree with two genes. Say, *There are many types of cancer, and many genes other than p53 are also associated with cancer. We heard that Lauren was concerned about breast cancer. Let's consider p53 and the BRCA1 gene, one of the genes associated with breast cancer.* Display **slide N**. Distribute *p53 BRCA1 Pedigree* and *Two-Gene Pedigree* to each student. Ask students to discuss the prompts with a partner and record their responses on their handout. If available, distribute 1-2 laminated color copy of *p53 BRCA1 Pedigree* to each pair.

ADDITIONAL GUIDANCE	The pedigree in slide N shows that the allele p53 B and BRCA1 D, on their own, increase the likelihood of cancer. If an individual has multiple genes with an allele that increases susceptibility to developing cancer, then the probability of having cancer increases. As needed, provide scaffolding like asking volunteers to talk about different parts of the image. For example: <i>In this pedigree, what does the shading represent? Does darker green mean you are more likely to get cancer or less likely? Who is most likely to get cancer in this pedigree? How many different alleles does this individual have for p53 and for BRCA1?</i> See <i>Two-Gene Pedigree</i> for additional support.
ADDITIONAL GUIDANCE	In addition to being relevant to Lauren's story, BRCA1 was chosen because students might already be familiar with it. The crossing over frequency is not known; however, a linkage map of chromosome 17 suggests there could be some crossing over between BRCA1 and p53. See the reference below for additional information. Haines, J. L., Ozelius, L. J., McFarlane, H. E., Menon, A. G., Tzall, S., Martiniuk, F., Hirschhorn, R., & Gusella, J. F. (1990). A genetic linkage map of chromosome 17. <i>Genomics</i>, 8(1), 1–6. https://doi.org/10.1016/0888-7543(90)90218-j

Whole-class discussion about a pedigree with two genes. Display **slide O** and lead a whole-class discussion using the prompts below as a guide.

Suggested prompt	Sample student response	Follow-up question
<i>What does this pedigree explain?</i>	That there are two genes, and each gene has two alleles. In the p53 gene, the B allele seems to increase the risk of cancer. A son has just the B allele and a shaded square. In the BRCA1 gene, the D allele seems to increase the risk of cancer. I know the daughter has one D allele and has a shaded circle. When an individual has two copies of the p53 A allele and BRCA1 B allele, they are less likely to get cancer.	<i>Which alleles seem to increase cancer risk?</i> <i>What evidence do you have?</i>
<i>Which individual do you think has a genotype most like Lauren's? Why?</i>	For p53 Lauren has one A and one B. For BRCA1 she either has 2 Cs (offspring 2) or a C and a D (offspring 3).	<i>If Lauren has Li-Fraumeni Syndrome, what genotype does she have?</i> <i>We do not know about her breast cancer risk, but based on her decision about surgery, what might it be?</i>
<i>If offspring 3 represents Lauren, which parent did she get each of her chromosomes from?</i>	She could have gotten the AC chromosome from either parent. Neither one of her parents had an AD chromosome, so we are not sure where that is from.	

6 • NAVIGATE

3 min

MATERIALS: None

Elicit ideas for next class. Display slide P. Say, *What do we need to figure out to be able to explain the pedigree with both p53 and BRCA1?* Listen for students to ask questions about mechanisms that might change chromosomes.

End of day 1

7 · NAVIGATE

3 min

MATERIALS: science notebook

Review what we figured out last class. Display **slide Q**. Ask students for their ideas about what we figured out last class and what we are going to look at today.

Suggested prompt	Sample student response	Follow-up question
<i>What did we figure out in the last class?</i>	We think Lakita got Li-Fraumeni syndrome from her father. Lakita got a chromosome from her father that had a cancer-causing p53 gene. She got a non-cancer-causing p53 gene from her mom. Lauren had surgery to prevent breast cancer. Risk can be higher for cancer when you have two alleles from two different genes that increase risk.	<i>Where did Lakita get her Li-Fraumeni syndrome from?</i> <i>Why might Lauren have had an increased risk for breast cancer?</i>
<i>What did we decide we still needed to know?</i>	Where did Lauren (offspring 2 and 3 in the pedigree) get her chromosomes/alleles from? Why do the chromosomes of offspring not match their parents? Is there another mechanism that can change alleles and chromosomes besides mutation? How do we know if it was a mutation? Which chromosome had the mutation?	<i>Can you think of something from this unit that we have already studied that might help us figure some of this out?</i>

8 · INITIAL IDEAS DISCUSSION ABOUT HOW ALLELES ARE PASSED ON

4 min

MATERIALS: science notebook

Turn and Talk about how alleles are passed on. Say, *We saw in Lakita's family pedigree and in our two-gene pedigree that when parents had certain alleles, their offspring also had those alleles, but how exactly do the alleles move from parent to offspring?* Display **slide R**. Ask students to turn and talk to a partner, jot their ideas down in their science notebooks, and be prepared to share with the class.

Initial Ideas Discussion. Call on a few pairs to share their ideas using the prompts below as a guide.*

* STRATEGIES FOR THIS INITIAL IDEAS DISCUSSION

Reasons for eliciting students' initial ideas include:

- To get students' prior knowledge and experiences on the table.
- To provide a supportive opportunity for students to make sense of what may not be fully formed ideas (either their own ideas or those of others).
- To help students realize that there are gaps in our understanding to promote curiosity and what we could do next to figure something out.

Suggested prompts	Sample student responses	Follow-up questions
<i>How did the p53 and BRCA1 alleles move from parents to offspring?</i> <i>If mutations explain what we observed in the two-gene pedigree, where would they have occurred?</i> <i>It seems like the pedigree has some limitations in helping us explain what is happening here. How can we use our pipe cleaner/bead model to help us answer these questions?</i>	Parents make eggs and sperm. Sperm fertilizes eggs and makes a baby. Each parent passes half of their genes onto their baby, so together the baby gets a full set. Both offspring 2 and 3 had chromosomes with alleles that did not match their parents. There would have had to be mutations between the two generations to create the differences. We can set up our pipe cleaners and beads to see if we can make sense of the alleles.	<i>How do parents pass their genetic info on to their kids?</i> <i>What cells are involved in passing on genetic material?</i> <i>Which chromosomes in generation two do not match the combinations of their parents?</i> <i>What kinds of questions can the pipe cleaner/bead model help us answer?</i>
KEY IDEAS	Purpose of this discussion: To elicit student ideas about sexual reproduction and inheritance and how their models can help them figure out allele combinations in families. Listen for these ideas: • Alleles are passed from parents to offspring through sexual reproduction. • Eggs and sperm are the cells that are involved in passing on genetic information. • In the case of our two-gene pedigree, we have some allele combinations that we cannot explain. • The pedigree model is limited in what it can help us understand and our pipe cleaner/bead model might help us.	
ADDITIONAL GUIDANCE	If students need additional support with middle school grade band ideas, such as MS-LS3.B <i>In sexually reproducing organisms, each parent contributes half of the genes acquired (at random) by the offspring. Individuals have two of each chromosome and hence two alleles of each gene, one acquired from each parent. These versions may be identical or may differ from each other.</i> Provide them with <i>Optional: Inheritance Extra Practice</i> prior to working through the next set of pedigrees.	

9 • MODEL THE PEDIGREE WITH PIPE CLEANERS AND BEADS

8 min

MATERIALS: science notebook, *p53 BRCA1 Pedigree*, laminated color copy of *p53 BRCA1 Pedigree*

Model the two-gene pedigree. Display **slide S**. Say, *Let's go back to our pedigree and see if we can explain it by modeling meiosis in the parent 1 (sperm parent) to show how parents could produce these offspring.* Ask students to take out *p53 BRCA1 Pedigree*. Organize small groups of 3-5 students and ask students to use pipe cleaners and beads to model how the two genes are passed on in this family. If available, distribute 1-2 laminated color copies of *p53 BRCA1 Pedigree* to each group. Circulate around the room as students work. Press them to go beyond mutations to explain how the alleles got to be in different combinations in the offspring.

ADDITIONAL GUIDANCE

Make sure the class is clear on which color represents which allele and what trait goes with each allele. Consider making a key on the board. The following matches the color scheme on the slide, but any four colors that are distinct from each other will work.
Dark blue=A= p53, corrects mutations
Light blue=B= p53, does not correct mutations
Red=C= BRCA1, low-risk breast cancer
Yellow=D=BRCA1, higher-risk breast cancer

10 • READ ABOUT HOW ALLELES ARE PASSED ON

8 min

MATERIALS: science notebook, *Passing on Alleles*

Introduce a reading. As students work on their models, they will recognize that while it is easy to replicate the pedigree and develop a model of the chromosomes and alleles, it is much more difficult to use the model to explain how those alleles got to where they are. * As students reach this point, display **slide T** and distribute *Passing on Alleles* to each student. Give students time to complete the reading, jot down what they notice and wonder in their science notebooks, and discuss with their group how to incorporate what they figure out from the reading into their models. *

* SUPPORTING STUDENTS IN ENGAGING IN DEVELOPING AND USING MODELS

Students can use the pipe cleaner/bead model to develop a mechanistic account for explaining how alleles are passed down in families. Encourage students to consider the merits and limitations of each model. The pedigree is a *model of inheritance* while the pipe cleaners and beads can be used as a *model for explaining inheritance*.

* ATTENDING TO EQUITY

Universal Design for Learning: Struggling readers may have more success engaging with the readings by implementing strategies such as these: reading with a partner, reading aloud, chunking the text, highlighting unknown words, or looking for key ideas.

11 • REVISE PIPE CLEANER AND BEAD MODELS

8 min

MATERIALS: science notebook, scissors



Small groups revise their models. Once students have had a chance to complete the reading, display **slide U**. Ask students to revise their models using what they figured out from the reading. They should use the prompts on the slide as a guide. In addition, provide each group with a pair of scissors to help them incorporate crossing over into their models.

ASSESSMENT OPPORTUNITY

What to look for/listen for in the moment: The use of pipe cleaners and beads in a model to explain (SEP: 2.4):

- Meiosis, including crossing over, as a mechanism for creating sperm with chromosomes that could produce offspring with different phenotypes from their parents. (SEP: 2.4; DCI: LS3.B.1; CCC: 2.2)
- Crossing over between paired chromosomes before cell division. (DCI: LS3.B.1)
- Four new cells, each with one chromosome. Each cell has a different combination of alleles (p53A/BRCA1C, p53B/BRCA1C, p53A/BRCA1D, p53B/BRCA1D). (DCI: LS3.B.1)
- Identify which of the new cells would produce which offspring in the pedigree. (CCC: 2.2)

What to do: Circulate around the room and talk to each group about their model.

- Encourage students to take photos of different steps in their model to use to explain the process. As an extension, consider having students submit their photos online in a shared slide deck or flip book or collect their drawings in class.
- If students struggle with where to start, refer them to their reading to identify what happens first.
- If students end up with different combinations of alleles than expected, ask them to show you how and where crossing over happens.
- As students complete their models, ask them to relate the offspring in generation two to what we know about Lauren.

Building toward 8.A.2 Develop and use multiple models to explain how the inheritance of p53 alleles and other gene alleles can cause cancer in multiple generations of a family through new combinations of alleles. (SEP: 2.4; DCI: LS3.B.1; CCC: 2.2)

12 · BUILDING UNDERSTANDINGS DISCUSSION ABOUT INHERITANCE

8 min

MATERIALS: science notebook

Building Understanding Discussion about inheritance. Display slide V. As students are finishing their models, ask them to discuss the following prompts with their groups and then lead a whole-class discussion using the prompts below. *

Suggested prompt	Sample student response	Follow-up question
How does your model help explain how alleles were passed down in this pedigree?	We used crossing over to make chromosomes that were similar to those found in the offspring. We produced four cells: two had chromosomes like the dad, and two had chromosomes different from the dad. All sperm had different combinations of alleles. With crossing over, we produced sperm cells that could have fertilized eggs in the pedigree.	Do you think the egg parent's chromosomes also crossed over during meiosis?

* STRATEGIES FOR THIS BUILDING UNDERSTANDINGS DISCUSSION

Asking students to restate what another student has said helps students listen carefully to each other so that they can work with others' ideas. This move can feel odd to students at first, so it will help if you let them know ahead of time that you will be asking this.

Suggested prompt	Sample student response	Follow-up question
<i>What effect does crossing over have on genes and alleles on chromosomes?</i>	Crossing over produced chromosomes with the same number of genes. The genes on the chromosomes stayed the same. The alleles got mixed up. New combinations of alleles were made that were not present in the dad's chromosomes. In the dad, all cancer-associated alleles (B and D) were on the same chromosome. After meiosis and crossing over, some cancer-associated alleles were on a chromosome with non-cancer-associated alleles.	<i>When does crossing over happen?</i>
<i>Where did the version of genes that increase the likelihood of cancer (p53 B and BRCA1 D) come from?</i>	They came from mutations sometime during replication. Those versions have to be in the body AND in the eggs and sperm. Lauren's dad had cancer AND she inherited that gene.	<i>Which cells in the parent's body have the p53 B and BRCA1 D versions of the genes?</i> <i>Is that mutation in the parent's body cells, their gametes, or both? How do you know?</i>
<i>How could crossing over help explain Lauren's situation?</i>	Lauren could have gotten p53 and BRCA1 genes that both increased the likelihood of cancer from her dad even though he had those genes on different chromosomes.	<i>What would Lauren have gotten without crossing over?</i> <i>How is that different from what alleles the pedigree shows?</i>

KEY IDEAS

Purpose of this discussion: To put together ideas about how inheritance of traits works, how crossing over introduces new combinations of alleles, and the impact that could have had on Lauren's cancer risk.

Listen for these ideas:

- Crossing over introduces new combinations of alleles.
- The alleles in the model were inherited because they were present in the parents' eggs and sperm.
- Lauren could have inherited a variation that increased her risk for cancer in both the p53 gene and the BRCA1 gene even though neither of her parents had a chromosome with that combination.

Update Personal Glossaries. Display **slide W**. Congratulate students on their work in figuring out inheritance for the pedigree with p53 and BRCA1. If inheritance has not come up in the course of students work in this lesson, pause to come to consensus and add a definition such as *the passing on of genetic material from parents to offspring*. Provide students with a few minutes to update their Personal Glossaries with this and any other definitions that have not yet been encountered.

ADDITIONAL GUIDANCE

The following vocabulary will likely be unfamiliar to most students. Students encountered these terms in the reading and should add definitions to their Personal Glossary after they identify them.

- Gametes: sperm and eggs.
- Meiosis: the process to make gametes that involves two cell divisions and reducing the number of chromosomes in half.
- Crossing over: swapping of genetic material between chromosome pairs during meiosis.
- Fertilization: the process of sperm fusing with an egg to create a new individual.

13 · NAVIGATE: ELECTRONIC EXIT TICKET

6 min

MATERIALS: science notebook, https://docs.google.com/forms/d/1MKGi-g_VGjflx7slyFqUoKgJSxSaKkX_RFqcSILO_QE/copy



Complete an exit ticket. Display slide X. Congratulate students on all they have figured out. Say, *We now know that cancer can be caused by mutations we get in our lifetime and by alleles that are inherited from parents. We still have not explained all of the causes of cancer. What other causes do we still need to investigate?* Listen for students to recall environmental factors that may cause cancer. Have students complete https://docs.google.com/forms/d/1MKGi-g_VGjflx7slyFqUoKgJSxSaKkX_RFqcSILO_QE/copy. Encourage students to use their notes to help them answer the questions on the electronic exit ticket. See *Exit Ticket Guidance* for instructions on how to make the electronic exit ticket.

ASSESSMENT OPPORTUNITY

What to look for/listen for in the moment: See *Electronic Exit Ticket Key* for guidance.

What to do: See *Electronic Exit Ticket Key* for guidance.

Building toward 8.A.3 Integrate information from multiple sources to answer questions about how changes to the **structure** of the **DNA in the p53 gene** relate to **protein function**. (SEP 8.2 ; DCI LS1.A.2 & LS3.A.1; CCC 6.2)

Additional Lesson 8 Teacher Guidance

SUPPORTING STUDENTS IN MAKING CONNECTIONS IN ELA

CCSS.ELA-LITERACY.9-10.9 Draw evidence from informational texts to support analysis, reflection, and research.

When students cite evidence from a scientific reading about inheritance to revise their models.

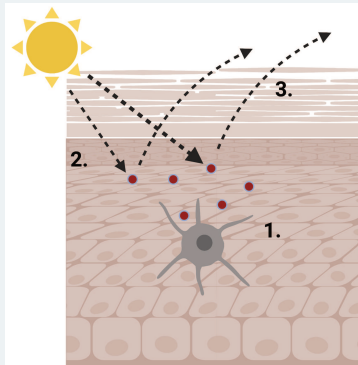
LESSON 9: How do genes interact with the environment to affect who gets cancer?

PREVIOUS LESSON We decided to investigate other reasons why someone might get cancer. We watched videos about two young individuals, Lakita and Lauren, who survived multiple cancers. We modeled Lakita's family in a pedigree and used a second model to try to understand more about Lauren's family. We figured out how mutations that increase the risk of cancer can be inherited in families. We decided to investigate mutations due to the environment next.

THIS LESSON

INVESTIGATION

3 days



Illustrations created by OpenSciEd in BioRender

We decide to investigate how the environment might explain cancer not accounted for by random and germline mutations. We investigate scientific data related to the incidence of skin cancer and design and carry out our own investigations. We read about the mechanism of UV radiation causing mutations in our cells and about a protective mechanism in our skin.

NEXT LESSON We will develop our consensus model to connect the ideas that we figured out about random mutations, inheritance, and environmental factors. We will decide that we need to test our ideas in a new context and complete a transfer task to make progress on figuring out who gets cancer and why.

BUILDING TOWARD NGSS

HS-LS1-1, HS-LS1-2, HS-LS1-4, HS-LS3-1, HS-LS3-2, HS-LS3-3, HS-ETS1-3



WHAT STUDENTS WILL DO

9.A Ask questions to determine how environmental factors cause mutations in genes. (SEP 1.6; DCI LS3.B.2; CCC 2.1)

9.B Make and defend a claim using evidence about how environmental factors cause mutations in genes. (SEP 7.5; DCI LS3.B.2; CCC 2.1)

WHAT STUDENTS WILL FIGURE OUT

- UV radiation can cause mutations in DNA.
- Those mutations can cause changes in protein structure and function and lead to cancer.
- The skin has a protective mechanism against damaging UV radiation that is governed by a protein called melanin.
- Variations in exposure to UV radiation and variations in melanin production lead to different levels of risk in the human population.

Lesson 9 • Learning Plan Snapshot

Part	Duration		Summary	Slide	Materials
1	2 min		NAVIGATE Guide students in a discussion about what they have figured out and what questions they have.	A	<i>Progress Tracker</i> , Driving Question Board
2	8 min		REVISIT CLASS CONSENSUS MODEL Review consensus model and ask students to propose and add new possible mechanisms related to the environment.	B-D	
3	8 min		INVESTIGATING SKIN CANCER DATA Share skin cancer data set and guide class discussion.	E-J	<i>Skin Cancer Data</i>
4	10 min		INTRODUCE AN INVESTIGATION Introduce the context for the yeast investigation.	K-N	<i>Investigation Plan: Environmental Factors and Cancer</i> , chart paper and chart paper markers (optional)
5	10 min		DESIGN INVESTIGATION PROTOCOL Guide students in planning their investigation.	O	
<i>End of day 1</i>					
6	5 min		NAVIGATE Help students recall what we decided to investigate during the last class.	P	
7	10 min		REVIEW INVESTIGATION PROTOCOL Help students recall what we decided to investigate during the last class.	Q-R	<i>Investigation Plan: Environmental Factors and Cancer</i>
8	25 min		SET UP INVESTIGATION Provide guidance to small groups as they set up their investigations.	S-T	Yeast Investigation
9	5 min		NAVIGATE: MAKE PREDICTIONS Support students in making predictions about their investigations.	U	
<i>End of day 2</i>					
10	3 min		NAVIGATE Ask students to recall their investigative questions and predictions.	V	
11	12 min		COLLECT DATA Support student data collection and compile class data.	W	
12	5 min		SMALL-GROUP SENSEMAKING Facilitate small-group sensemaking around the investigation data.	X	

Part	Duration		Summary	Slide	Materials
13	10 min		INVESTIGATE MECHANISM OF SKIN CANCER Provide students with a scientific text and facilitate small-group sensemaking.	Y-Z	<i>Skin Cancer Background Reading</i>
14	10 min		BUILDING UNDERSTANDINGS DISCUSSION Facilitate a Building Understandings Discussion about the investigation and reading and to reach consensus around the causal link between the environment and skin cancer.	AA-CC	<i>Skin Cancer Background Reading, Data Collection</i>
15	5 min		NAVIGATE Update Progress Tracker	DD	<i>Progress Tracker</i>

End of day 3

Lesson 9 • Materials List

	per student	per group	per class
Yeast Investigation materials	• <i>Investigation Plan: Environmental Factors and Cancer</i> • indirectly vented chemical splash goggles • nitrile gloves • and non-latex apron	• 2 petri dishes • 2 sterile transfer pipettes (1mL) • 8 sterile glass beads • 6 sterile toothpicks • 1 small dish or container to collect used glass beads • 1 permanent marker	• 1-2 test tubes of wild-type yeast • 1-2 test tubes of UV-sensitive yeast • test tube rack • UV (or similar) light source • incubator or dark location at room temperature • Depending on investigation: Plastic wrap and Aluminum foil and Sunscreen (varying types and strengths) and Fabric (varying types)
Lesson materials	• <i>Progress Tracker</i> • science notebook • <i>Skin Cancer Data</i> • <i>Investigation Plan: Environmental Factors and Cancer</i> • <i>Skin Cancer Background Reading</i> • <i>Data Collection</i>		• Driving Question Board • chart paper and chart paper markers (optional)

Materials preparation (120 (spread out over one week) minutes)

Review teacher guide, slides, and teacher references or keys (if applicable).

Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

Three-hole-punch all handouts so they can be added to student notebooks.

Day 2: Environmental Factors and Cancer

Note: Set aside approximately one week to adequately prepare the materials and yeast for this investigation. Prep for this lab will require approximately 3 hours spread over the span of one week. Be sure to order your yeast so that it arrives approximately 1-2 weeks before you begin this lesson. Yeast that is older than 3-4 weeks may behave unpredictably and yield unexpected results. Once your yeast arrives, protect it from light and keep it stored in a 4°C refrigerator.

- **Group size:** 4-5 students
- **Setup:** You will need the following materials to begin preparing for this lab activity:
 - 1 vial of wild-type yeast
 - 1 vial UV-sensitive yeast
 - 20mL of sterile water
 - 350mL bottle of YED medium
 - Heat source to melt medium (water bath or microwave)
 - Box of sterile toothpicks
 - 4 sterile culture test tubes
 - 6 sterile 1mL transfer pipettes
 - Test tube rack

- UV (or similar) light source
- Permanent marker
- Incubator or dark location at room temperature
- **Safety:** Ensure that students take appropriate precautions. Direct supervision will be required during all aspects of these activities.
 - Wear indirectly vented chemical splash goggles, non-latex aprons, and nitrile gloves during set-up, preparation and take down.
 - Do not pour hot water into beakers. Use caution when working with heated liquids--these can burn skin!
 - Immediately wipe up any spilled water on the floor--this is a slip and fall hazard.
 - While yeast is generally safe for use, in case of inhalation, move to fresh air and rest; in case of contact with eyes, rinse immediately with water; after contact with skin, wash immediately; if swallowed, seek medical advice.
 - Use caution when working with UV radiation sources. Sources can damage eyes and skin after exposure. Use caution when working with glass bulbs. They can break/shatter and cut skin.
 - Wash hands with soap and water and use hand sanitizer wipes immediately after completing this activity.
- **Disposal:** Dispose in accordance with all applicable federal, state, and local regulations. Always contact a permitted waste disposer to assure compliance.
- **Storage:** When not in use, store yeast and petri dishes with media in the refrigerator as directed by the supplier.

For details on setting up this investigation, see *Environmental Factors and Cancer Preparation*.

Lesson 9 • Where We Are Going and NOT Going

Where We Are Going

In this lesson, students add to their understanding of who gets cancer and why by investigating the environmental basis of cancer in the context of UV radiation and skin cancer. This builds on the middle school understanding that mutations may result in changes to the structure and function of proteins, some of which may be harmful. (MS LS3.B)

Students continue to develop and use the focal practices of the unit: *asking questions* and *engaging in argument from evidence*. Students are supported in learning to ask questions through a scaffolded approach in which they transform general questions into investigative questions to figure out how environmental factors, such as exposure to UV radiation, cause mutations in genes and potentially lead to an increased incidence of skin cancer. Students are supported in making claims supported by evidence as they compare data sources (from research and through investigation) in order to determine whether the link between environmental factors and skin cancer is causal or correlational. Students will continue to develop and use these practices throughout the unit.

Students develop the focal crosscutting concept: *cause and effect* throughout the lesson and will specifically focus on using empirical evidence to make claims about the potential impact of specific environmental factors on the incidence of cancer within a population. Additionally, by using multiple data sources, students will differentiate whether the association between skin cancer and exposure to UV radiation is casual or correlational in nature.

On day 3, students co-construct a definition for causation. Using evidence to claim whether a correlational or causal link exists is a critical part of the crosscutting concept (2.1) assessed in this lesson. Students began to develop this skill in Lesson 1 and will continue to practice using evidence to substantiate claims throughout the unit.

Where We Are NOT Going

While students read about the chemical changes in DNA that happen when UV radiation rearranges chemical bonds in DNA, they are not investigating whether those chemical reactions can be understood in terms of the collisions of molecules and the rearrangements of atoms into new molecules (PS1.B.1). Chemical reactions and bonding as part of HS-PS1-4 and HS-PS1-5 will be explored in OpenSciEd Chemistry Unit 5 (Fuels and Nuclear Energy) and Unit 4 (Oysters), respectively.

This lesson builds on the middle school physical science ideas that when light shines on an object, energy from that light can be absorbed by some materials (MS-PS4-2) and converted into kinetic energy of particles. If students need support in understanding the relationship between light and energy, refer to OpenSciEd Middle School Unit 6.1 (Light and Matter) and Unit 6.2 (Thermal Energy).

In this lesson, students find out that UV radiation can damage DNA. However, they are not developing the idea that shorter wavelength electromagnetic radiation can ionize atoms and cause damage to living cells (PS4.B.2). This will be examined in greater detail as part of HS-PS4-4 in OpenSciEd Physics Unit 5. Furthermore, this is not a time to examine the entire electromagnetic spectrum in detail, as students only consider the role that UV radiation plays in skin cancer. Whether other forms of radiation cause cancer does not aid in the progression and coherence of this storyline.

LEARNING PLAN for LESSON 9

1 • NAVIGATE

2 min

MATERIALS: *Progress Tracker*, Driving Question Board

Review what we have figured out. Display **slide A**. Ask students to recall the progress that we have made in figuring out who gets cancer and why. Tell students to refer to their *Progress Tracker* if needed. Listen for responses such as:

- We know some people get cancer due to random mutations during cell division. This usually happens to people who are older.
- Some people can inherit genes that make it more likely for them to get cancer.

Elicit ideas about next steps. Remind students that the mechanism we figured out so far only accounts for some of the cancer that occurs in the United States but not the majority of cancers. Ask them to consider what we might investigate to figure out what factors might be responsible for other types of cancer that occur more frequently. Refer to the Driving Question Board and focus on students' questions connected to the environment and its possible link to cancer. Listen for responses such as:

- We need to look at things in the environment.
- We should look at things like smoking, the sun, or pollution.

2 • REVISIT CLASS CONSENSUS MODEL

8 min

MATERIALS: science notebook

Introduce cancer statistics. Say, *It sounds like you have some ideas about environmental conditions that might affect cancer.* Display **slide B** and then **slide C** and read students the quotes about lung and skin cancer.

Stop and Jot. Display **slide D**. Ask students to think about how smoking or sunlight might cause those cancers. Display the class consensus model from Lesson 7 and prompt students to review the mechanisms they figured out about mutations resulting in changes in DNA and protein. Give students a minute or two to write their ideas down in their science notebooks. *

Turn and Talk. Ask students to talk to their neighbors and share the ideas they have written down. Make sure each student has time to share. To help ensure equity, tell students to be prepared to share their partner's ideas with the class. Once partners have had time to share, call on a few pairs to share with the class. Listen for ideas such as the environment:

- could cause the mutations due to changes in the DNA sequence (bases).
- could change the shape of the protein.
- could make the DNA or proteins work differently.

Consider adding sticky notes to the class consensus model to represent the ideas students have about what the mechanism could be.

* ATTENDING TO EQUITY

Social and Emotional Learning: Some students will know someone or be related to someone who smokes and perhaps even someone who has been diagnosed with cancer related to smoking. It is important that you explain to students that they should not feel pressured to share anything about their families during this unit.

If a student decides to share something with the class about their family as it relates to cancer, it is important that they do not feel stigmatized by this. Instead, you might applaud their bravery for sharing and explain to the class that diseases like cancer can occur, and it can be upsetting to hear or receive such news. Although cancer often impacts students in ways they cannot always control, the aim of this lesson (and unit) is to help students consider how and why cancer

occurs and to empower them to use what they learn to respond in ways that can help them and their loved ones.

3 · INVESTIGATING SKIN CANCER DATA

8 min

MATERIALS: *Skin Cancer Data*

Introduce skin cancer data set. Display **slide E**. Say, *I found some research that examined skin cancer rates by geographical location and by race. Let's take a look at some data and think about the questions on this slide.* Organize students in small groups. Pass out *Skin Cancer Data*. Display **slide F**. Ask students to review the data from the graphs as a group and then individually record what they notice and wonder in their science notebooks. Tell students to be prepared to share what they noticed with the whole class.

Students may notice and wonder about the term “melanoma” from the graphs. Explain to them that the term refers to a type of skin cancer that develops in specialized cells that give skin its tan or brown color. Pause and give students a moment to record this definition in their personal glossaries as a definition we encounter.

ADDITIONAL GUIDANCE

Clarifying Population Labels in the Data: To help students make sense of the data in the graphs, the demographic labels have been simplified to White, Black and Hispanic. The original research used the labels: “White Non-Hispanic” to refer to populations identifying as White or Caucasian; “Black” to refer to populations identifying as Black and Black-Hispanic; and “White Hispanic” to refer to all non-Black members of the Latino/x community. This study included those identifying as Black-Hispanic under “Black” because of the higher concentration of melanin in their skin.

Whole-group sensemaking. Ask students to share what they noticed and wondered about each of the three graphs. Be prepared to show **slides G-I** as students discuss the patterns they notice. Use the following prompts as a guide:

Suggested prompt	Sample student response
<i>What did you notice and wonder about the first graph?</i>	It seems like people who identify as White and who live in sunnier places tend to get more skin cancer. There is a direct relationship between UV radiation and skin cancer for people who identify as White.
<i>What did you notice and wonder about the second and third graphs?</i>	The relationship is more complicated for people who identify as Black or Hispanic. It is not as clear what is happening for Black or Hispanic populations as the amount of UV radiation goes up. There is NOT a direct relationship between UV radiation and skin cancer for people who identify as Black or Hispanic. In some places (like Utah and Atlanta) there is a lot of skin cancer but not as much UV radiation as in other places.

If students do not use the term positive to describe the relationship seen in the first graph, remind them about the relationships they investigated in *OpenSciEd Unit B.1: How do ecosystems work, and how can understanding them help us protect them? (Serengeti Unit)*. Scientists say a relationship is positive when both values on the graph increase simultaneously. For example, on **slide J**, as the average yearly UV index (average amount of UV a location receives over the course of one year) increases, the incidence of melanoma (occurrence of skin cancer) also increases.

Motivate an Investigation. Display **slide J**. Say, *We noticed some interesting patterns regarding skin color, exposure to UV radiation from sunlight, and who tends to get skin cancer. It seems like we think there may be a connection between cancer and our environment – in this case, exposure to the sun. One way to answer some of our questions and to gather more information is to conduct an investigation.*

Read the prompt on the slide and ask some students to share their ideas. If questions or ideas about using sunscreen or sunblock to protect against skin cancer came up earlier, revisit those now. Guide students to think about how we might investigate those questions as well.

Students may share some of the following ideas or possible questions to investigate:

- *We could expose cells to sunlight and see what happens to them? Maybe they will die or change somehow?*
- *We could put some cells out in the sun and see if they get sick, like with cancer?*
- *We could try using sunscreen with some cells and then put them in the sun to see if anything happens to them? Maybe they will be more protected than cells without sunscreen?*
- *What if we could cover some cells with clothing to protect them from the sunlight? Can we test different types of clothing?*

Applaud students for sharing their ideas and say, *Many of your ideas involve using living cells, so let's discuss what types of cells we might be able to use in the classroom.*

4 · INTRODUCE AN INVESTIGATION

10 min

MATERIALS: *Investigation Plan: Environmental Factors and Cancer*, chart paper and chart paper markers (optional)

Introduce yeast as our model organism. Explain that sometimes scientists use other organisms when researching cancer because it is difficult and unethical to experiment on people. Thankfully, all organisms are made up of cells, and cells grow, divide, and behave similarly in all organisms, including unicellular organisms. Therefore, sometimes other organisms can serve as a model for figuring out how cancer works in the human body. Remind students that they used yeast as their model organism in *OpenSciEd Unit B.2: What causes fires in ecosystems to burn and how should we manage them? (Fires Unit)*.

Make a case for investigating yeast as a model organism. Display **slide K**. Show images of yeast and explain that yeast is a particularly good model organism because:

- it is easy to grow and use in the lab.
- its DNA is organized and replicates similarly to human DNA.
- its DNA can be repaired, similar to human DNA.

Say, *Knowing that scientists often use yeast to investigate cancer in humans, I did some research and found a special UV-sensitive strain of yeast we can use to investigate the effect of UV radiation on cells.*

Make an analogy between human and yeast cells. Display **slide L**. Explain to students that typical yeast cells, like the type you find in the wild (or “wild-type”), that are exposed to the sun will grow and divide without problems because they have a DNA repair mechanism (similar to p53 in humans) that repairs mutations caused by UV radiation. Scientists have also developed a special strain (or mutant strain) of yeast that is UV-sensitive, meaning that they have removed (or “knocked out”) the gene that repairs mutations caused by UV radiation. In a human cell this would be like removing the p53 gene and eliminating the protection it provides against DNA damage. Unlike humans, yeast is single-celled, and therefore it does not form a tumor or get cancer. Instead, if the yeast cell is damaged by UV radiation, it simply dies.

* ATTENDING TO EQUITY

To help ensure greater equity and to promote student agency, guide the class to investigate one environmental factor that affects yeast cell growth and one factor that protects against UV damage. By running two simultaneous investigations, students may select one that interests them more. Though their top choice may not be available, students still have an opportunity to exercise their agency. Depending on available materials, you may need to ensure that roughly equal numbers of students investigate each question.

Consider possible relationships to investigate. Display **slide M**. Tell students that we have access to UV-sensitive yeast, as well as wild-type yeast, in order to explore the relationship between the environment and cell growth, and what this tells us about skin cancer. Review the ideas for investigation discussed earlier by students on **slide J**. Let students know that based on their ideas for investigations and the materials available in the classroom, the class can investigate two possible relationships:

- (1) how environmental factors (such as UV radiation) affect cell growth in yeast, OR
- (2) how environmental factors (like sunscreen) can protect yeast cells from UV damage.

Should other ideas for investigation come up that you are comfortable exploring as a class, adjust this text on this slide as needed.

Elicit ideas for investigation variables. Write the two general questions on the whiteboard or chart paper. Say, *Let's think about how we can use this special yeast strain to investigate the mechanism of damage or protection based on the data in the three graphs we just examined. We saw that people in different locations and with different UV exposure had different outcomes in terms of skin cancer. We also saw that people of different races had different outcomes. What could we do with our yeast cells to investigate that?* Record ideas that students share on the whiteboard or chart paper. Listen for ideas such as the ones listed below:

Environmental Factors That Affect Growth	Environmental Factors That Protect Against UV Damage
• Longer time in the light. • Different amounts of light. • Different intensities of light.	• Protection with sunscreen. • Protection with different kinds of clothes (fabric). • Put an umbrella over it. • Cover it with something that could absorb the light, like melanin.

Decide on investigative variables. Once the class comes up with a list, help them narrow it down by providing guidance based on materials available. Consider having students vote on their preferred variable from the list.



Develop an investigative question. Support students in moving from a general question toward an experimental or investigative question. Distribute the *Investigation Plan: Environmental Factors and Cancer*. Explain that scientists develop questions that they can test by collecting evidence about a phenomenon or problem. In order to do this, they need to know what to observe or measure that would answer their question. Tell students that the *Investigation Plan: Environmental Factors and Cancer* will help them develop an investigative, testable question that we will use to guide our next investigation.

Display **slide N**. Tell students to work with a partner to complete part 1. Prompt students to start by writing the original question(s) agreed upon by the class. Be sure to revise the question on this slide to match the question(s) that the class has decided to investigate.

ASSESSMENT OPPORTUNITY

What to look for/listen for in the moment:

- Selection of an investigative question. (SEP: 1.6)
- Identification of an independent variable and dependent variables, which will be observed during their investigation and provide empirical evidence that environmental factors can cause mutations. (DCI: LS3.B.2; CCC: 2.1)

What to do: Support students in choosing investigative variables that are supported by the available materials and that will help them generate evidence to answer their questions. For example, if they are interested in the protective mechanism, guide them toward variables such as different types of sunscreen or different types of fabric. If they are interested in the effect of latitude and exposure to sunlight, guide them toward varying the time the yeast cells are exposed to the light source.

Listen for the independent and dependent variables students identify and the cause and effect relationship students describe as they develop their investigative question. If students need support developing investigative questions, use *Unknown material with identifier: bi.l9.tref* to support them.

Use what you hear during the partner discussion and what you see on the *Investigation Plan: Environmental Factors and Cancer* to anticipate how you will guide students to design an investigation protocol.

Building toward 9.A.1 Ask questions to determine how environmental factors cause mutations in genes. (SEP: 1.6; DCI: LS3.B.2; CCC: 2.1)

ADDITIONAL GUIDANCE

Opportunity for an extension: Questions may arise about different types of sunscreens. The two most common types of sunscreen commercially available are mineral and chemical sunscreens. **Mineral sunscreens** contain small particles, often zinc oxide and titanium dioxide, which remain on the skin's surface and physically block UV rays from penetrating the skin. **Chemical sunscreens** allow UV rays to be absorbed by the skin where they react with chemicals in the sunscreen. As a result of this reaction, the energy from the UV light is converted into heat, which dissipates away from the skin.

As an extension, students could investigate how these different sunscreens affect the yeast cell growth. Then, students could be asked to use the ideas around structure and function to explain how the two sunscreens work differently to protect against UV damage.

5 • DESIGN INVESTIGATION PROTOCOL

10 min

MATERIALS: None

Design the investigation protocol. Once students decide on their variable and develop two investigative questions, have them decide how they will vary conditions across the class. Distribute *Investigation Plan: Environmental Factors and Cancer* and guide students to fill in the table based on the class's decision as you discuss the protocol together. Students should record the investigative question and the variables they choose to manipulate. Then they should fill in the table based on the number of groups in the class and what variable each group will investigate. For example, if the class is investigating how environmental factors offer protection and they choose to vary the SPF strength of sunscreen, which SPF strength will each group use? Similarly, if the class decides to investigate how the amount of exposure to sunlight affects cell growth, how long will each group expose their cells to a light source?

* ATTENDING TO EQUITY

To help build student motivation, consider allowing students to bring items from home, like sunscreen or clothing made from

Design a fair test. Prompt students to consider how they know that their results are due to the condition they are investigating. For example, how will they know that differences in yeast growth are due to the different SPF strengths and not due to the increased temperature from being exposed to the sun? Help them consider the role of a control, one dish in the dark to see what happens when no light is present and have one dish without any sunscreen.

Guide students to consider the variables they need to control in order to make sure the evidence they collected can help them answer their investigative question. For example, if they are varying SPF strength, all the petri dishes should be exposed to the same amount of UV radiation. Display **slide O** and see the sample table below:

Group	Environmental Conditions for Petri Dishes	Exposure to Light
1	No SPF	15 min
2	SPF 15	15 min
3	SPF 18	15 min
4	SPF 20	15 min
5	SPF 30	15 min
6	SPF 50	15 min
7	No SPF, covered in aluminum foil	15 min

Finally, remind students that though they will work with the UV-sensitive yeast, you also have wild-type yeast available to ensure that the investigation is a fair test. Decide whether you or the students will run a parallel set of wild-type petri dishes under the same conditions. At the end of the class, remind students to bring any materials from home for the investigation.

End of day 1

different fabrics. Deciding on materials on day 1 gives students time to plan and locate materials from home to use on day 2.

Involving students in the planning steps encourages their active participation throughout the investigation. Also, to help students see themselves as scientists, it's important for them to participate in and experience the creativity involved in planning an investigation, as opposed to only being asked to follow a series of predetermined steps.

6 • NAVIGATE

5 min

MATERIALS: science notebook

Summarize what we figured out. Display **slide P**. Remind students of the unanswered questions we had about the relationship between skin cancer and UV radiation from the graphs on the previous day. Call on students to explain what questions we decided to investigate to help us understand why we see the patterns in the data. Also, ask students to recall why it is appropriate to use yeast in our investigation rather than human skin cells.

7 • REVIEW INVESTIGATION PROTOCOL

10 min

MATERIALS: *Investigation Plan: Environmental Factors and Cancer*

Review full protocol. Review the parts of the protocol found on **slides Q-R**, which will be required to support yeast growth no matter the condition students investigate. Depending on the number of students and/or groups in your class, provide each group with petri dishes that you have prepared ahead of time with yeast-extract dextrose (YED) media. Distribute *Investigation Plan: Environmental Factors and Cancer* to students so the class can review the protocol together.

In summary, each group will:

1. Use a sterile toothpick to remove a yeast sample from a suspension you have prepared.
2. Spread UV-sensitive and wild-type yeast on separate petri dishes.
3. Expose their plates to the variable selected for their group.
4. Place their plates under a light source for the required amount of time.
5. Remove plates from the light source and allow the yeast to grow untouched and in the dark for 3-5 days, depending on the room temperature. This can be done more quickly with an incubator.

Check for understanding. Once students have had a chance to review the protocol, call on students to explain different steps until you are confident they know how to proceed.

8 • SET UP INVESTIGATION

25 min

MATERIALS: Yeast Investigation



Review safety protocols. Display **slides S-T**. Review safety procedures with students. Be sure to specify where materials are located and how to clean up.

Small groups set up investigations. Direct students to get their materials. As students are ready, walk around with the transfer solutions of UV-sensitive yeast (labeled “A”) and wild-type yeast (labeled “B”). Direct students to spread their yeast on the corresponding petri dishes. Next, instruct students to set up their group conditions and expose their dishes to UV light as needed. When UV exposure is complete, collect all petri dishes and place them in a dark location to incubate.

ADDITIONAL GUIDANCE

Be aware that the UV exposure time may extend beyond the class time on day 2. As part of planning an investigation, decide with students whether the investigation will continue uninterrupted beyond class time or if they will stop and continue on the following day. In case you decide to continue the exposure time, you or a student volunteer will need to keep track of when to remove the plates from UV exposure and then incubate them. If the timing works out, you might ask for volunteers to return during lunch or after school to complete the UV exposure.

Clean up. Provide students with enough time to clean up their work areas. Provide directions for returning materials to the appropriate locations.

9 • NAVIGATE: MAKE PREDICTIONS

5 min

MATERIALS: None

Guide students to make predictions. Display **slide U**. Ask students to complete the table in Part 3 of *Investigation Plan: Environmental Factors and Cancer* by making predictions about what they think will happen in each condition and what evidence they are basing their predictions on. Encourage students to use words and/or drawings when making their predictions.

ADDITIONAL GUIDANCE

At the end of day 2, the petri dishes should be placed in an incubator or in a dark location at room temperature to incubate for 2-5 days. You should not proceed with day 3 of Lesson 9 until there is sufficient growth on the plates for students to collect their data. If you set up the investigation on a Friday, you may be able to collect data on Monday. However, it is more likely that you will need to proceed to Lesson 10 and return to Lesson 9, day 3 at a later point.

End of day 2

10 · NAVIGATE

3 min

MATERIALS: None

Review investigative questions and predictions. Display **slide V**. Ask students to recall the investigative questions the class was trying to answer and the predictions the class made about what they expected to find. Students recorded their predictions in *Investigation Plan: Environmental Factors and Cancer*.

Turn and Talk. Ask students to talk to a neighbor about how they will go about collecting their data. Call on a few pairs to share their thinking. Listen for responses that indicate that students plan to mark how much growth was on each of their petri dishes and compile evidence across the class.

11 · COLLECT DATA

12 min

MATERIALS: None

Organize students for data collection. Display **slide W** and distribute *Data Collection*. Organize students into their investigation groups and provide them with access to their petri dishes. Instruct them to remove any foil or other coverings and observe the growth on the plate. Students should fill out the data collection table by recording both a drawing of their petri dishes and written observations.

Compile class data. To compile a class set of data, make a summary table on the whiteboard or ask students to rotate around the room to observe and record data from every other group's plates.

12 · SMALL-GROUP SENSEMAKING

5 min

MATERIALS: None

Small-group sensemaking. Once the class data has been compiled or students have recorded observations from other groups, tell students to return to their own small group to complete the Making Sense questions #1-3 in *Data Collection*. Questions #4-5 will be completed after a reading about skin cancer. Display **slide X**. Circulate around the room and prompt students to use evidence from both the scientific data they reviewed on day 1 and from their own investigation. After most groups have discussed the questions, pause the small-group discussions and introduce the reading. Responses will vary based on the investigative questions.

13 · INVESTIGATE MECHANISM OF SKIN CANCER

10 min

MATERIALS: science notebook, *Skin Cancer Background Reading*

Introduce reading. Say, *You all noticed some patterns when we explored how environmental factors impacted cell growth in our yeast investigation. Some of you may even have more questions when comparing your data to the graphs about skin cancer and UV exposure on day 1.* Tell students that you did some research and found additional information about UV radiation and skin cancer that you want to share with them. Explain that the reading may help them with their claims for question #3. Distribute *Skin Cancer Background Reading* to each student.

Students read individually. Display **slide Y**. Ask students to make a Notice and Wonder chart in their science notebooks. Give students 4–5 minutes to read the article individually and tell them to record what they notice and wonder while they read. For students who may struggle reading informational texts, consider allowing them to collaborate with a partner to read, discuss, and annotate one paragraph at a time.

Small-group sensemaking. Organize students into small groups to answer the questions on **slide Z**. Circulate around the room and prompt students to use evidence from the reading to explain both the mechanisms of mutation and protection. Remind students to be prepared to share their ideas with the class.

* ATTENDING TO EQUITY

Equity in representation: Dr. Jewel Plummer Cobb is highlighted in this reading not only because her work led to the development of a wide range of chemotherapy treatments related to melanin and skin cancer, but also because she is a woman of color. By highlighting the representation of women and people of color in scientific disciplines like medicine, more students can increasingly see themselves as belonging in similar fields and see value in developing an increasingly diverse work space.

14 · BUILDING UNDERSTANDINGS DISCUSSION

10 min

MATERIALS: science notebook, *Skin Cancer Background Reading*, *Data Collection*

Facilitate a Building Understandings Discussion. * Be sure that students have *Skin Cancer Background Reading*, *Data Collection*, and their science notebook available to reference during this discussion. Display **slide AA**. Say, *Between the graphs from day 1, our investigation, and the reading, we have gathered more information about possible connections between cancer and our environment. Let's take a moment to hear what new ideas we have developed from this information.*

Use the prompts from the slide to guide the discussion.

Suggested prompt

What evidence do you have from your investigation and the reading about how UV radiation affects DNA?

Sample student response

The energy from the sun changes a C to a T.

There is energy stored in UV light that can rearrange cytosine and turn it into thymine.

With more UV radiation there was less growth because there were mutations and the cell died without being able to repair DNA.

* STRATEGIES FOR THIS BUILDING UNDERSTANDINGS DISCUSSION

As students share, encourage them to use specific evidence from their investigations to relate what they figured out in their own investigations to what they figured out from the reading.

* ATTENDING TO EQUITY

As the topic of skin color and race comes up during discussion, revisit your Classroom Agreements to help promote your classroom as a safe space. Be sensitive to greater attention being placed on the Black and Hispanic members of your class because of this discussion around skin color and melanin. You may overhear conversation around how melanin provides a type of “protective factor” for people with darker skin. This could make some students uncomfortable.

Suggested prompt	Sample student response	
<i>What evidence do you have from your investigation and the reading about how UV radiation affects the structure and function of the p53 protein?</i>	Changes in the DNA lead to differences in amino acids. Different amino acids lead to proteins with different shapes. If the shape is different, it does not function to repair DNA and can lead to cancer. UV radiation causes mutations, when the yeast had mutations it died and did not grow.	According to data from the Centers for Disease Control (CDC), from 2015-2019 in the United States, there were 1,848 new cases of skin cancer among Black Non-Hispanic people. Of those cases, 604 people died from skin cancer for a mortality rate of approximately 33%. In the White Non-Hispanic population, there were 393,916 new cases of skin cancer. Of those cases, 39,114 resulted in death for a mortality rate of approximately 10%. To help students understand these differences, you can present visualizations of this data using an CDC online resource (https://gis.cdc.gov/Cancer/USCS/#/AtAGlance/).
<i>What evidence do you have from your investigation and the reading about how melanin protects us from UV radiation?</i>	Melanin absorbs the UV radiation so it does not reach our DNA. It releases the energy as heat. Like melanin sunscreen protected the DNA in the yeast from UV radiation so it did not get mutations and die.	Explain to students that from this data set, we see that though the incidence of skin cancer is lower among the Black population in the United States, the likelihood of a Black person dying as a result of skin cancer is nearly three times higher than for a White person. One would expect the opposite to be true if more melanin and darker skin did in fact provide a “protective benefit.”

KEY IDEAS

Purpose of this discussion: To build understanding of the mechanism of DNA damage caused by UV radiation and the protective role of melanin in skin cancer.

Listen for these ideas:

- UV radiation contains energy that causes changes in our DNA.
- The energy changes one base (C) into another base (T).
- When this happens, proteins with different amino acids may result, thus changing the structure and function of the protein.
- A change in the structure and function of p53 in skin cells contributes to a greater likelihood of developing skin cancer.
- Melanin, sunscreen, and other factors such as exposure time and clothing protect DNA from UV radiation by absorbing its energy and releasing it as heat.

Considering skin cancer risk. Display **slide BB**. Ask students to consider who is most protected from skin cancer and who is most at risk for skin cancer. Remind them to consider the variation in melanin production and also variations in geographical location from the graphs on day

1. Likely responses may include:

- People who produce more melanin are more protected.
- People who produce less melanin are less protected.
- People who are exposed to a lot of UV radiation are less protected.
- People who are exposed to less UV radiation are more protected.

Small-group sensemaking. Ask students to return to the *Data Collection* and discuss the Making Sense questions 4-5 in their small groups. After 1-2 minutes, bring the class back together and ask, *Why might it be helpful to know whether the variable you investigated caused the change you observed?* Accept all responses for now, although ideally students will respond by saying that if we know that UV exposure damages DNA, which can lead to skin cancers, then we might do more to reduce UV exposure.

Revisiting correlation and causation. Display **slide CC**. Explain that scientists often investigate whether two things are connected in some way, that one has something to do with the other. However, sometimes scientists want to know more than whether two things are connected (correlation); they want to know if one thing actually may cause the other to occur (causation).

Say, In order for scientists to determine whether something is a cause, they need to have empirical evidence. This type of evidence often comes from the documentation of observations, patterns, and data collected through investigation.

Revisit definitions in Personal Glossaries. Call on a few students to contribute their ideas for any updates they should make to the definition of causation in the Personal Glossaries. and create a public record on the whiteboard of chart paper. Prompt students work together with their group to complete the remaining Making Sense questions.



Facilitate a Building Understandings Discussion. Use the prompts on **slide CC** as a guide.

KEY IDEAS

Purpose of this discussion: To build understanding about the evidence students collected during their investigation. Student data will likely support some of their predictions about how UV light affects cell growth and division and/or how protective mechanisms, such as sunscreen, may reduce cellular damage.

Specific student ideas will vary based on investigative question and design; however, you can **listen for these ideas** in general:

- Yeast cell growth decreased with greater exposure to UV radiation.
- Some protective factors, such as sunscreen or fabric covering, prevent damage from UV radiation and support more cell growth.
- We collected specific evidence of yeast growth with investigative conditions to support claims.
- Our own data, combined with the informational text on melanin and the scientific study on skin cancer, allows us to infer causation even though we had a small amount of data.

Suggested prompt

Do you have enough evidence to say that the variable you investigated caused the change you observed? Explain your thinking.

What new evidence do we have to answer the question, Who gets cancer and why?

Sample student response

Responses will vary based on investigative questions, but in general students should agree that a causal link exists between the environment and skin cancer based on the melanin reading, skin cancer data, and the yeast investigation.

We have data that provides us with evidence that the environment can affect cell growth by altering DNA.

We now see that we change our environment in order to reduce our chances of getting skin cancer or even prevent it altogether.

Specific responses will vary based on investigative questions.

ASSESSMENT OPPORTUNITY

What to look for/listen for: As students complete the Making Sense questions on [BI.L9.HO3] and discuss their ideas in small groups and as a whole class, look and listen for the following:

- Identification of patterns in the class data that serves as **empirical evidence** of **environmental factors causing mutations**. (DCI: LS3.B.2; CCC: 2.1)
- **Evidence from informational text, evidence from a scientific study, and their own investigation to support arguments**. (SEP: 7.5)
- Understanding of **causation and correlation** as it applies to the data. (CCC: 2.1)

What to do: If students struggle to reach consensus around the causal link between the environment and skin cancer, support students by reviewing and displaying the three sources of evidence from this lesson. Have the *Skin Cancer Background Reading* and *Skin Cancer Data* ready for students to review. Prompt students to look back in their notes to look for specific evidence from the melanin reading, the scientific study about UV exposure and skin cancer, and their own investigations to support their claims, such as:

- From our reading, we found out that:
 - UV exposure can cause damage to the DNA in skin cells, which may alter p53 function and affect cell growth and cell division.
 - Melanin is a naturally produced protein that helps protect against UV radiation damage.
- From the scientific study on UV exposure and skin cancer, we found out that for people who produce less melanin, an increase in UV radiation leads to higher incidences of skin cancer.
- From our own investigation, we found out that (varies depending on investigative question, but hypothetically):
 - Greater exposure to UV radiation led to less growth in yeast cells, indicating DNA damage.
 - Protective measures such as sunscreen lead to increased cell growth when exposed to UV radiation, indicating protection from DNA damage.

Building toward 9.B Make and defend a claim using evidence about how **environmental factors cause mutations in genes**. (SEP: 7.5; DCI: LS3.B.2; CCC: 2.1)

MATERIALS: science notebook, *Progress Tracker*

Update Progress Trackers. Display **slide DD**. Ask students to turn to *Progress Tracker* and update their Progress Trackers based on what they figured out about how environmental factors can lead to cancer.

Navigate to the next lesson. Recall with students that we found out that our skin produces melanin, which helps protect our cells' DNA from being damaged by UV light from the sun. Explain that from the reading, we also found out that people with darker skin tend to produce more melanin. Remind students that though we might expect darker-skinned people to have some added protection against certain types of skin cancer because they have more melanin, what we actually see is that though there are fewer new cases of skin cancer in the Black population, Black people are 3 times more likely to die from skin cancer than White people in the United States. Ask students why they think this might occur. Accept all responses for now and tell students that we will examine this discrepancy more in Lesson 12.

Display **slide EE**. Say, *As I did more research on skin cancer, I found out that there is a different type of skin cancer called acral lentiginous melanoma, or ALM, which is not caused by exposure to UV light. Also, it primarily affects people with darker skin and who belong to Asian and sub-Saharan African ethnic groups.*

If there are questions on the DQB about differences in who gets cancer, point those out now. Then ask students if they have any ideas on why this phenomenon might occur.

After students share their ideas, say, *So how can it be that people in different groups and from different places get cancer at different rates? Let's look more closely at that in our next lesson!*

See sample completed Progress Tracker below.

	What I figured out in pictures and/or words	Questions I have
Lesson 9: How do genes interact with the environment to affect who gets cancer?	UV radiation causes mutations in DNA, which can change the structure and function of proteins. Melanin can have protective properties against damage from UV radiation. Because there are different amounts of UV radiation and different amounts of melanin in the skin, there are different amounts of cancer in the population.	Why do different people in different places get cancer at different rates?

Additional Lesson 9 Teacher Guidance

**SUPPORTING
STUDENTS IN
MAKING
CONNECTIONS IN
ELA**

WHST.9-12.1 Write arguments focused on discipline-specific content.

Students write claims based on evidence related to their investigative question and the data they generate during their investigations.

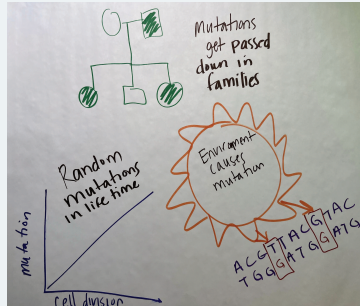
LESSON 10: Who gets cancer and why?

PREVIOUS LESSON We decided to investigate how the environment might explain cancer not accounted for by random and germline mutations. We investigated scientific data related to the incidence of skin cancer and designed and carried out our own investigations. We read about the mechanism of UV radiation causing mutations in our cells and about a protective mechanism in our skin.

THIS LESSON

PUTTING PIECES TOGETHER

2 days



We develop our consensus model that puts together all of the ideas that we figured out about random mutations, inheritance, and environmental factors. We acknowledge that we have made a lot of progress since the last consensus model and pause to put these new ideas together. We decide that we need to figure out if our ideas would hold up in a different context and complete a transfer task to continue to make progress on figuring out who gets cancer and why.

NEXT LESSON We will consider what we already know about cancer treatment options and hear about the different treatments that Lakita and Lauren experienced. We will explore how different treatments work and revise our Cell Game model to predict the relationship between treatment and the cell cycle.

BUILDING TOWARD NGSS

HS-LS1-1, HS-LS1-2, HS-LS1-4, HS-LS3-1, HS-LS3-2, HS-LS3-3, HS-ETS1-3



WHAT STUDENTS WILL DO

10.A Develop a model based on evidence to illustrate the smaller-scale mechanisms that can result in cancer, such as random mutation, inheritance, and environmental factors. (SEP: 2.3; DCI: LS3.B.1 & LS3.B.2; CCC: 2.2)

10.B 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. (SEP: 7.5; DCI: LS3.B.1 & LS3.B.2; CCC: 2.1)

WHAT STUDENTS WILL FIGURE OUT

- The more your cells divide, the greater the chance of accumulating mutations.
- Li-Fraumeni Syndrome is an inherited condition.
- Meiosis is a process where a cell undergoes two divisions to produce gametes.
- During meiosis, chromosome pairs can swap regions of DNA in a process called crossing over.
- UV radiation and other environmental factors can cause mutations in DNA.

Lesson 10 • Learning Plan Snapshot

Part	Duration		Summary	Slide	Materials
1	3 min		NAVIGATE Summarize what we have figured out so far and motivate pausing to make sense of it all.	A-B	<i>Progress Tracker</i>
2	10 min		BRAINSTORM IDEAS FOR GOTTA-HAVE-IT CHECKLIST Guide students in brainstorming a list of components, interactions, and mechanisms needed in consensus models.	C-D	whiteboard, chart paper, and chart paper markers (optional)
3	12 min		DEVELOP CONSENSUS MODEL IN SMALL GROUPS Support small groups in model development.	E	chart paper and chart paper markers (optional), 3x3 sticky notes
4	15 min		DEVELOP A CLASS CONSENSUS MODEL Organize students in a Scientists Circle to develop a class consensus model.	F-H	small group model, chart paper and chart paper markers (optional), 3x3 sticky notes
5	5 min		NAVIGATE Reflect on the Consensus model and Introduce the Transfer Task.	I	
<i>End of day 1</i>					
6	5 min		NAVIGATE Prepare students for Transfer Task.	J	<i>Progress Tracker</i>
7	35 min		TRANSFER TASK Support students as they engage in the Transfer Task.	K	<i>Genetics Transfer Task</i>
8	5 min		NAVIGATE Motivate where we are going in the next lesson set.	L-N	<i>Progress Tracker</i> , Ideas for Investigations chart paper
<i>End of day 2</i>					

Lesson 10 • Materials List

	per student	per group	per class
Lesson materials	• <i>Progress Tracker</i> • science notebook • <i>Genetics Transfer Task</i>	• small group model	• whiteboard • chart paper • and chart paper markers (optional) • chart paper and chart paper markers (optional) • 3x3 sticky notes • Ideas for Investigations chart paper

Materials preparation (20 minutes)

Review teacher guide, slides, and teacher references or keys (if applicable).

Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

Make sure chart paper and chart paper markers, or an alternative way to capture the consensus model, are available.

Make sure the Driving Question Board, Classroom Community Agreements, and Ideas for Investigations posters (from Lesson 1) are accessible.

Lesson 10 • Where We Are Going and NOT Going

During this culminating lesson of Lesson Set 2, students put the pieces together to create a consensus model and explain additional mechanisms for the genetic basis for cancer. Students use the evidence collected in Lessons 7-9 to support their explanations.

Students use the science practices of *developing and using models* by developing a consensus model as a class where they establish connections between all of the components, interactions, and mechanisms that they had been investigating up to that point. Students review the ideas that they figured out from their Progress Trackers, where they have to gather evidence from several different types of models that they have engaged in up to this point. Then they create a Gotta-Have-It-Checklist as a way to include the necessary components, interactions, and mechanisms.

Students use the crosscutting concept of *cause and effect* throughout the lesson as they explain mutations in DNA and the structure and function of proteins by looking at small-scale changes such as mutations in DNA and how that leads to changes in proteins, which affect the function of p53 protein and its ability to repair DNA. They build on the initial use of examining small-scale mechanisms from Lessons 1 through 9 in this unit and *OpenSciEd Unit B.2: What causes fires in ecosystems to burn and how should we manage them? (Fires Unit)* to achieve this goal.

LEARNING PLAN for LESSON 10

1 · NAVIGATE

3 min

MATERIALS: *Progress Tracker*

Turn and Talk. Display **slide A**. Say, *We have done a lot of sensemaking over the last several lessons. Let's pause to take stock of our progress.* Review the ideas that we figured out in Lessons 7-9 with your partner.

Facilitate a discussion about what we have figured out so far. Display the class consensus model from Lesson 7 and ask students to review their Progress Trackers. Display **slide B**. Call on a few students to remind the class of the progress the class made in Lesson Set 1. Then call on a few students to share the progress we made in Lesson Set 2.

2 · BRAINSTORM IDEAS FOR GOTTA-HAVE-IT CHECKLIST

10 min

MATERIALS: science notebook, whiteboard, chart paper, and chart paper markers (optional)

Develop a Gotta-Have-It Checklist. Display **slide C**. Say, *If we are going to make a detailed model to explain who gets cancer and why, what do we need to include?* Ask students to share as a class all of the possible components needed. Ensure this list is visible to students while completing their Gotta-Have-It Checklist.

Have students title a new page *Gotta-Have-It Checklist* in their science notebooks. Say, *In your notebook, you will need a table with three columns. The wide column should be titled "Who gets cancer and why?" The two right columns are "Used" and "Not Used" so we can keep track of our ideas.*

Work with a partner to populate the checklist. Display **slide D**. Say, *Working with your partner, you will go through your science notebook, Progress Tracker, and handouts to complete the first row of the Gotta-Have-It Checklist. We will complete the rest of this checklist later.* Give students a few minutes to complete the first column of their Gotta-Have-It Checklist. Please see the sample checklist below.

Who gets cancer and why?	Used	Not Used
Lesson 7: The taller you are and the older you are, the more cell divisions you will have over your lifetime. As the number of cellular divisions increases, the number of mutations also increases. This increase in mutations increases your risk of getting cancer, if these mutations are in p53.		
Lesson 8: Some cancer is inherited from alleles that you get from your parents. People with Li-Fraumeni inherit a mutation in their p53 gene and get cancer more often and can get it at a younger age.. Crossing over happens during meiosis, randomly causing more genetic variation than would be predicted otherwise.		

Lesson 9: UV radiation can cause mutations in DNA that can cause cancer.

Mutations from radiation can change the protein structure and function, leading to cancer.

 **Complete the Gotta-Have-It Checklist.** Have students draw a line to create a new row after each set of ideas. Encourage students to continue to fill in the rows of their checklists and add a line after each one. Remind students that the purpose of this checklist is to make sure that as a class we have everything we figured out through our investigations accounted for when we make a consensus model for explaining why different people in different places have different cancer risks.

ASSESSMENT OPPORTUNITY

What to look for/listen for in the moment:

Students deciding on the necessary ideas to explain more mechanisms for the genetic basis for cancer, including the following to be included in the [Gotta-Have-It-Checklist](#):

- The taller you are and the older you are, the more **cell divisions** you will have over your lifetime. (DCI: LS3.B.1)
- As the number of **cellular divisions** increases, the number of **mutations** also increases.
- This **increase** in **mutations** increases your risk of **getting cancer**. (DCI: LS3.B.1; CCC: 2.2)
- Some **cancer is inherited** from **alleles** that you get from your parents. (DCI: LS3.B.1)
- People with **Li-Fraumeni** inherit a **mutation** in their **p53 gene** and **get cancer more often**. (DCI: LS3.B.1; CCC: 2.2)
- **Crossing over** happens during **meiosis**, randomly **causing additional genetic variation**. (DCI: LS3.B.1)
- UV radiation can cause **mutations** in **DNA** that can **cause cancer**. (DCI: LS3.B.2; CCC: 2.2)
- **Mutations from radiation** can **change the protein structure and function**, leading to **cancer**. (DCI: LS3.B.2; CCC: 2.2)

What to do: Guide students to return to the sensemaking they have done throughout Lessons 7-9. Prompt students with questions such as:

- How can you use cause and effect to think about what is happening here?
- What evidence do you have to support that relationship?
- How will your model illustrate this?

For an optional assessment, have students do the self-assessment that they did on their Gotta-Have-It-Checklists in Lesson 7. Students can: Circle evidence.

- Underline the evidence that answers the question, *Who gets cancer and why?*
- Could the model be improved by adding more science ideas? Challenge them to add an idea that was not already included in the initial draft of the checklist.
- If you identify gaps in their understanding, encourage a peer to build on the ideas they have shared to explain what is happening to the random, inherited, and environmentally caused mutations. Focus on a single lesson and return to the components, interactions, and mechanisms, asking them to help identify ways to use pictures and/or words to make the invisible mechanisms visible.

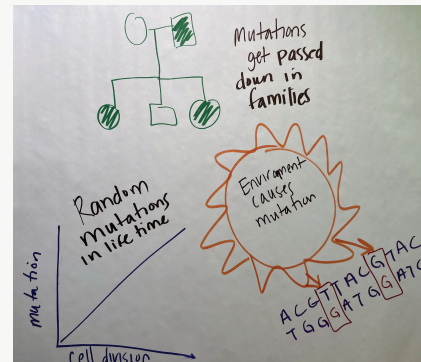
Building toward 10.A.1 [Develop a model](#) based on evidence to illustrate the **smaller-scale mechanisms** that can **result in cancer**, such as **random mutation, inheritance, and environmental factors**. (SEP: 2.3; DCI: LS3.B.1 & LS3.B.2; CCC: 2.2)

3 · DEVELOP CONSENSUS MODEL IN SMALL GROUPS

12 min

MATERIALS: science notebook, chart paper and chart paper markers (optional), 3x3 sticky notes

Develop a small-group consensus model. * Display slide E. Organize students into small groups of 3-4. Have students bring their science notebooks and their completed Gotta-Have-It Checklists with them to their group. Provide each group with materials for developing their model and ask them to explain *who gets cancer and why*. Students models may look something like the following:



4 · DEVELOP A CLASS CONSENSUS MODEL

15 min

MATERIALS: science notebook, small group model, chart paper and chart paper markers (optional), 3x3 sticky notes

Create the consensus model as a class. Display slide F. Call on volunteers from each of the groups to share parts of their model until you have included all of the necessary parts of the model. As you add parts to the model, make sure that you have a consensus. Say, *Do we all agree with what we have here? Thumbs up if you agree, thumbs down if you do not.* If students disagree, be sure to address their concerns before moving on. *

Discuss moving components around. Say, *Now that we have some components on the poster, we may need to move them around so that we can show relationships and organize this story. As we review our past lessons, thinking of how these ideas are related can help us do this.* Encourage students to add and build on each other's ideas until the class is confident in their model. **

KEY IDEAS

Purpose of this discussion: To help students synthesize their thinking to explain who gets cancer and why, connect what components are essential for explaining why different people in different places have differences in their cancer risk, how those components interact, and what the underlying mechanisms are in the system.

See the Gotta-Have-It Checklist for what students will include in their models.



Review the model with students. Display slide G. Say, *Now that we have developed this model, does it explain who gets cancer and why? What is missing that we need?* Call on a few volunteers to talk through the model to answer the lesson questions. Say, *As we review the model, let's go back to the Gotta-Have-It Checklist to complete columns 2 and 3. If we used that idea in the model, put a check in the "Used" column (column 2). If the idea is not in the model, then put a check in the "Not Used" column.* Display slide H. Guide students to consider how to add the elements that were in the "Not Used" column. If there are missing components, make sure to add them to the model. * See one possible representation of this model on the following page.

* ATTENDING TO EQUITY

Asking students to restate what another student has said supports the goal of students listening carefully to each other so that they can work with others' ideas. This move can feel odd to students at first, so it will help if you let them know ahead of time that you will be asking this.

* STRATEGIES FOR THIS CONSENSUS DISCUSSION

A Consensus Discussion is different from other kinds of discussions because the purpose of the discussion is to converge on one or more ideas that the whole class agrees upon. In this discussion, your classroom community is pressing toward a common (class-level) explanation of how different human populations in different places can have varying cancer risks.

ASSESSMENT OPPORTUNITY

What to look for/listen for in the moment:

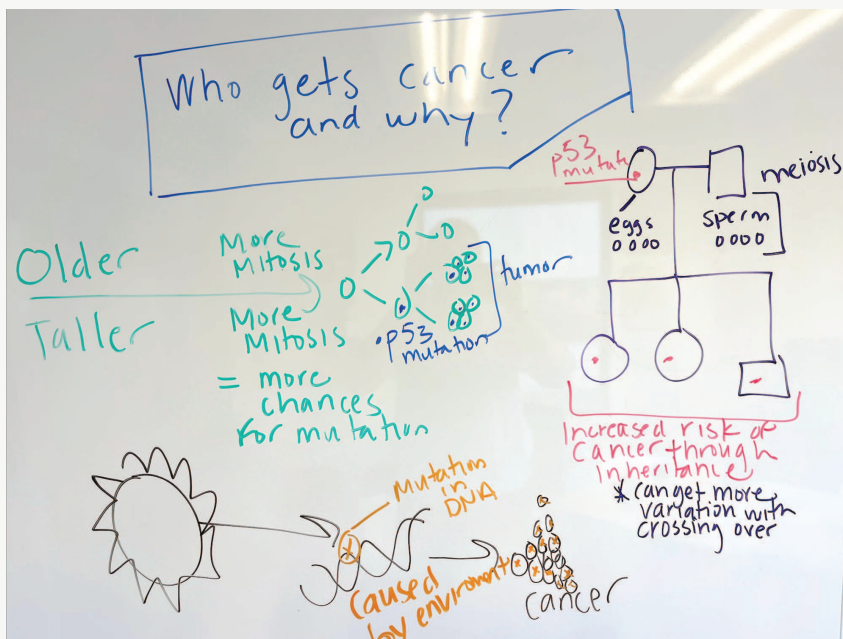
Students deciding on the necessary ideas to explain more mechanisms for the genetic basis for cancer, including the following to be included in the *Gotta-Have-It-Checklist*:

- The taller you are and the older you are, the more **cell divisions** you will have over your lifetime. (DCI: LS3.B.1)
- As the number of **cellular divisions** increases, the number of **mutations** also increases.
- This **increase** in **mutations** increases your risk of **getting cancer**. (DCI: LS3.B.1; CCC: 2.2)
- Some **cancer is inherited** from **alleles** that you get from your parents. (DCI: LS3.B.1)
- People with **Li-Fraumeni** inherit a **mutation** in their **p53 gene** and **get cancer more often**. (DCI: LS3.B.1; CCC: 2.2)
- **Crossing over** happens during **meiosis**, randomly **causing additional genetic variation**. (DCI: LS3.B.1)
- UV radiation can cause **mutations** in **DNA** that can **cause cancer**. (DCI: LS3.B.2; CCC: 2.2)
- **Mutations from radiation** can **change the protein structure** and **function**, leading to **cancer**. (DCI: LS3.B.2; CCC: 2.2)

What to do: Push students to include a mechanism for each interaction. For example:

- What explains why older and taller people get more mutations?
- How do environmental factors like the sun cause mutations?
- How are mutations passed on in families?

Building toward 10.A.2 Develop a model based on evidence to illustrate the **smaller-scale mechanisms** that can **result in cancer**, such as **random mutation**, **inheritance**, and **environmental factors**. (SEP: 2.3; DCI: LS3.B.1 & LS3.B.2; CCC: 2.2)



During this work, the class resolves disagreements where possible. Your role is to help students see where they agree and where they still disagree. Helpful prompts include:

- What ideas are we in agreement about?
- Would anyone have represented this idea in a different way?
- Who feels like their idea is not quite represented here?
- Are there still places where we disagree? Can we clarify these?

* SUPPORTING STUDENTS IN DEVELOPING AND USING CAUSE AND EFFECT

As students explain the cause of cancer, make sure to press them on the smaller scale mechanism at play in cases where; mutations accumulate over a lifetime, affecting older people, mutations are inherited affecting families and sometimes younger individuals, and mutations caused by the environment that affect people with different levels of exposure.



5 · NAVIGATE

5 min

MATERIALS: science notebook

Reflect on the consensus model. Put together the class consensus model from Lesson 7 with the new class consensus model and help students reflect on everything they have figured out to explain both the genetic basis of cancer and who gets cancer and why. Give students a moment to reflect in writing about their progress using the prompts on **slide I**.*

Introduce the next lesson's transfer task. Say, *In our next you will have a chance to demonstrate what you have figured out to a new scenario.*

* ATTENDING TO EQUITY

Building classroom culture and Community Agreements: It is important to celebrate class progress along the way to explaining our anchoring phenomenon. Figuring ideas out through inquiry and discussion may be new or challenging for some students, and taking a moment to celebrate steps along the way can help them recognize the progress they are making.

End of day 1

6 · NAVIGATE

5 min

MATERIALS: *Progress Tracker*, science notebook

Prepare for an assessment. Instruct students to find *Progress Tracker* and their Gotta-Have-It Checklists in their science notebooks.

Review science notebook and Progress Tracker. Display **slide J**. Say, *We have figured out a lot of great science ideas in this unit, but we have really only applied these ideas to p53. Today, you will have a chance to look at a different problem.* Ask students to review *Progress Tracker* and any additional materials they wish in their science notebooks.

7 · TRANSFER TASK

35 min

MATERIALS: *Genetics Transfer Task*

Orient students to the Transfer Task. Display **slide K**. Distribute *Genetics Transfer Task* and give students a few minutes to read over the task and ask clarifying questions. Allow students to use their Progress Trackers, Gotta-Have-It Checklists, and science notebooks as resources as they complete the task.



Administer the task. Give students the rest of the period to complete the task, then collect assessments before students leave.

ASSESSMENT OPPORTUNITY

What to look/listen for in the moment: See *Genetics Transfer Task Key* for guidance.

What to do: Collect *Genetics Transfer Task* from each student. Provide feedback using *Genetics Transfer Task Key* and return to students. Consider providing students with an opportunity to revise their responses based on your feedback.

Building toward 10.B 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. (SEP: 7.5; DCI: LS3.B.1 & LS3.B.2; CCC: 2.1)

8 • NAVIGATE

5 min

MATERIALS: *Progress Tracker*, science notebook, Ideas for Investigations chart paper

Update Progress Tracker. Display slide L and say, *I think it is time for us to keep a record of what we did today. Take out your Progress Tracker.*

Generate ideas for new investigations. Display slide M. Say, *We have so many ideas to explore! How could we start to investigate the answers to some of these new and unanswered questions? Revisit your original Ideas for Investigations in your science notebook or title the next page in your science notebook “Ideas for Investigations.” Choose one question or category of questions from our Driving Question Board and talk with a partner or partners near you to consider how we might find the answer—what investigation could we design, what data should we gather, and how could we figure this out in our classroom? Keep track of your ideas in your notebook. After you have discussed one question, move on to another. We will work for about three minutes, then we will share with the group.*

Accept all ideas and add them to the Ideas for Investigations chart paper. Thank students for sharing their ideas and tell them that the class will start the next lesson by thinking about medical treatments and other ways to treat cancer.

Additional Lesson 10 Teacher Guidance

SUPPORTING STUDENTS IN MAKING CONNECTIONS IN ELA

WHST.9-10.9 Draw evidence from informational texts to support analysis, reflection, and research.

Students use evidence from unit materials and the Transfer Task to support their claims and ideas.

LESSON 11: How do cancer treatments work?

PREVIOUS LESSON We developed our consensus model to connect the ideas that we figured out about random mutations, inheritance, and environmental factors. We decided that we needed to figure out if our ideas would hold up in a different context and completed a transfer task to make progress on figuring out who gets cancer and why.

THIS LESSON

INVESTIGATION

2 days



Bill Branson (Photographer) and National Cancer Institute

We consider what we already know about cancer treatment options and hear about different treatments that Lakita and Lauren experienced. We explore how different treatments work and revise our Cell Game model to predict the relationship between treatment and the cell cycle. We wonder about access to treatment in different places.

NEXT LESSON This is the last lesson of the unit.

BUILDING TOWARD NGSS

HS-LS1-1, HS-LS1-2, HS-LS1-4, HS-LS3-1, HS-LS3-2, HS-LS3-3, HS-ETS1-3



WHAT STUDENTS WILL DO

- 11.A** Obtain, evaluate, and communicate information about current treatment options using criteria related to human systems and predict outcomes for individuals. (SEP: 8.5; DCI: LS1.B.1 & ETS 1.B.1; CCC: 2.2)
- 11.B** Use a model to explain how cancer treatments affect cell division for cancer and non-cancer cells. (SEP: 2.3; DCI: LS1.B.1; CCC: 2.2)

WHAT STUDENTS WILL FIGURE OUT

- Chemotherapy, radiation, surgery, and immunotherapy are common cancer treatments.
- These treatments affect cancer cells and non-cancer cells and can disrupt body systems.
- There are a number of constraints that affect decisions about cancer treatment.

Lesson 11 • Learning Plan Snapshot

Part	Duration		Summary	Slide	Materials
1	5 min		NAVIGATE Review the DQB to determine questions we have answered and still need to answer in a Scientists Circle.	A	3x3 sticky notes, colored markers
2	5 min		INITIAL IDEAS DISCUSSION ABOUT CANCER TREATMENTS Facilitate sharing of initial ideas about how cancer treatments work.	B	
3	10 min		REVISIT LAKITA AND LAUREN'S STORIES Share an additional video of Lakita and Lauren discussing their experiences with cancer.	C-E	
4	10 min		INVESTIGATE TREATMENT OPTIONS Share a reading and organizer to support students in investigating treatment options individually and then in small groups.	F	<i>Cancer Treatments, Treatment Options Organizer</i>
5	10 min		BUILD A CLASS ORGANIZER Organize students to build a class data table.	G	<i>Treatment Options Organizer</i>
6	3 min		NAVIGATE Ask students to reflect on what they learned in their notebooks.	H	
<i>End of day 1</i>					
7	3 min		NAVIGATE Share ideas from the previous class.	I	
8	14 min		PREDICT TREATMENT OUTCOMES Use the Cell Game model to predict treatment outcomes for cancer cells.	J-K	<i>Treatment Options Organizer, DNA and Chromosomes, Cell Game gameboard, 4 red cancer chips, Game Card Template</i>
9	10 min		PEER REVIEW OF GAME CARDS Facilitate the exchange and review of game cards by groups.	L	<i>Peer Feedback Rubric</i>
10	12 min		GAME CARD REVISION Support students in revising their gamecards.	M	
11	3 min		NAVIGATE Facilitate Turn and Talk about what students figured out and what questions they have.	N	
<i>End of day 2</i>					

Lesson 11 • Materials List

	per student	per group	per class
Lesson materials	- science notebook <i>Cancer Treatments</i> <i>Treatment Options Organizer</i> <i>DNA and Chromosomes</i>	- Cell Game gameboard 4 red cancer chips <i>Game Card Template</i> <i>Peer Feedback Rubric</i>	3x3 sticky notes - colored markers

Materials preparation (15 minutes)

Review teacher guide, slides, and teacher references or keys (if applicable).

Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

Three-hole-punch all handouts so they can be added to student notebooks.

For day 2, gather enough supplies for each group to have the following:
1 Cell Game gameboard, 4 red cancer chips

Lesson 11 • Where We Are Going and NOT Going

Where We Are Going

In this lesson, students continue to build an understanding developed in Lessons 3, 6, 7, and 8 of LS1.B.1 *In multicellular organisms, individual cells grow and then divide via a process called mitosis, thereby allowing the organism to grow. The organism begins as a single cell (fertilized egg) that divides successively to produce many cells, with each parent cell passing identical genetic material (two variants of each chromosome pair) to both daughter cells. Cellular division and differentiation produce and maintain a complex organism composed of systems of tissues and organs that work together to meet the needs of the whole organism.*

They also develop an understanding of ETS.1.B.1 *When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts.*, which they began to develop in *OpenSciEd Unit B.1: How do ecosystems work, and how can understanding them help us protect them? (Serengeti Unit).*

While students have been using *developing and using models* in OpenSciEd Biology and throughout this unit, they use this practice in a new way as they revise their models to predict the effects of cancer treatments on the cell cycle.

Students also use *cause and effect* with more independence as they figure out that different cancer treatments cause different outcomes for cancer and non-cancer cells in the context of the Cell Game model.

Students encounter definitions for chemotherapy, radiation, surgery, and immunotherapy in this lesson and should add these terms to their personal glossaries as they come up.

Where We Are NOT Going

While this lesson focuses on the most common cancer treatments, there are many different kinds of cancer treatments. These include new and emerging treatments and alternative treatments. Encourage interested students to research these and add them to their organizer on day 1. If appropriate, they can use these treatments in their cards on day 2.

LEARNING PLAN for LESSON 11

1 · NAVIGATE

5 min

MATERIALS: science notebook, 3x3 sticky notes, colored markers

Review the Driving Question Board. Display **slide A**. Have students join a Scientists Circle with their science notebooks. Ask students to consider which group of questions they have already answered and which questions remain. Ask students to mark the questions with a check if they have been or can be answered and add a question mark if they are unanswered. Use the prompts below as a guide.

Suggested prompt	Sample student response
<i>What questions have we answered?</i>	How people get cancer. How p53 works. How we can get random mutations, inherit cancer, or get cancer from mutations from the environment.
<i>What are we still wondering about?</i>	We are wondering about how cancer is treated. Why are the treatments so hard on the body and on the family with all of the technology that we have available?

Add any new questions to the DQB. Encourage students to write new questions on a sticky note and add them to the DQB.

2 · INITIAL IDEAS DISCUSSION ABOUT CANCER TREATMENTS

5 min

MATERIALS: science notebook

Initial Ideas Discussion.* Display slide B. Say, *We have talked about the genetic basis of cancer and who gets cancer and why, but we have not explored how cancer is treated. It sounds like we still have some questions.* Ask students to turn and talk to a partner about what they know about cancer treatments. After they have had a few moments to discuss, call on a few pairs to share their thinking.

Suggested prompt	Sample student response
<i>How is cancer treated?</i>	Chemotherapy Radiation Surgery
<i>What do you know about how those treatments work?</i>	Chemo and radiation kill cancer cells. Surgery removes the cancer from the body. Radiation causes mutations that keep the cells from dividing.
<i>How do cancer treatments affect non-cancer cells?</i>	I am not sure. Maybe they are harmful, and that is why chemo makes you sick. The treatments also hurt the good cells when they are trying to kill the cancer cells.

KEY IDEAS

Purpose of this discussion: To surface student ideas about cancer treatments.

Listen for these ideas:

Various types of treatments such as chemotherapy, radiation and surgery.
Ways that the treatment might remove cancer or stop it from growing.
Ideas about ways treatment interacts with the cell cycle/cell division/mitosis.

Pay attention to any students that may be in emotional distress. Refer to the resources in Lesson 1 to support their emotional well-being.

ADDITIONAL GUIDANCE

Students may have personal experiences with cancer treatments that could evoke an emotional response. Be prepared to offer resources to students who need them by reaching out to the counselor and/or other support staff in your school prior to the lesson. Revisit the resources provided in Lesson 1 to support student emotional well being, especially for any students who have experienced trauma related to cancer.

* STRATEGIES FOR THIS INITIAL IDEAS DISCUSSION

Reasons for eliciting students' initial ideas include:

- To get students' prior knowledge and experiences on the table.
- To provide a supportive opportunity for students to make sense of what may not be fully formed ideas (either their own ideas or those of others).
- Help students realize that there are gaps in our understanding to promote curiosity and what we could do next to figure something out.

3 · REVISIT LAKITA AND LAUREN'S STORIES

10 min

MATERIALS: None

Introduce new cancer data. Display **slide C**. Let students know that while cancer is a concern, much progress has been made in their lifetimes to reduce the number of deaths resulting from cancer. Say, *Let's investigate how treatment is involved in reducing death from cancer.*

Revisit Lakita and Lauren's cancer stories. Display **slide D**. Remind students that they were introduced to Lakita and Lauren and their families in Lesson 8. Ask students to turn and talk to a neighbor and share what they remember. Then call on a few pairs to share with the class. Refer back to the videos from Lesson 8 if students have trouble remembering.

Share interviews with Lakita and Lauren describing their cancer treatments. Let students know that you will share additional pieces of the interviews with Lakita and Lauren. Say, *As we watch the video, complete the Notice, Wonder, Feel chart, paying particular attention to personal accounts of costs, access to treatment, treatment process, decisions that have to be made, and any recommendations.* Remind students that in Lesson 8 we added a column to capture feelings that the video brings up. Encourage students to capture their feelings in this space. Display **slide E** and play the videos <https://youtu.be/-NhqJRlJsw> and <https://youtu.be/R2-b39uNO-E>. After watching the video, call on a few students to share with the class. See sample student responses in the table below.

Notice	Wonder	Feel
Lauren had chemo and radiation. Lauren had a double mastectomy at age 20. Lakita had chemo, radiation, and a bone marrow transplant. Lakita had her leg amputated.	Why did Lauren have that surgery? What is a bone marrow transplant?	Getting surgery sounds scary.

4 • INVESTIGATE TREATMENT OPTIONS

10 min

MATERIALS: *Cancer Treatments, Treatment Options Organizer*

Investigate treatments. Say, *We have some ideas about treatment from our own experience and from Lakita and Lauren's stories. You all have a lot of questions, so let's investigate the treatment options further.* Let students know you have some information to share in a reading. Display **slide F**. Distribute *Cancer Treatments* and *Treatment Options Organizer*. Give students a few minutes to read individually and take notes in the organizer. Then organize them into small groups to compare their notes and revise their summaries for each of the treatment options.

ADDITIONAL GUIDANCE

Students with a connection to a particular type of cancer treatment may wish to research a treatment that is not on the list. Encourage them to do so, with your guidance, and to add it to their organizer.

Students who demonstrate mastery of the LLPE early in the lesson may benefit from an extension that introduces them to new areas of cancer treatment research using CRISPR. See *Extension: CRISPR-based Therapy*

5 • BUILD A CLASS ORGANIZER

10 min

MATERIALS: science notebook, *Treatment Options Organizer*

Build a class organizer. Display **slide G**. Assign each group, pair, or individual student to be responsible for a row or cell in the organizer, depending on the size of your class. Try to ensure that everyone has a role. Create a class organizer on the whiteboard, chart paper, or other public space in your classroom for students to contribute to. As each member of the class shares, press for an understanding of the following:

- How does the treatment disrupt the cell cycle for cancer cells?
- How do disruptions to non-cancer cells lead to side effects at the cellular and system levels?
- What additional considerations are there?



Revise individual organizers. Give students an opportunity to revise their organizers following the class build.

ASSESSMENT OPPORTUNITY

What to look for/listen for in the moment: See *Treatment Organizer* for guidance.

What to do: Provide individual feedback to students using *Treatment Organizer*. If needed, provide them with additional time on day 2 to return to *Cancer Treatments* and revise their responses.

Building toward 11.A Obtain, evaluate, and communicate information about current treatment options, using criteria related to human systems, and predict outcomes for individuals. (SEP: 8.5; DCI: LS1.B.1 & ETS 1.B.1; CCC: 2.2)

6 • NAVIGATE

3 min

MATERIALS: science notebook

Navigate. Display **slide H**. Ask students to stop and jot in their science notebooks about what they figured out and what questions they still have.

End of day 1

7 • NAVIGATE

3 min

MATERIALS: science notebook

Turn and Talk. Display **slide I**. Ask students to turn and talk to a partner about what they figured out and questions they have in the previous class.

8 • PREDICT TREATMENT OUTCOMES

14 min

MATERIALS: *Treatment Options Organizer*, *DNA and Chromosomes*, Cell Game gameboard, 4 red cancer chips, *Game Card Template*

Revisit the Cell Game. Say, *Now that you have some ideas about cancer treatments how can we figure out more about how the treatments affect how cancer cells grow and divide? What tools have we used to model cell division that could help us investigate this?* Listen for students to recall the Cell Game from Lesson 3. Display **slide J**. Remind students of the set-up of the Cell Game. Ask students to generate ideas about how they can use the Cell Game model to predict how cancer treatments work. Listen for students to share ideas about where, when, or how the treatments could be added to the game.

Add treatment options to the game. Explain to students that they will use what they now know about treatment options to add treatments to the game. They will write a card for each treatment and will use evidence from the reading to determine where the card will be added to the game and what action it will ask players to take. Display **slide K**. Distribute a copy of the Cell Game gameboard, 4 red cancer chips, and *Game Card Template* to each group and ask each group to develop their game cards. Students will need to use information from *DNA and Chromosomes* to figure out where in the cell cycle the game cards should be placed and what the actions will be.

9 · PEER REVIEW OF GAME CARDS

10 min

MATERIALS: *Peer Feedback Rubric*

Peer review of small-group game cards. Display [slide L](#). Let students know that they will have a chance to give feedback to and receive feedback from another group. Distribute *Peer Feedback Rubric* to each group. Walk them through the rubric and give them time to complete it. When they are finished, ask them to return the cards and feedback to the authors. Each group should review their feedback and ask and answer questions with their peer reviewers.

10 · GAME CARD REVISION

12 min

MATERIALS: None



Revise game cards. Display [slide M](#). Provide each small group with time to revise their game cards based on peer feedback. As students work, circulate around the room to support their revisions.

ASSESSMENT OPPORTUNITY

What to look for/listen for in the moment: Cards designated in a part of the [model that predicts relationship between cell cycle and treatments](#). ([SEP: 2.3](#) ; [CCC: 2.2](#))
For example:

- Taxol should be placed in the M phase.
- Carboplatin should be placed in the S phase.
- Radiation should be placed in the S phase.
- Surgery and immunotherapy could be placed anywhere.
- The action on all of the cards should ask students to stop the progression of that cell through the game or remove the token from play as the [cell does not divide or progress through the cell cycle](#). ([DCI: LS1.B.1](#))

What to do:

If students need support identifying the mechanism of the treatment, point them back to *Cancer Treatments* and *Treatment Options Organizer* for additional support.

Building toward 11.B Use a [model to explain how cancer treatments affect cell division](#) for cancer and non-cancer cells. ([SEP: 2.3](#); [DCI: LS1.B.1](#) ; [CCC: 2.2](#))

11 · NAVIGATE

3 min

MATERIALS: None

Turn and Talk. Display [slide N](#). Ask students to turn and talk to their partners about what they figured out and what questions they have now. Call on a few pairs to share their thinking.

Additional Lesson 11 Teacher Guidance

SUPPORTING STUDENTS IN MAKING CONNECTIONS IN ELA

WHST.9-10.7 Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation.

Students use a reading to research cancer treatments to answer questions about how they work.

LESSON 12: What can we do to support people in our communities who have cancer?

PREVIOUS LESSON We considered what we already know about cancer treatment options and heard about different treatments that Lakita and Lauren experienced. We explored how different treatments work and revised our Cell Game model to predict the relationship between treatment and the cell cycle. We wondered about access to treatment in different places.

THIS LESSON

INVESTIGATION

3 days



We decide to further investigate cancer incidence and mortality data and conclude that both are affected by geography and access to health services. We learn about social determinants of health and the constraints that they bring that can determine whether you survive cancer or not. We hear about advocates called health navigators who can support friends and family in cancer treatment and develop an interview protocol as a resource.

NEXT LESSON There is no next lesson.

BUILDING TOWARD NGSS

HS-LS1-1, HS-LS1-2, HS-LS1-4, HS-LS3-1, HS-LS3-2, HS-LS3-3, HS-ETS1-3



WHAT STUDENTS WILL DO

12.A Make and defend a claim supported by evidence about the factors that could cause differences between cancer rates and deaths in different states. (SEP 7.5; DCI: LS3.B.2; CCC 2.2)

12.B. Propose a solution about how to use health navigators in cancer prevention and treatment that considers a wide range of constraints within the context of the healthcare system. (SEP 6.3; DCI: ETS1.B.1; CCC 4.1)

WHAT STUDENTS WILL FIGURE OUT

- There were differences in national cancer incidence and mortality data.
- Social determinants impact health and wellness, and we may not have control over them.
- There is specific evidence about how distance from cancer specialists and changes in health insurance impact health outcomes.
- Even as students, there are ways that we can be a solution in co-constructing equitable and effective treatment plans.

Lesson 12 • Learning Plan Snapshot

Part	Duration		Summary	Slide	Materials
1	5 min		NAVIGATE Review treatment options, criteria, and potential causes of some of the disparities from previous lessons.	A	
2	5 min		INTRODUCE GEOGRAPHIC DISPARITIES Analyze a quote to help students to think about the relationship between zip code and health and wellness.	B-C	
3	15 min		ANALYZE NATIONAL CANCER DATA Explore national incidence and mortality data at the state level.	D-E	<i>National Cancer Data, Calculating Survival Rates, https://gis.cdc.gov/Cancer/USCS/#/AtAGlance/, chart paper and chart paper markers (optional)</i>
4	10 min		INITIAL IDEAS DISCUSSION Lead an Initial Ideas Discussion about geographic data.	F	
5	5 min		DEFINE HEALTH EQUITY Compare student definitions of health equity with a standard definition to explore how it relates to their criteria and decision-making priorities.	G-H	chart paper and chart paper markers (optional)
6	5 min		NAVIGATE Review ideas about how geography affects the likelihood of cancer and survival and brainstorm additional factors that impact health and wellness.	I	
<i>End of day 1</i>					
7	3 min		NAVIGATE Review student ideas from the previous day.	J	
8	12 min		INTRODUCE SOCIAL DETERMINANTS OF HEALTH Explore social determinants of health through a reading.	K-M	<i>Social Determinants Health, Social Determinants Table</i>
9	15 min		ANALYZING DATA ON SOCIAL DETERMINANTS OF HEALTH Explore evidence around two different factors in how health is impacted by social determinants.	N-O	<i>Distance from Specialists, Health Insurance Disruptions</i>
10	10 min		BUILDING UNDERSTANDINGS DISCUSSION Lead a Building Understandings Discussion about social determinants of health.	P	
11	3 min		NAVIGATE Ask students to complete an exit ticket about possible solutions.	Q-S	
<i>End of day 2</i>					

Part	Duration		Summary	Slide	Materials
12	3 min		NAVIGATE Review solutions students felt they could take on.	T	exit tickets from the previous class
13	8 min		EXPLORE NAVIGATORS AS A SOLUTION Introduce health navigators as a way to help address health inequities and support family and community members.	U-V	
14	6 min		CLASS DISCUSSION IN PREPARATION FOR INTERVIEW PROTOCOLS Generate ideas for health navigators.	W	<i>Social Determinants Table</i> , class consensus model
15	18 min		DEVELOP INTERVIEW PROTOCOLS Develop interview protocols to assess the needs of the family or community member to support as a health navigator.	X	<i>Designing Interview Protocols</i> , <i>Sample Interview Protocol Key</i>
16	10 min		NAVIGATE: CLOSE THE DQB Celebrate progress with students and close the DQB.	Y	

End of day 3

Lesson 12 • Materials List

	per student	per group	per class
Lesson materials	• science notebook • <i>National Cancer Data</i> • <i>Calculating Survival Rates</i> • https://gis.cdc.gov/Cancer/USCS/#/AtAGlance/ • <i>Social Determinants Health</i> • <i>Social Determinants Table</i> • <i>Distance from Specialists</i> • <i>Health Insurance Disruptions</i> • exit tickets from the previous class • <i>Designing Interview Protocols</i>		• chart paper and chart paper markers (optional) • class consensus model • <i>Sample Interview Protocol Key</i>

Materials preparation (minutes)

Review teacher guide, slides, and teacher references or keys (if applicable).

Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

Make copies of *Social Determinants Health* so that there are enough for each student to get one section. Cut the readings into strips. Some readings are longer and more technical, and you can differentiate by literacy skill and language development by selecting which students will do each reading.

Lesson 12 • Where We Are Going and NOT Going

Where We Are Going

This lesson asks students to investigate factors known as social determinants of health that, in addition to genetic factors, affect cancer diagnosis and survival outcomes. These socio-cultural constructs are some of the underlying causes of the systemic inequities that some populations face when trying to navigate the American healthcare system. Many of these factors influence health more than lifestyle choices and behavior, and individuals may have little or no control over these factors. As a potential strategy to increase agency and advocacy for their family and loved ones, students hear about health navigators as a potential solution to problems related to treatment and prevention and create interview protocols to gather evidence that is needed to create an equitable treatment plan.

This lesson continues to develop an understanding of HS-ETS1.B.1 and from *OpenSciEd Unit B.1: How do ecosystems work, and how can understanding them help us protect them? (Serengeti Unit)*, when students made recommendations about different road proposals in the Serengeti. In this context, they will build on the idea that in order to effectively evaluate solutions, you have to understand how well it meets the constraints and criteria of a problem. The systematic processes that students use in gathering evidence during the lesson help them to understand the constraints to be able to tailor the health navigator interview protocol.

Students build on ideas related to the following disciplinary core idea:

- ETS.1.B.1: When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts. (HS-ETS1-3)

Students use the science practice *constructing explanations and designing solutions* to investigate and communicate their findings about the unequal results of cancer survival rates caused by the social determinants of health.

Students use the crosscutting concept *systems and system models* to explore the relationship between these larger human social systems, the American healthcare system, different human populations, and their own experiences with these different systems.

Definitions we encounter: health equity and social determinants of health.

Where We Are NOT Going

There are many different ways to support equitable health care outcomes. This lesson focuses on health navigators as a single example rather than exploring multiple means. Many students may find themselves in situations where they have to advocate for a loved one in a healthcare setting and navigator provides a tangible way to do so.

LEARNING PLAN for LESSON 12

1 · NAVIGATE

5 min

MATERIALS: science notebook

Turn and Talk. Display **slide A**. Ask pairs of students to discuss the treatment options they investigated in our last class and the criteria they used to evaluate them.

Suggested prompt	Sample student response
<i>What treatment options did you investigate in our last class?</i>	Surgery Chemotherapy Radiation
<i>What constraints and criteria did you use to evaluate those treatments?</i>	Side effects Cost Effectiveness
<i>What were the key takeaways you discovered about each treatment type?</i>	Surgery is only effective when the cancer is in a particular area and can be quite expensive. Radiation can only be used on one area and not for extended use. Chemotherapy causes those cells that divide quickly to die, like hair cells, which is why a person's hair falls out. Immunotherapies are newer therapies that show a lot of promise, including at later stages.
<i>What new questions did that raise for you? What are some potential constraints that we need to investigate? Consider the two cases we heard about at the end of class.</i>	How can there be more equal or fair access to treatment? How can we help people without resources access treatment?

2 · INTRODUCE GEOGRAPHIC DISPARITIES

5 min

MATERIALS: science notebook

Reflect on quote individually. Display **slide B** and read the quote, “Research indicates one’s zip code is more important to health than one’s genetic code.” Give students two minutes to think and write their thoughts in their science notebooks. Ask, *What do you think the authors mean by this?*

Whole-class discussion. Display **slide C**. Ask students to share their thoughts about the questions on the slide. Listen for ideas such as:

Suggested prompt	Sample student response
<i>What are some possible explanations for why where people live might matter for their health?</i>	Some people live in areas with more pollution. Maybe some people do not have health insurance or do not go to the doctor.
<i>Is it fair or just that your zip code affects your health? Explain your thinking.</i>	Since we have so many treatments, people should be able to get them. Quality health care should be available for everyone. It is unfair that we live in the same country and can't get the same level of healthcare and options.

3 · ANALYZE NATIONAL CANCER DATA

15 min

MATERIALS: *National Cancer Data*, *Calculating Survival Rates*, <https://gis.cdc.gov/Cancer/USCS/#/AtAGlance/>, chart paper and chart paper markers (optional)

Introduce geographic data. Say, *It sounds like we have some ideas about treatment not being equitable or fair for all people. I have some data to help us think about that.*



Review national cancer incidence and mortality data. Display **slide D**. Ask students to review the maps in *National Cancer Data* in small groups. Distribute *Calculating Survival Rates* and ask students to calculate the mortality and survival rate for sample states and other states they are interested in and answer the questions. Display **slide E**. Once students have had a chance to discuss and record their answers, call on a few groups to share their thinking. Draw on examples that students shared in the whole-class discussion. For example, in some states, like Montana, the survival rate is 68%. In other states, survival rates are different. Encourage students to look carefully at the differences between rates of new cancers and rates of death.

ASSESSMENT OPPORTUNITY

What to look for/listen for in the moment:

- Differences between mortality rates and survival rates in different states.
- Evidence about what could account for these differences, such as environmental factors that might cause mutations. (SEP 7.5; LS 3.B.2; CCC 2.2)

What to do: Prompt students to review *National Cancer Data* and consider what they know about the differences between the states they have chosen. Encourage them to draw on their classmates' resources and experiences in different states to help them.

Building toward 12.A Make and defend a claim supported by evidence about the factors that could cause differences between cancer rates and deaths in different states. (SEP 7.5; LS 3.B.2; CCC 2.2)

4 • INITIAL IDEAS DISCUSSION

10 min

MATERIALS: science notebook

Lead an Initial Ideas Discussion about what could explain the differences we observed.* Display slide F. Use the prompts below as a guide.

KEY IDEAS

Purpose of the discussion: To help students grapple with national cancer data as evidence that geography in fact impacts a person's ability to be diagnosed and survive cancer.

Listen for these ideas:

- Some states have high incidence rates but high survival rates.
- Some states have low incidence rates, and they have high survival rates.
- Some states have high incidence rates and low survival rates.
- For cancer incidence and survival, it seems to matter what state you live in.

* STRATEGIES FOR THIS INITIAL IDEAS DISCUSSION

During this discussion, use talk moves like revoicing and "say more" to help clarify the ideas so that others can work with them. The goal is to elicit multiple ideas and reasoning; don't privilege some ideas over others. Draw out the controversy around these competing ideas to help motivate students to figure out a way to further investigate.

Suggested prompt

What do the maps show us about how rates of new cancer compare by state?

What do the maps show us about the rate at which people die from this cancer by state (mortality)?

Sample student response

Some states have more cancer than others.

Some states are better at helping people survive cancer than others are.

Suggested prompt	Sample student response
<i>What could account for differences between incidence of new cancer and death?</i>	Some people get more mutations than others. Some people have cancer in their families. Some people live in places with more sun, pollution or where people smoke more. There are other factors we learned about, like access and cost, that might prevent people from getting effective treatments.
<i>If there are effective treatments, why are there differences between the new cancer and death?</i>	There should be no differences. When cancer is found, you should be able to get the most effective treatment, which would give you the best chance to survive it.

5 • DEFINE HEALTH EQUITY

5 min

MATERIALS: science notebook, chart paper and chart paper markers (optional)

Define health equity as a class. Say, *It sounds like you noticed some differences between cancer occurrence and cancer death across different states that we cannot explain with what we figured out about the genetic basis of cancer and who gets cancer and why. The kinds of differences we see here are known as inequities.* Display **slide G**. Say, *Before we continue, let's pause to write about what you think it means to have health equity.* Ask students to stop and jot in their science notebooks before sharing with the class. Write their ideas on the whiteboard or chart paper until the class comes to a consensus about their definition.

Compare the class's definition to scientists' definition. Display **slide H**. Say, *What is similar between our definitions? What is different? Should we go back and modify our definition?* Ask students to add the term to their Personal Glossaries with the definition co-constructed by the class.

6 • NAVIGATE

5 min

MATERIALS: science notebook

Stop and Jot. Display **slide I**. Ask students to respond to the questions on the slide in their science notebooks.

End of day 1

7 • NAVIGATE

3 min

MATERIALS: science notebook

Review navigation from the previous day. Display **slide J**. Ask students to review the ideas they recorded in their science notebooks in the previous day's lesson and ask them to share some of the questions they had about health equity and cancer.

8 · INTRODUCE SOCIAL DETERMINANTS OF HEALTH

12 min

MATERIALS: *Social Determinants Health*, *Social Determinants Table*

Introduce social determinants of health. Display **slide K**. Explain to students that scientists have named the additional factors that affect health equity “social determinants of health” and explain how they came to be from a partnership between medical doctors and public health researchers.

Introduce a reading. Say, *I have a reading that I think will help you answer some of your questions about these factors.* Display **slide L**. Pass out *Unknown material with identifier: bi.l12.h02* to each student. Assign each student a determinant and distribute the pre-cut strips you prepared from *Social Determinants Health*. Say, *You will read about your determinant and complete your row in the Unknown material with identifier: bi.l12.h02. Consider how your determinant could be a constraint in cancer treatment or survival.* If necessary, revisit the definition of *constraints* which students used in *OpenSciEd Unit B.1: How do ecosystems work, and how can understanding them help us protect them? (Serengeti Unit)* and *OpenSciEd Unit B.2: What causes fires in ecosystems to burn and how should we manage them? (Fires Unit)*.

Small-group sensemaking. Display **slide M**. Organize students that read about the same social determinant of health. Ask them to share what they wrote down in *Unknown material with identifier: bi.l12.h02* and come to consensus on what they should share with the whole class.

ADDITIONAL GUIDANCE

Make enough copies of the reading so that each student can get one and cut the readings into strips. Some readings are longer and more technical, and you can differentiate by literacy skill and language development by selecting which students will do each reading. If students need additional support with the idea of social determinants of health, provide them with access to the following video: <https://www.youtube.com/watch?v=8PH4jYfF4Ns>

Whole-class share. Display **slide M**. Have students share about the determinants that they read about, what they mean for people and their health and wellness, and the ideas that were highlighted in their small-group discussions. Have the speaker from each group share the key takeaways from each social determinant. Students complete the *Unknown material with identifier: bi.l12.h02* with notes from each group. Use *Social Determinants Table Key* to offer feedback as students share their ideas.

9 · ANALYZING DATA ON SOCIAL DETERMINANTS OF HEALTH

15 min

MATERIALS: *Distance from Specialists*, *Health Insurance Disruptions*, science notebook

Motivate the need for looking at data. Say, *We have done some reading exploring several social determinants of health, and we have some ideas about how they could affect cancer treatment. How can we figure out if and how these determinants affect cancer outcomes?* Listen for responses related to looking at data, research, or scientific studies. If students do not suggest investigating with data, ask them to consider how we have investigated these kinds of ideas in the past.

Introduce data sets. Display **slide N**. Let students know you have research summaries to share with them to read and share what they find out about the relationship between where you live, your health, and how location impacts cancer care. Say, *As you read the studies, think about what evidence supports the claim that this social determinant matters for who gets cancer treatment? What evidence is there that this social determinant matters for health equity? What evidence is there that this social determinant is a constraint for cancer treatment and health equity?* Divide the class in half and distribute the summaries. One half of the class will read *Distance from Specialists* and the other half of the class will read *Health Insurance Disruptions*.

* ATTENDING TO EQUITY

Health Insurance Disruptions and *Distance from Specialists* are written at different reading levels and vary in length. Consider differentiation based on reading ability. The content in *Health Insurance Disruptions* contains challenging data with vocabulary that may be unfamiliar to students, including terms such as *odds*, *hazard ratio*, *confidence intervals*, and *p value*. In contrast, students

Sensemaking with a partner. Display **slide O**. Once students have completed the readings individually, ask them to find a partner who looked at the same study as they. They should work together to answer the questions on *Distance from Specialists* or *Health Insurance Disruptions*.

may have more background knowledge to apply to the content in *Distance from Specialists* and will encounter fewer unfamiliar terms. Some readers may choose to focus on one of the cases in *Distance from Specialists* instead of both.

10 · BUILDING UNDERSTANDINGS DISCUSSION

10 min

MATERIALS: science notebook

Share conclusions from each study. Call on students to share the takeaways from the different studies they read about with the class.

Lead a Building Understandings Discussion.* Display **slide P** and use the prompts below as a guide.

Suggested prompt	Sample student response
What evidence is there that social determinants affect cancer outcomes?	African American and Hispanic people were more likely to live in areas where they did not have access to doctors. Native American people and people who live in rural areas are often far from cancer centers. The readings talk about distance from doctors and changes in health care, so this fits with the health systems and services one. People with health insurance are more likely to get treatment and survive cancer.
How might they be part of an explanation for why cancer outcomes are different by state?	Maybe if some states are more rural, they are less likely to have cancer centers, and people cannot travel to get the care they need. Some states might have lower health insurance coverage than others, so the outcomes are worse for people in those states. If people are unable to get to treatment or doctors, then it could explain why there could be problems getting diagnosed or effectively treated.

*** STRATEGIES FOR THIS BUILDING UNDERSTANDINGS DISCUSSION**

These discussions support learning by creating opportunities for students to share claims and reasoning based on **evidence**, to connect, critique, and build on others' findings, claims, evidence, and explanations. Lastly, students are able to arrive at tentative conclusions as they continue to figure out their own ideas alongside new ideas presented in class.

Suggested prompt	Sample student response
What other information do we need to know to be more confident in our explanation?	We would need to know more about the conditions in each state. Such as: How many doctors do they have? How many people have health insurance? Do they have cancer centers?
KEY IDEAS	Purpose of this discussion: This discussion helps students explore data that makes it clear that geography is a strong influencer in access to cancer prevention and treatment. Listen for these ideas: • One study found that some demographics and neighborhoods were more likely to be in shortage areas for primary care physicians than others. • Another study found that there were vast differences in access to cancer treatment centers depending on where in the country you lived. • A group of studies examined the impact of having health care without disruption before diagnosis and during treatment and likelihood for survival. The evidence pointed to continuous health insurance creating more positive health outcomes across all indicators.

11 · NAVIGATE

3 min

MATERIALS: None

Develop a list of possible solutions. Display **slide Q**. Say, *You all have done a great job with thinking about all of these bigger systems that have bigger impacts on our health than the parts that we can actually control. Let's use what we know to propose some solutions to the constraints that these social determinants of health have on cancer treatment and survival.* Have students work in pairs and record their ideas in their science notebooks.

Share possible solutions. Call on volunteers to share their ideas. Record some of their ideas on the whiteboard to compare with the list of solutions that you are going to offer them. Display **slide R**. Say, *There are some groups who have also been thinking about these ideas as well and have come to some of their own conclusions.* The ideas on the slide are from the American Society for Clinical Oncology. Ask students to review the solutions on the slide. Say, *How do our ideas compare to their ideas? What are some considerations that we made that they did not? Remember this is not a complete list, but we can see if we are on the right track.*

Exit ticket. Display **slide S**. Ask students to complete an exit ticket where they write down the number of the solution they think they would be most likely to be able to help with personally and explain why.

End of day 2

12 · NAVIGATE

3 min

MATERIALS: exit tickets from the previous class

Review exit ticket results. Display **slide T**. Hand back exit tickets to each student. Share student ideas from their exit tickets from the last class. Students most likely indicated that they could provide personal assistance or educate people about cancer and cancer care.

13 · EXPLORE NAVIGATORS AS A SOLUTION

8 min

MATERIALS: None

Introduce health navigators. Display **slide U**. Say, *You all have a lot of ideas about solutions. I heard of something called health navigators that might be a solution that includes a lot of your ideas. This can be a role that you can take on for family or a close friend.* Explain that health navigators are people who help educate patients and their families, schedule and provide transportation, and ask questions of healthcare providers. Let students know that in order to be a navigator, a person needs a lot of information both from the person they are supporting and the health care providers they see. Say, *How do you think the role of health navigator fits into the overall healthcare system?*

Listen for ideas such as:

- The role of the health navigator can help people understand their cancer experience.
- Social workers advocate for their clients and help them navigate their healthcare and treatment plans.
- Nurses sometimes have to help their patients understand their treatment plans.

Revisit Lakita and Lauren. Display **slide V**. Say, *Let's revisit Lauren's and Lakita's cancer stories. This time we are going to focus on the support they receive during treatment from friends, families, and others.* Play the videos <https://youtu.be/jf41CcQqZ0?si=zZO9274zofSCg2zO> and <https://youtu.be/Yrohl8DCQE4>.

Whole class shares what they heard in the video. Ask the class to share what they heard in the video about who acted as a healthcare navigator for Lauren and Lakita and how they felt supported.

Listen for the following:

- Both Lauren and Lakita have connected with the Li-Fraumeni Association to help support them emotionally by connecting them with others going through cancer at a young age.
- Lakita feels that people her age understand what she is going through better than adults and that patients understand fellow patients.
- Lauren uses music to help her through treatment.
- Lauren recommends bringing care packages and writing letters to loved ones with cancer.
- Lauren and Lakita have relied on friends and family to support their emotional health during treatment.

14 · CLASS DISCUSSION IN PREPARATION FOR INTERVIEW PROTOCOLS

6 min

MATERIALS: science notebook, *Social Determinants Table*, class consensus model

Whole-class discussion. Display **slide W**. Say, *For us to think about how to be effective navigators for someone we care about, we need to brainstorm what we would need to know from both the patient (person we care about) and their health care provider.* Use the prompts below to guide a class discussion.

Suggested prompt	Sample student response
<i>Based on everything we figured out about the genetic basis of cancer and who gets cancer and why, what are some things that we would need to know from the patient?</i>	When they first got diagnosed, what were their symptoms? Did they have a family history of cancer? Did environmental factors (i.e., smoking) put them at risk for cancer?
<i>Based on everything we figured out about the genetic basis of cancer and who gets cancer and why, what are some things that we will need to know from the health care provider?</i>	What kind of cancer is this? How did they get it? What treatment options are available? Are other family members at risk? Is this cancer inherited?
<i>Based on everything we figured out about the health equity and social determinants of health, what are some things we would need to know from the patient?</i>	Do they have health care? What will their health care plan cover? How far do they live from a doctor? Do they have a support system to drive them to appointments and help them with their medicine?
<i>Based on everything we figured out about the health equity and social determinants of health, what are some things we would need to know from the health care provider?</i>	What is the treatment? How effective is the treatment?

15 · DEVELOP INTERVIEW PROTOCOLS

18 min

MATERIALS: *Designing Interview Protocols, Sample Interview Protocol Key*



Introduce the interview protocol. Display *slide X*. Say, *We will be working to create an interview protocol to understand our family member's or friend's cancer and needs in our preparation to support them as an effective health care navigator for a loved one who is visiting a doctor about a disease with a genetic component.* Distribute *Designing Interview Protocols*. Consider using the Gotta-Have-It Checklist to complete an example row in the interview protocol together as a class.

Say, *You will complete the Interview Protocols handout. For each question, say what you hope to learn and why you are asking it. When developing your justification for why it is important to ask each question you propose, draw on what you have learned in this unit about genetics. Also, draw on what you have learned about how both disease and healing from disease are shaped by genetics and the environment.*

ASSESSMENT OPPORTUNITY

What to look for/listen for in the moment: Use *Sample Interview Protocol Key* as guidance to help you support students in developing their interview protocols.

What to do:

Prompt students to review their science notebooks and other resources to look for the genetic basis of cancer, how your environment impacts your health, and how the social determinants of health increase or limit your cancer health care.

Building Toward 12.B Propose a solution about how to use health navigators in cancer prevention and treatment that considers a wide range of constraints within the context of the healthcare system. (SEP 6.3; DCI ETS1.B; CCC 4.1)

16 · NAVIGATE: CLOSE THE DQB

10 min

MATERIALS: None

Revisit the Driving Question Board. Display slide Y. Organize students into pairs. Ask each pair to choose approximately three questions that they can answer based on what they have figured out over the course of the unit (assign the number each pair is responsible for based on the actual number of questions and number of pairs. Go around the room and have each pair share at least one answer. If there are questions that remain unanswered, let students know that they will have opportunities to answer some of their questions in future units. Encourage them to explore the answers to questions they still have on their own.

Celebrate student progress over the course of the unit. Say, *As a class, let's celebrate that we have figured out a lot when it comes to who gets cancer and why and what we can do about it!*

Additional Lesson 12 Teacher Guidance

SUPPORTING STUDENTS IN MAKING CONNECTIONS IN ELA

RST.11-12.9 Key Ideas and Details

Students use information from many sources to develop an interview protocol to assess the potential needs of a family member before creating their role as navigator to support their community in co-constructing an effective treatment plan.

**SUPPORTING
STUDENTS IN
MAKING
CONNECTIONS IN
MATH**

MP2. Reason Abstractly and Quantitatively

Students calculate the survival rates for several states in order to identify trends in national cancer data.



Unit B.3 Teacher Reference Materials



ASSESSMENT SYSTEM OVERVIEW

Each OpenSciEd unit includes an assessment system that offers many opportunities for different types of assessments throughout the lessons, including pre-assessment, formative assessment, summative assessment, and student self assessment. Formative assessments are embedded and called out directly in the lesson plans. Please look for the “Assessment Icon” in the teacher support boxes to identify places for assessments. In addition, the table below outlines where each type of assessment can be found in the unit.

Overall Unit Assessment

When	Assessment and Scoring Guidance	Purpose of Assessment
Lesson 1	Initial Models Driving Question Board	Pre-Assessment The student work available for assessment in Lesson 1 should be considered a pre-assessment. It is an opportunity to learn more about the ideas your students bring to this unit. Revealing these ideas early can help you be more strategic in how to build from and leverage student ideas across the unit. The initial models developed during Lesson 1 are a good opportunity to pre-assess student understanding of genetics. Refer to “look fors” listed in the table below and in the Lesson 1 Teacher Guide. The Driving Question Board is another opportunity for pre-assessment. Reinforce for students to generate open-ended questions, such as how and why questions, to post to the board, but celebrate any questions students share even if they are close-ended questions. Make note of any close-ended questions and use navigation time throughout the unit to have your students practice turning these kinds of questions into open-ended questions when they relate to the investigations underway.
Lesson 2		
Lesson 2, 3, 4, 6, 7 and 9	Progress Tracker Update	Formative There are key formative assessment moments because students are capturing their ideas about what cancer is, how non-cancer cells become cancer cells, mitosis, how mutations occur in DNA replication, how environmental factors contribute to incidence of cancer, and as a review to prepare for a consensus model.
Lesson 3	<i>Making Sense Key</i> <i>Mitosis Card Sort Key</i>	Formative Students complete the Round 1 Scorecard to relate what they saw in the Cell Cycle game (model) to what it represents in cells. The Card Sort gives students the opportunity to relate actual photos of a cell undergoing mitosis to the scientific model, sequence the phases of mitosis, and describe what they see happening at each phase.
Lesson 5	<i>Checklist and Explanation Key</i> <i>Student Explanation Key</i>	Formative A key is provided to support students in generating a Gotta-Have-It Checklist on day 1. On day 2, students construct explanations based on their investigation with a simulation about how mutations occur and affect cancer. A rubric is provided to support scoring and feedback for this task.

When	Assessment and Scoring Guidance	Purpose of Assessment
Lesson 6	<i>Gene Expression Simulation</i> <i>Electronic Exit Ticket Key</i>	Formative A key is provided to support students in making sense of the kinesthetic model on day 1 On day 2, students complete an Electronic Exit Ticket which addresses 3-D elements associated with the lesson-level performance expectations (LLPEs) for Lesson 6. This task allows teachers to collect data and provide rapid feedback related to student ideas about the structure and function of DNA, chromosomes, genes, and proteins. Students also have an opportunity to share feedback about their experiences in the classroom. A key is provided to support teachers.
Lesson 8	<i>Lakita's Pedigree Key</i> <i>Two-Gene Pedigree</i> <i>Electronic Exit Ticket Key</i>	Formative On day 1, students develop a model of inheritance. Two keys are provided to support student model development. On day 2, the Electronic Exit Ticket offers another opportunity for a formative assessment for students to use different modalities to explain their understanding of inheritance as well as share feedback about their experiences in the classroom.
Lesson 9	<i>Unknown material with identifier: bi.l9.key2</i>	Formative On day 1, students develop investigative questions. A key is provided to support their development.
Lesson 10	<i>Genetics Transfer Task Key</i>	Summative This lesson includes a Transfer Task to give students an opportunity to make sense of a new phenomenon. A rubric is provided to assist in scoring and feedback.
Lesson 11	<i>Treatment Organizer</i>	Formative Students investigate different cancer treatment options. A key is provided to support students.
Lesson 12	<i>Social Determinants Table Key</i> <i>Sample Interview Protocol Key</i>	Formative Students investigate several determinants of health and record their key takeaways from the discussions. A key is provided to support students. Summative Students develop an interview protocol for the role of health navigator. They use their understanding of the genetic basis of cancer as well as the social determinants of health to develop their questions.
Embedded in each lesson	Lesson-by-Lesson Assessment Opportunities (below)	Formative Assessment Use this document to see which parts of lessons or student activity sheets can be used as embedded formative assessments.

When	Assessment and Scoring Guidance	Purpose of Assessment
Occurs in several lessons	<i>Progress Tracker</i> <i>Sample Progress Tracker</i>	Formative and Self-Assessment The Progress Trackers are thinking tools designed to help students keep track of important discoveries that the class makes while investigating phenomena and figure out how to prioritize and use those discoveries to develop a model to explain phenomena. It is important that what the students write in the Progress Trackers reflects their own thinking at that particular moment in time. In this way, the Progress Trackers can be used to formatively assess individual student progress or for students to assess their own understanding throughout the unit. Because the Progress Trackers are meant to be a thinking tool for kids, we strongly suggest it is not collected for a summative “grade” other than for completion. In addition to this flexible resource, Progress Trackers have been written directly in the unit in Lessons 2, 3, 4, and 9.
Occurs in several lessons	Student Self-Assessment Rubrics	Self-Assessment Student self-assessment rubrics for giving and receiving feedback can be used throughout the unit. Opportunities include, after a discussion or at the end of a class period. The rubric helps students reflect on their participation in the class that day. Choose to use this at least once a week or once every other week. Initially, you might give students ideas for what they can try to improve for the next time, such as sentence starters for discussions. As they gain practice and proficiency with discussions, ask for their ideas about how the whole-class and small-group discussions can be more productive. Additional support can be found in the <i>OpenSciEd Teacher Handbook: High School Science</i>.
Occurs in several lessons	Routines and Tools to Support Peer Assessment <i>Peer Feedback Protocol</i>	Peer Assessment There will be times in your classroom when facilitating students to give each other feedback will be very valuable for their three-dimensional learning and for learning to give and receive feedback. We suggest that peer feedback happen at least two times per unit. Peer feedback is most useful when there are complex and diverse ideas visible in student work and not all work is the same. Student models or explanations are good opportunities to use a peer feedback protocol. They do not need to be final pieces of student work; rather, peer feedback will be more valuable to students if they have time to revise after receiving it. This should be a formative rather than summative type of assessment. It is also necessary for students to have experience with past investigations, observations, and activities in which they can use these experiences as evidence for the feedback they give. Additional support can be found in the <i>OpenSciEd Teacher Handbook: High School Science</i>. In addition to this flexible resource, peer feedback has been written directly in the unit in Lessons 2, 4, and 5.

For more information about the OpenSciEd approach to assessment and general program rubrics, visit the OpenSciEd Teacher Handbook.

Lesson-by-Lesson Assessment Opportunities

Every OpenSciEd lesson includes one or more lesson-level performance expectations (LLPEs). The structure of every LLPE is designed to be a three-dimensional learning, combining elements of science and engineering practices, disciplinary core ideas and cross cutting concepts. The font used in the LLPE indicates the source/alignment of each piece of the text used in the statement as it relates to the NGSS dimensions: alignment to [Science and Engineering Practice\(s\)](#), alignment to [Cross-Cutting Concept\(s\)](#), and alignment to the [Disciplinary Core Ideas](#).

The table below summarizes opportunities in each lesson for assessing every lesson-level performance expectation (LLPE). Examples of these opportunities include student handouts, home learning assignments, progress trackers, or student discussions. Most LLPEs are recommended as potential formative assessments. Assessing every LLPE listed can be logistically difficult. Strategically picking which LLPEs to assess and how to provide timely and informative feedback to students on their progress toward meeting these is left to the teacher's discretion.

Lesson	Lesson-Level Performance Expectation(s)	Assessment Guidance
Lesson 1	1.A Develop an initial model to explain and predict factors that cause cancer and the possible protective effects from p53. (SEP: 2.3; DCI: LS3.B.2; CCC: 2.2) 1.B Ask questions to clarify and seek additional information about the cause and effect of cancer based on genetic and environmental differences. (SEP: 1.1; DCI: LS1.A.1 & LS3.B.2; CCC: 2.2)	1.A When to check for understanding: On day 2, when students develop initial models. What to look for/listen for in the moment : - Interactions between factors that might cause cancer, such as geographic location, size, and age in humans. (SEP: 2.3; DCI: LS3.B.2; CCC: 2.2) - Interactions between nonhuman animals and p53 that prevent cancer. (SEP: 2.3; DCI: LS3.B.2) - Questions about the mechanisms that both cause and protect from cancer. (SEP 2.3; CCC 2.2) 1.B When to check for understanding: On day 1 and day 3, when students develop initial questions and the Driving Question Board. What to look for/listen for in the moment: Day 1 - Why are some cancers more common than others? (DCI: LS3.B.2; CCC: 2.2) - Why are some cancers more deadly than others? (DCI: LS3.B.2; CCC: 2.2) - How can where you live affect cancer rate? (DCI: LS3.B.2; CCC: 2.2) Day 3 - What cancer is and how it can cause illness. (DCI LS1.A.1; CCC 2.2) - What p53 is and how it can provide cancer protection. (LS3.B.2; CCC 2.2) - Effects of cancer treatment and prevention. (DCI LS1.A.1; CCC 2.2) - Genetic and environmental factors that affect incidence of cancer. (DCI LS3.B.2; CCC 2.2)

Lesson	Lesson-Level Performance Expectation(s)	Assessment Guidance
Lesson 2	2.A Ask questions that will help identify patterns that explain the relationships between non-cancer and cancer cells. (SEP: 1.6; DCI: LS1.A.1 & LS1.A.3; CCC: 1.1) 2.B Develop and revise a model to illustrate the relationship between systems of specialized cells and cancer cells at the scales of the cells, the tissue, the organ, and the body. (SEP: 2.3; DCI: LS1.A.1 & LS1.A.3; CCC: 2.2)	2.A When to check for understanding: On day 1, during the Initial Ideas Discussion. What to look for/listen for in the moment: Questions (SEP: 1.6) such as: • What do cancer and non-cancer cells have in common?(DCI: LS1.A.1 & LS1.A.3; CCC: 1.1) • What differences are there between cancer and non-cancer cells across cell types?(DCI: LS1.A.1 & LS1.A.3; CCC: 1.1) • How do cancer cells look when they are in different cell types?(DCI: LS1.A.1 & LS1.A.3; CCC: 1.1) • Do cancer cells disrupt the cells in the different cell types?(DCI: LS1.A.1 & LS1.A.3; CCC: 1.1) 2.B When to check for understanding: On day 1, when students develop initial models and on day 2, when they revise them. What to look for/listen for in the moment: Models that explain: (SEP: 2.3) • Cancer and non-cancer cells interact at the level of the cell, tissue, organ, body system, and organism. (DCI: LS1.A.3; CCC: 2.2) • Those interactions may disrupt the typical function of the cells. (DCI: LS1.A.1; CCC: 2.2) • If the typical function is disrupted, the person might feel sick because they do not get what they need from that organ or system. (DCI: LS1.A.1 & LS1.A.3; CCC: 2.2)

Lesson	Lesson-Level Performance Expectation(s)	Assessment Guidance
Lesson 3	3.A Use a model to illustrate the role of p53 in the cell cycle and new cell production. (SEP: 2.3; DCI: LS1.B.1; CCC: 2.2) 3.B Use a model to explain how changes to the cell cycle can affect the system, resulting in non-cancer cells producing cancer cells. (SEP: 2.3; DCI: LS1.B.1; CCC: 2.2) 3.C Identify the limits of the Cell Game model and use additional models to illustrate how the cell cycle produces two cells with identical chromosomes. (SEP: 2.4; DCI: LS1.B.1; CCC: 4.4)	3.A When to check for understanding: On day 1 during the Building Understandings Discussion. What to look for/listen for in the moment: Students use the model presented in the Cell Game. (SEP: 2.3) Listen for these ideas: - Cells acquire resources, such as nutrients, organelles, and chromosomes, which contribute to their growth. (DCI: LS1.B.1; CCC: 2.2) - Once a cell has adequate resources, it divides via mitosis. (DCI: LS1.B.1; CCC: 2.2) - At checkpoints, p53 regulates the cell cycle, making sure it has what it needs before it divides. (DCI: LS1.B.1; CCC: 2.2) Building toward 3.A Use a model to illustrate the role of p53 in the cell cycle and new cell production. (SEP: 2.3; DCI: LS1.B.1; CCC: 2.2) 3.B When to check for understanding: On day 2 during the Building Understandings Discussion. What to look for/listen for in the moment: - When p53 was working properly in the cell cycle, cells that did not have all of the requirements could not pass the checkpoints and divide. (DCI: LS1.B.1; CCC: 2.2) - When the cell cycle is not working properly, cells can pass checkpoints without meeting the requirements. (DCI: LS1.B.1; CCC: 2.2) - If a cell does not have all the resources it needs and divides anyway, it can form a cancer cell. (DCI: LS1.B.1; CCC: 2.2) Building toward 3.B Use a model to explain how changes to the cell cycle can affect the system, resulting in non-cancer cells producing cancer cells. (SEP: 2.3; DCI: LS1.B.1; CCC: 2.2) 3.C When to check for understanding: On day 3 during the Consensus Discussion. What to look for/listen for in the moment: - When a cell divides into non-cancer cells, they are identical/their chromosomes are the same. (DCI: LS1.B.1; CCC: 2.2) - When a non-cancer cell divides into a cancer cell, something is different about the chromosomes. (DCI: LS1.B.1; CCC: 2.2) - The scientific model helped us see what was happening with the chromosomes; the Cell Game model was limited in that way. (SEP: 2.4; DCI: LS1.B.1) Building toward 3.C Use the game and scientific models of the cell cycle to explain what causes non-cancer cells to become cancer cells with attention to the merits and limits of each model. (SEP: 2.4; DCI: LS1.B.1; CCC: 2.2)

Lesson	Lesson-Level Performance Expectation(s)	Assessment Guidance
Lesson 4	7.A Use a computer simulation as evidence to develop and revise a model that predicts how the rate of cell division affects the likelihood of cancer. (SEP: 2.3; DCI: LS3.B.1 & LS1.B.1; CCC: 4.4)	7.A When to check for understanding: Following the Cell Growth and Cancer computer simulation, when students revise their models. What to look for/listen for in the moment: Revised initial models (SEP 2.3) explaining how getting older and taller affects mutation rates and its relationship to cancer. • Different cell types form after mitosis. (DCI LS1.B.1) • Different cell types divide at different rates. (DCI LS1.B.1 & LS3.A.1; CCC 4.4) • The more cells divide, the more chances for mutations to happen. (DCI: LS3.B.1; CCC: 4.4) • The more mutations a person has, the higher their likelihood of getting cancer. (DCI: LS3.B.1; CCC: 4.4) • Cells divide as you grow, so an older person has more cell divisions than a younger person. Because of this, the older person will likely have more mutations than the younger person. (DCI: LS3.B.1; CCC: 4.4) • Taller people have more cells than shorter people, so there are more divisions happening in the same amount of time for the taller person. Because of this, taller people will accumulate mutations more frequently than shorter people. (DCI: LS3.B.1; CCC: 4.4)
Lesson 5	5.A Construct an explanation based on evidence about how mutations can occur during DNA replication, resulting in differences in chromosomes, and the role of p53 in their repair. (SEP: 6.2; DCI: LS3.B.1; CCC: 2.2)	5.A.1 When to check for understanding: On day 1, when students generate ideas for their Gotta-Have-It Checklist. What to look for/listen for in the moment: Ideas that will support student explanations (SEP: 6.2): • The relationship between DNA and chromosomes. • Why/how/when is the DNA replicating. (DCI: LS3.B.1) • Where/how/why errors occur during replication. (DCI: LS3.B.1; CCC: 2.2) • Where/how/why errors are corrected. (DCI: LS3.B.1; CCC: 2.2) • What happens to the DNA after replication. • How the DNA with mutations relates to cancer cells with differences in their chromosomes. (DCI: LS3.B.1; CCC: 2.2) 5.A.2 When to check for understanding: On day 2, when students revise their explanations. What to look for/listen for in the moment: Ideas that will support student explanations (SEP: 6.2) on day 2: • The relationship between DNA and chromosomes. • Why/how/when is the DNA replicating. (DCI: LS3.B.1) • Where/how/why errors occur during replication. (DCI: LS3.B.1; CCC: 2.2) • Where/how/why errors are corrected. (DCI: LS3.B.1; CCC: 2.2) • What happens to the DNA after replication. • How the DNA with mutations relates to cancer cells with differences in their chromosomes. (DCI: LS3.B.1; CCC: 2.2)

Lesson	Lesson-Level Performance Expectation(s)	Assessment Guidance
Lesson 6	6.A Use a model to illustrate the relationships between DNA structure and the structure and function of p53. (SEP: 2.3; DCI: LS1.A.2; CCC: 6.2) 6.B Integrate information from multiple sources to answer questions about how changes to the structure of the DNA in the p53 gene relates to protein function. (SEP: 8.2; DCI: LS1.A.2 & LS3.A.1; CCC: 6.2)	6.A When to check for understanding: On day 1, when students revise their responses based on peer discussion. What to look for/listen for in the moment: See <i>Gene Expression Simulation</i> for guidance. 6.B When to check for understanding: On day 2, when students complete an Electronic Exit Ticket. What to look/listen for in the moment: See <i>Electronic Exit Ticket Key</i> for guidance.
Lesson 7	6.A Develop and use a model based on evidence to explain the genetic cause and effect of cancer. (SEP: 2.3; DCI: LS1.A.1, LS1.A.2, LS1.A.3, LS1.B.1; CCC: 2.2)	6.A When to check for understanding: During the discussion while developing the consensus model. What to look for/listen for in the moment: Students making connections explaining the genetic basis for cancer, including the following to be included in the class consensus model: • The cell cycle has p53 checkpoints to reduce the likelihood that cancer cells will form. • A mutation in p53 DNA causes changes in the shape of the protein, which does not allow it to repair mutations. (DCI LS1.A.2; CCC2.2) • Cancer cells have differences in their chromosomes compared to non-cancer cells. (DCI LS1.A.1) • When cancer cells form, they clump together, becoming a tumor that can invade surrounding tissue, divert resources, and cause disease. (DCI LS1.B.1; CCC 2.2) • Cells go through the cell cycle, ending in mitosis when they divide for growth or repair. (DCI LS1.B.1) • p53 tightly regulates new cell formation at checkpoints during the cell cycle. (DCI LS1.B.1) • Mutations are errors that occur in DNA replication during the cell cycle because there is an error in the DNA. • If p53 fails, non-cancer cells can become cancer cells. • Most DNA codes for proteins; therefore mutations in DNA can cause the proteins to have different shapes. (DCI LS1.A.2; CCC2.2) • The structure of proteins is related to their function, so when the structure changes due to a mutation, so does the function. (DCI LS1.A.2; CCC2.2)

Lesson	Lesson-Level Performance Expectation(s)	Assessment Guidance
Lesson 8	8.A Develop and use multiple models to explain how the inheritance of p53 alleles and other gene alleles can cause cancer in multiple generations of a family through new combinations of alleles. (SEP: 2.4; DCI: LS3.B.1; CCC: 2.2)	8.A.1 When to check for understanding: On day 1, when students develop a model of inheritance for p53 for a family with a history of Li-Fraumeni syndrome. What to look for/listen for in the moment: See <i>Lakita's Pedigree Key</i> for guidance. - Using pipe cleaners and beads to illustrate genotypes for Lakita's family pedigree. (SEP: 2.4) - Correctly identifying genotypes based on phenotypes and inheritance for different individuals over multiple generations. (DCI: LS3.B.1; CCC: 2.2) - Lakita's grandfather and mother will be homozygous for the p53 allele that corrects mutation. - Lakita and her father, aunts, and uncles will be heterozygous for the p53 allele that does not correct mutation. - Lakita's aunts that have not been tested could be homozygous for the p53 allele that corrects mutation or heterozygous for the p53 allele that does not correct mutations. - Lakita's grandmother could be homozygous or heterozygous for the p53 allele that does not correct for mutations. 8.A.2 When to check for understanding: On day 2, when students apply meiosis and crossing over to revise their model of inheritance to explain a pedigree with two genes (slide P). What to look for/listen for in the moment: - Use of pipe cleaners and beads to show meiosis, including crossing over, as a mechanism for creating sperm with chromosomes that could produce offspring with different phenotypes from their parents. (SEP: 2.4; DCI: LS3.B.1; CCC: 2.2) - Two different cell divisions: 1st: splitting of paired chromosomes to produce two cells. 2nd: splitting of duplicated chromosomes to produce four cells. - Crossing over between paired chromosomes before the first cell division. - Full meiosis in sequence: - Starting cell looks like the dad's cell from the pedigree. - Chromosomes duplicate (X-shaped). - Chromosome pairs lined up next to each other in the middle of the cell. - Chromosomes crossing over (swapping of genetic material). (DCI: LS3.B.1) - Chromosomes pairs moving apart. - Two cells, each with one X-shaped chromosome. - X-shaped chromosome in center of both cells. - Arms of the X-shaped chromosome being pulled apart in both cells. - Four new cells, each with one chromosome. Each cell has a different combination of alleles (p53A/BRCA1C, p53B/BRCA1C, p53A/BRCA1D, p53B/BRCA1D). (DCI: LS3.B.1) - Identify which of the new cells would produce which offspring in the pedigree. (CCC: 2.2) 8.A.3 When to check for understanding: On day 2, when students complete an Electronic Exit Ticket. What to look for/listen for in the moment: See <i>Electronic Exit Ticket Key</i> for guidance. 8.A Develop and use multiple models to explain how the inheritance of p53 alleles and other gene alleles can cause cancer in multiple generations of a family through new combinations of alleles. (SEP: 2.4; DCI: LS3.B.1; CCC: 2.2)

Lesson	Lesson-Level Performance Expectation(s)	Assessment Guidance
Lesson 9	9.A Ask questions to determine how environmental factors cause mutations in genes. (SEP: 1.6; DCI: LS3.B.2; CCC: 2.1) 9.B Make and defend a claim using evidence about how environmental factors cause mutations in genes. (SEP: 7.5; DCI: LS3.B.2; CCC: 2.1)	9.A When to check for understanding: On day 1, when students formulate an investigative question. What to look for/listen for in the moment: Students deciding on what to include in their investigative question. • Selection of an investigative question.(SEP: 1.6) • Identification of an independent variable and dependent variables, which will be observed during their investigation and provide empirical evidence that environmental factors can cause mutations. (DCI: LS3.B.2; CCC: 2.1) 9.B When to check for understanding: On day 3, when students complete the Making Sense questions on [BI.L9.HO3]. What to look for/listen for in the moment: • Identification of patterns in the class data that serve as empirical evidence of environmental factors causing mutations. (DCI: LS3.B.2; CCC: 2.1) • Evidence from informational text, evidence from a scientific study, and their own investigation to support arguments. (SEP: 7.5) • Understanding of causation and correlation as it applies to the data. (CCC: 2.1)
Lesson 10	10.A Develop a model based on evidence to illustrate the smaller-scale mechanisms that can result in cancer, such as random mutation, inheritance, and environmental factors. (SEP: 2.3; DCI: LS3.B.1 & LS3.B.2; CCC: 2.2) 10.B 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. (SEP: 7.5; DCI: LS3.B.1 & LS3.B.2; CCC: 2.1)	10.A When to check for understanding: One day 1 when students complete the Gotta-Have-It Checklist and develop the class consensus model. What to look for/listen for in the moment: Students deciding on the necessary ideas to explain the small-scale mechanisms for the mutations they previously figured out in the genetic basis for cancer, including the following to be included in the Gotta-Have-It-Checklist: • The taller you are and the older you are, the more cell divisions you will have over your lifetime. (DCI: LS3.B.1) • As the number of cellular divisions increases, the number of mutations also increases. • This increase in mutations increases your risk of getting cancer. (DCI: LS3.B.1; CCC: 2.2) • Some cancer is inherited from alleles that you get from your parents. (DCI: LS3.B.1) • People with Li-Fraumeni inherit a mutation in their p53 gene and get cancer more often. (DCI: LS3.B.1; CCC: 2.2) • Crossing over happens during meiosis, randomly causing mutations and genetic variation. (DCI: LS3.B.1) • UV radiation can cause mutations in DNA that can cause cancer. (DCI: LS3.B.2; CCC: 2.2) • Mutations from radiation can change the protein structure and function, leading to cancer. (DCI: LS3.B.2; CCC: 2.2) 10.B When to check for understanding: On day 2 when students complete a Transfer Task. What to look for/listen for in the moment: See <i>Genetics Transfer Task Key</i> for guidance.

Lesson	Lesson-Level Performance Expectation(s)	Assessment Guidance
Lesson 11	11.A Obtain, evaluate, and communicate information about current treatment options using criteria related to human systems and predict outcomes for individuals. (SEP: 8.5; DCI: LS1.B.1 & ETS 1.B.1; CCC: 2.2) 11.B Use a model to explain how cancer treatments affect cell division for cancer and non-cancer cells. (SEP: 2.3; DCI: LS1.B.1; CCC: 2.2)	11.A When to check for understanding: On day 1, when students complete <i>Treatment Options Organizer</i>. What to look for/listen for in the moment: See <i>Treatment Organizer</i> for guidance. 11.B When to check for understanding: On day 2, when students revise their game cards. What to look for/listen for in the moment: Cards designated in a part of the model that predicts relationship between cell cycle and treatments. (SEP: 2.3 ; CCC: 2.2) For example: • Taxol should be placed in the M phase. • Carboplatin should be placed in the S phase. • Radiation should be placed in the S phase. • Surgery and immunotherapy could be placed anywhere. • The action on all of the cards should ask students to stop the progression of that cell through the game or remove the token from play, as the cell does not divide or progress through the cell cycle. (DCI: LS1.B.1)
Lesson 12	12.A Make and defend a claim supported by evidence about the factors that could cause differences between cancer rates and deaths in different states. (SEP 7.5; DCI: LS3.B.2; CCC 2.2) 12.B. Propose a solution about how to use health navigators in cancer prevention and treatment that considers a wide range of constraints within the context of the healthcare system. (SEP 6.3; DCI ETS1.B.1; CCC 4.1)	12.A When to check for understanding: On day 1, when students complete <i>Calculating Survival Rates</i>. What to look for/listen for in the moment: • Differences between mortality rates and survival rates in different states. • Evidence about what could account for these differences, such as environmental factors that might cause mutations. (SEP 7.5; LS 3.B.2; CCC 2.2) 12.B When to check for understanding: On day 2, when students create interview protocols as an assessment tool to ascertain the needs of a family member who is challenged by a disease with a genetic component. What to look for/listen for in the moment: • The interview protocols need to be able to assess the patient's experience with cancer, access to resources, and potential challenges with their treatment plan.



Lesson-Specific Teacher Materials



Example Community Agreements

Respectful Our classroom is a safe space to share.	• We provide one another with support and encouragement. • We share our time to talk. We do this by giving others time to think and share. • We critique the <i>ideas</i> we are working with but not the <i>people</i> we are working with.
Equitable Everyone's participation and ideas are valuable.	• We monitor our own time spent talking. • We encourage others' voices that we have not heard yet. • We recognize and value that people think, share, and represent their ideas in different ways.
Committed to Our Community We learn together.	• We come prepared to work toward a common goal. • We share our own thinking to help us all learn. • We listen carefully and ask questions to help us understand everyone's ideas. • We speak clearly and loud enough so that everyone can hear.
Moving Our Science Thinking Forward We work together to figure things out.	• We use and build on others' ideas. • We use evidence to support our ideas, ask for evidence from others, and suggest ways to get additional evidence. • We are open to changing our minds. • We challenge ourselves to think in new ways.

Trauma-Informed SEL Supports

Creating a Safe Classroom Environment

In this unit, students will experience a unit called *Who gets cancer and why? What can we do about it?* as part of the OpenSciEd high school science curriculum. Students will investigate the causes of and treatments for cancer. Specifically, they will investigate how cancer can be caused by mutations accumulated in our lifetime, mutations we inherit, and mutations caused by the environment. They will also hear from two young women, via video interviews about their personal experience with cancer.

It is important to keep in mind throughout this unit that experiences with cancer can be traumatic, and recalling past experiences or learning about others' experiences can be triggering. **Never ask students to share their personal experiences unless they volunteer to do so.** While it is generally pedagogically productive to encourage students to connect their personal experiences to the content in science class, in this case it is more important to protect students who may have had a traumatic experience or lost a loved one to cancer. This topic is very strongly relevant to most students' lives, and you do **not** need to proactively draw out their prior experiences to help them see that relevance.

Adolescents may develop symptoms following an accident, such as difficult behaviors or emotions shown at home or school. According to the CDC, "Adopting a trauma-informed approach is not accomplished through any single particular technique or checklist. It requires constant attention, caring awareness, [and] sensitivity."

Below are some conditions to strive for in the classroom to help students feel socially and emotionally safe as you teach this unit, adapted from Transforming Education. <https://transformingeducation.org/>

- The classroom environment feels physically and psychologically safe.
- Interpersonal interactions between all educators and students promote a sense of safety.
- Decisions about changes in the classroom are made with transparency.
- Building and maintaining trust among teachers and students, and between peers, is a top priority.
- Peer support, mutual help, and collaboration are foundational for establishing safety and hope in the classroom.
- The identities and stories of members of the school and classroom community are acknowledged and celebrated.
- There is partnering on work (between teachers and students, and peer to peer).
- There is meaningful sharing of power and decision-making when possible.
- Students' strengths and experiences are recognized and built upon.
- The school and classroom community believes in its students' resilience, empowerment, and ability to make good choices.
- Members of the school and classroom community strive to move past cultural stereotypes and biases, promote culturally responsive teaching, and celebrate and welcome all students' identities.

Engaging in Mindfulness

Below are several strategies to help students engage in mindfulness. These approaches can help students who may have had negative experiences or trauma associated with cancer and other themes in this unit. These strategies help to ground students and help them recognize they are in a safe environment and ready to learn. These can be done before a lesson, mid-lesson, or at any point that you feel students might benefit from these strategies.

Strategy #1: 5-4-3-2-1.

This strategy can be done either as a whole class, in partners, or in small groups.

5- Look at five things around you. Make note of their qualities. What color are they? What shape are they? What other qualities do they have?

4- Acknowledge 4 things that you are touching, or things you can touch. How do they feel? How would they feel?

3- Listen for 3 sounds you can hear. Tune in to them each individually.

2- Breathe in and identify two smells around you. What do these smells remind you of?

1- identify one thing you can taste around you. What would it taste like?

Some alternatives to this approach can be found at the following web page: <https://cognitiontoday.com/5-step-mindfulness-grounding-technique-to-ease-anxiety-why-it-works/>

Strategy #2: Check in

This strategy works well at the beginning of a lesson.

Have students reflect on these questions:

- Think about the previous lesson. What went well?
- What was hard?

Ask students to share their answers with peers and consider how they can become more invested and present in the lesson today.

Strategy #3: Box Breathing

This strategy can be done at any point in a lesson, and can be helpful to do during or after any point where students show signs of stress or anxiety. Box breathing helps students with stress management and is broken down into 4 steps.

- Ask students to visualize a box with 4 equal sides in their minds. Guide students as each inhale or exhale takes them around the perimeter of the box.
- Step One: Breathe in through the nose for a count of 4.
- Step Two: Hold breath for a count of 4.
- Step Three: Breathe out for a count of 4.
- Step Four: Hold breath for a count of 4.
- Repeat.

Note: The length of the steps can be adjusted to accommodate the individual (e.g., 2 seconds instead of 4 seconds for each step).

Strategy #4: Progressive Muscle Relaxation

This strategy works well at any point during a lesson, individually, in small groups, or classwide as the teacher narrates. This exercise asks students to relax muscles in order through the body to help foster relaxation.

- **Step One:** Have students sit down and minimize distractions.
- **Step Two:** Starting at the feet, curl the toes under and tense the muscles in the foot. Hold for 5 seconds, then slowly release for 10 seconds. During the release, focus attention on the alleviation of tension and the experience of relaxation.
- **Step Three:** Tense the muscles in the lower legs. Hold for 5 seconds, then slowly release for 10 seconds. During the release, focus attention on the alleviation of tension and the experience of relaxation.

- **Step Four:** Tense the muscles in the hips and buttocks. Hold for 5 seconds, then slowly release for 10 seconds. During the release, focus attention on the alleviation of tension and the experience of relaxation.
- **Step Five:** Tense the muscles in the stomach and chest. Hold for 5 seconds, then slowly release for 10 seconds. During the release, focus attention on the alleviation of tension and the experience of relaxation.
- **Step Six:** Tense the muscles in the shoulders. Hold for 5 seconds, then slowly release for 10 seconds. During the release, focus attention on the alleviation of tension and the experience of relaxation.
- **Step Seven:** Tense the muscles in the face (e.g., squeezing eyes shut). Hold for 5 seconds, then slowly release for 10 seconds. During the release, focus attention on the alleviation of tension and the experience of relaxation.
- **Step Eight:** Tense the muscles in the hand, creating a fist. Hold for 5 seconds, then slowly release for 10 seconds. During the release, focus attention on the alleviation of tension and the experience of relaxation.

Strategy #5: Guided Imagery

This can be done at any point in the lesson. Students visualize a relaxing environment to help manage stress, and walk through what they would sense in the environment. Guided imagery can be practiced individually or with the support of a narrator.

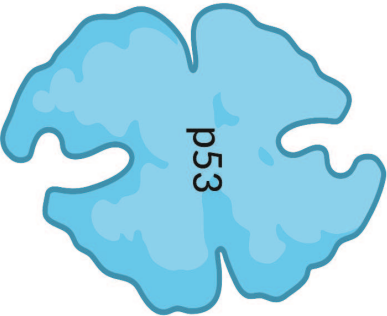
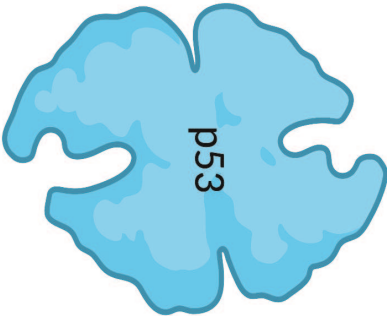
- **Step One:** Have students sit down. Ideally, the space will have minimal distractions.
- **Step Two:** Visualize a relaxing environment by either recalling one from memory or creating one through imagination (e.g., a day at the beach). Elicit elements of the environment using each of the five senses using the following prompts:
 1. What do you see? (e.g., deep-, blue color of the water)
 2. What do you hear? (e.g., waves crashing along the shore)
 3. What do you smell? (e.g., fruity aromas from sunscreen)
 4. What do you taste? (e.g., salty sea air)
 5. What do you feel? (e.g., warmth of the sun)
- **Step Three:** Sustain the visualization as long as needed or able, focusing on taking slow, deep breaths throughout the exercise. Focus on the feelings of calm associated with being in a relaxing environment.

These are not the only mindfulness activities available for use. Consider using other mindfulness techniques as suggested by your school counselors. As experts in their fields, they can recommend strategies that are relevant and targeted to your specific students.

Strategies #2-#5 were adapted from the following source for classroom- specific use:

References

Norelli SK, Long A, Krepps JM. Relaxation Techniques. [Updated 2021 Sep 6]. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2022 Jan-. Available from: <https://www.ncbi.nlm.nih.gov/books/NBK513238/>

Check your scorecard. If you have: At least 3 nutrients, 3 proteins, and 3 organelles, YOU PASS THE CHECKPOINT. 2 in any category, GO BACK 3 SPACES. 1 in any category, GO BACK 5 SPACES. A 0 in any category, YOU HAVE BEEN DESTROYED by p53 AND MUST GO BACK TO THE START.	G1 Checkpoint  Illustrations created by OpenSciEd in BioRender
Check your scorecard. If you have: At least 4 DNA and at least 1 nutrient, 1 protein, and 1 organelle, YOU PASS THE CHECKPOINT. Fewer than 4 DNA, GO BACK TO THE FIRST SPACE. A 0 in any category, YOU HAVE BEEN DESTROYED by p53 AND MUST GO BACK TO THE START.	G2 Checkpoint  Illustrations created by OpenSciEd in BioRender

M Checkpoint

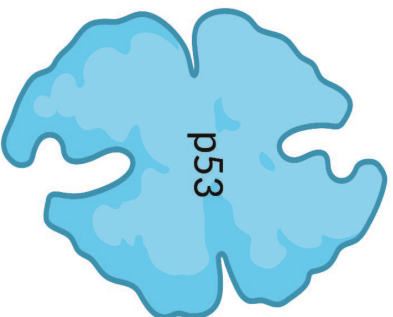
Double-check your scorecard. Make sure you have:

G1: at least 3 nutrients, 3 proteins, and 3 organelles.

S: at least 4 DNA.

G2: at least 1 nutrient, 1 protein, and 1 organelle.

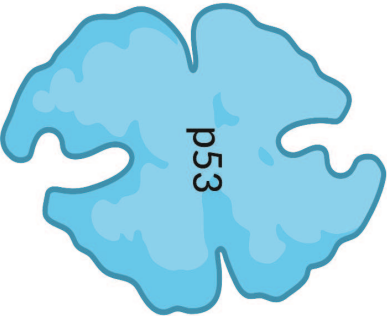
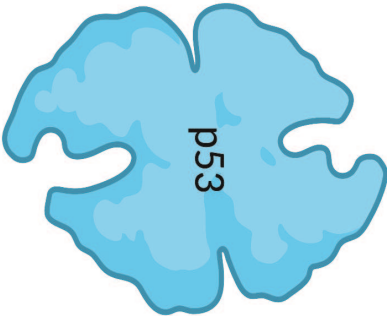
YOU SUCCESSFULLY DIVIDED! Take a new blue cell chip!



Illustrations created by OpenSciEd
in BioRender

Lesson 3: Teacher Reference 1

CartasDeJuego 1

Revisa tu tarjeta de puntuación. Si tienes: Al menos 3 nutrientes, 3 proteínas y 3 orgánulos, PASAS EL PUNTO DE CONTROL. 2 en cualquier categoría, RETROCEDE 3 PLAZAS. 1 en cualquier categoría, RETROCEDE 5 PLAZAS. Un 0 en cualquier categoría, HAS SIDO DESTRUIDO por p53 Y DEBES VOLVER AL INICIO.	punto de control G1  Illustrations created by OpenSciEd in BioRender
Revisa tu tarjeta de puntuación. Si tienes: Al menos 4 ADN y al menos 1 nutriente, 1 proteína y 1 orgánulo, PASAS EL PUNTO DE CONTROL. Menos de 4 ADN, REGRESA AL PRIMER ESPACIO. Un 0 en cualquier categoría, HAS SIDO DESTRUIDO por p53 Y DEBES VOLVER AL INICIO.	punto de control G2  Illustrations created by OpenSciEd in BioRender

punto de control M

Vuelve a revisar tu tarjeta de puntuación.

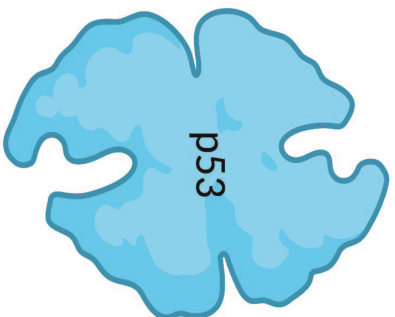
Asegúrate de tener:

G1: al menos 3 nutrientes, 3 proteínas y 3 orgánulos.

S: al menos 4 ADN.

G2: al menos 1 nutriente, 1 proteína y 1 orgánulo.

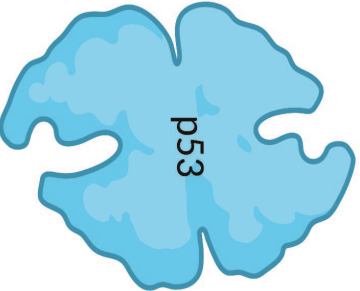
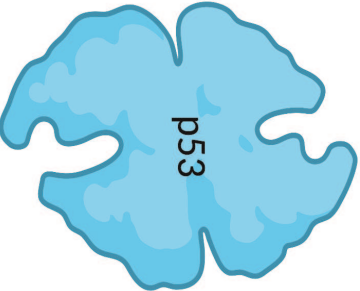
¡TE HAS DIVIDIDO CON ÉXITO! Toma una nueva ficha de célula azul!



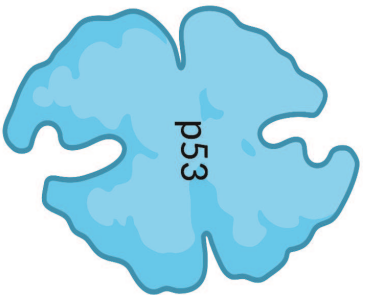
Illustrations created by OpenScied
in BioRender

Lesson 3: Teacher Reference 2

cartas juego 2

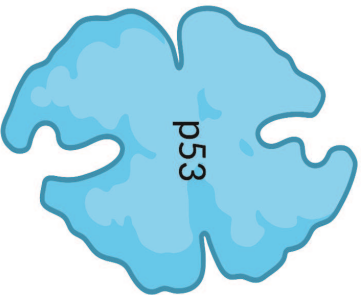
 p53 Illustrations created by OpenScied in BioRender ip53 está funcionando bien! ¡Obtienes una tirada extra!	 tarjeta de azar celular
 p53 Illustrations created by OpenScied in BioRender ip53 está funcionando bien! ¡Obtienes una tirada extra!	 tarjeta de azar celular

p53 Illustrations created by OpenSciEd in BioRender ¡p53 está funcionando bien! ¡Obtienes una tirada extra!	tarjeta de azar celular ?
p53 Illustrations created by OpenSciEd in BioRender ¡p53 está funcionando bien! p53 detecta daños en el ADN y destruye la célula. Vuelve al inicio.	tarjeta de azar celular ?



Illustrations created by
OpenScied in BioRender

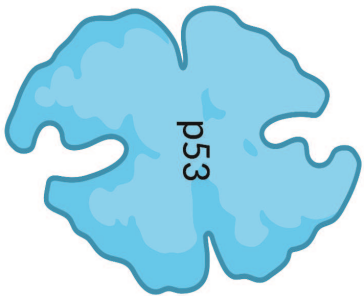
p53 está funcionando bien!
p53 detecta daños en el ADN y destruye la
célula.
Vuelve al inicio.



Illustrations created by
OpenScied in BioRender

p53 está funcionando bien!
p53 detecta daños en el ADN y destruye la
célula.
Vuelve al inicio.

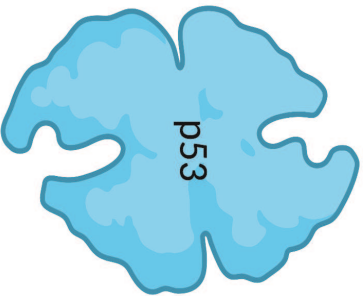




Illustrations created by
OpenScied in BioRender

**¡p53 está funcionando bien!
¡Cumple todos tus requisitos de ADN para
esta ronda!**

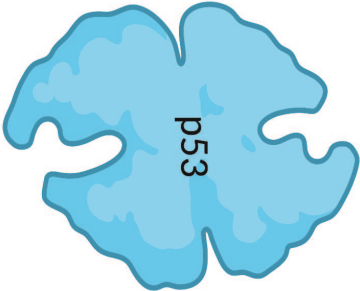
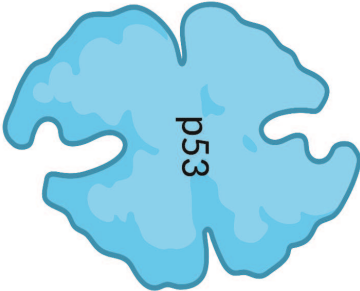
tarjeta de azar
celular
?

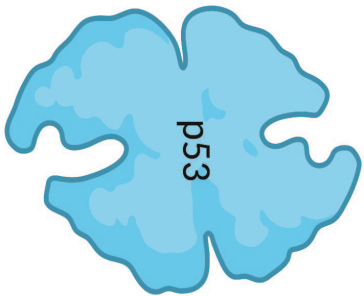


Illustrations created by
OpenScied in BioRender

**¡p53 no está funcionando!
Mueve tu ficha de juego al espacio después del
siguiente punto de control sin revisar tu tarjeta
de puntuación.**

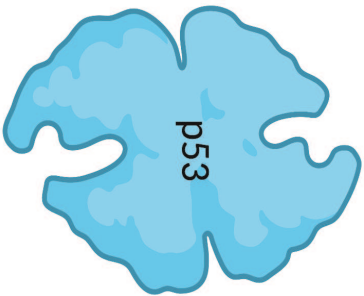
tarjeta de azar
celular
?

Illustrations created by OpenSciEd in BioRender  p53 is working well! ¡Te llevas un rollo extra!	tarjeta de azar celular 
Illustrations created by OpenSciEd in BioRender  ¡p53 no está funcionando! Muévete directamente a la Meta. Recoge una nueva ficha de célula ROJA y empieza el juego de nuevo.	tarjeta de azar celular 



Illustrations created by
OpenScied in BioRender

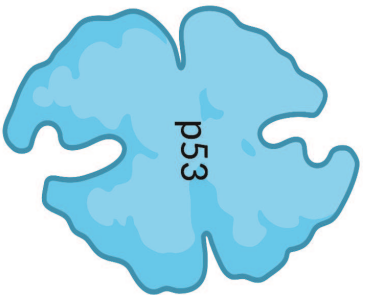
**¡p53 no está funcionando!
p53 no te dejará pasar.
¡Pierdes un turno!**



Illustrations created by
OpenScied in BioRender

**p53 is working well!
¡Te llevas un rollo extra!**

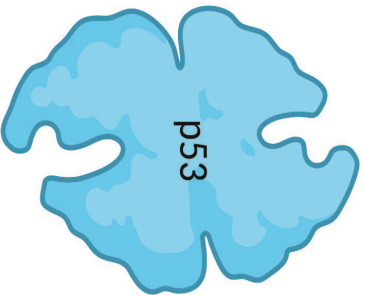




Illustrations created by
OpenScied in BioRender

**!p53 no est funcionando!
Avanza 3 espacios.**

tarjeta de azar
celular
?



Illustrations created by
OpenScied in BioRender

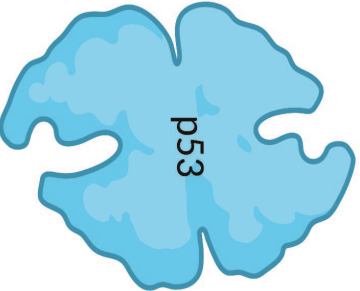
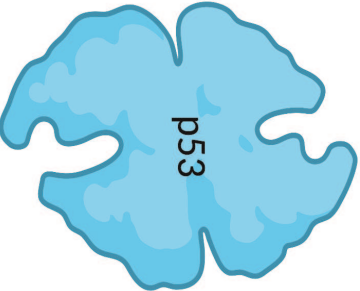
**!p53 no est funcionando!
Sltate dos puntos de control y revisa tu tarjeta
de puntuacin.**

**Si solo queda un punto de control, sltate
hasta el punto de control final y revisa tu
tarjeta de puntuacin.**

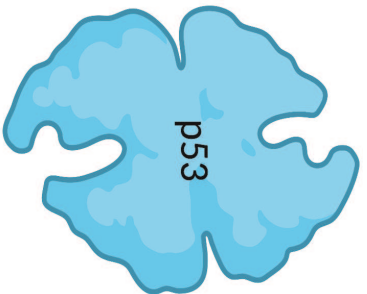
tarjeta de azar
celular
?

Lesson 3: Teacher Reference 2

Game Cards 2

 Illustrations created by OpenScied in BioRender p53 is working well! You get an extra roll!	Cellular Chance Card 
 Illustrations created by OpenScied in BioRender p53 is working well! You get an extra roll!	Cellular Chance Card 

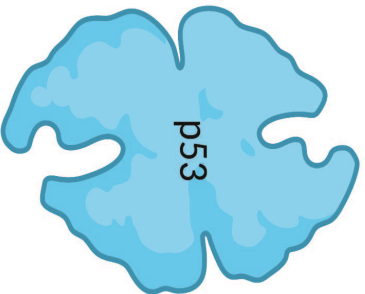
Cellular Chance Card



Illustrations created by
OpenSciEd in BioRender

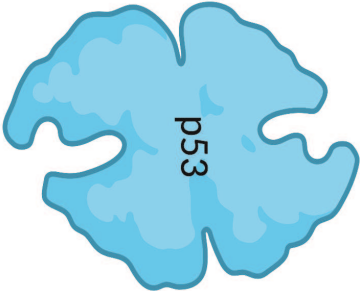
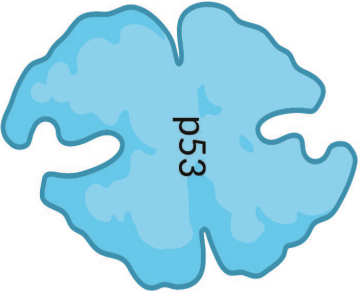
**p53 is working well!
You get an extra roll!**

Cellular Chance Card

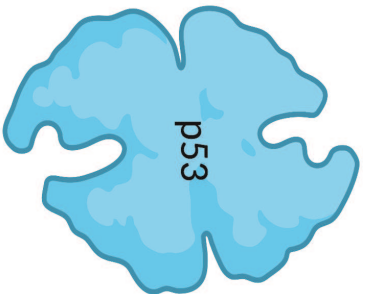


Illustrations created by
OpenSciEd in BioRender

**p53 is working well!
p53 detects damage to your DNA and destroys
your cell.
Go back to the start.**

Illustrations created by OpenSciEd in BioRender  p53 is working well! p53 detects damage to your DNA and destroys your cell. Go back to the start.	Cellular Chance Card 
Illustrations created by OpenSciEd in BioRender  p53 is working well! p53 detects damage to your DNA and destroys your cell. Go back to the start.	Cellular Chance Card 

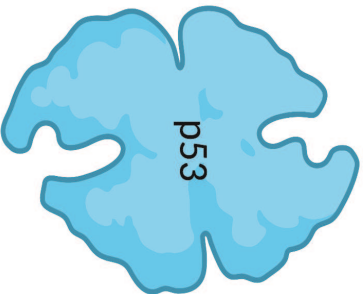
Cellular Chance Card



Illustrations created by
OpenScied in BioRender

**p53 is working well!
You fill all your DNA requirements for this
round!**

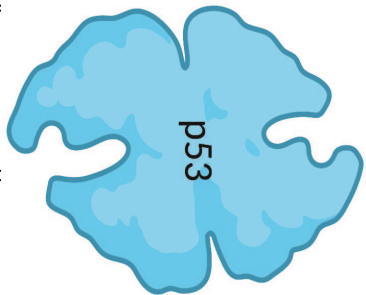
Cellular Chance Card



Illustrations created by
OpenScied in BioRender

**p53 is not working!
Move your game piece to the space after the
next checkpoint without checking your
scorecard.**

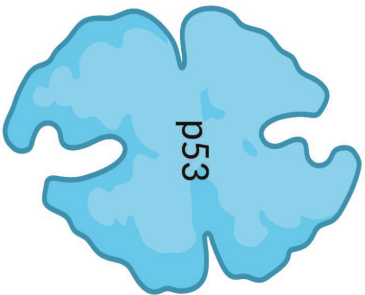
Cellular Chance Card



Illustrations created by
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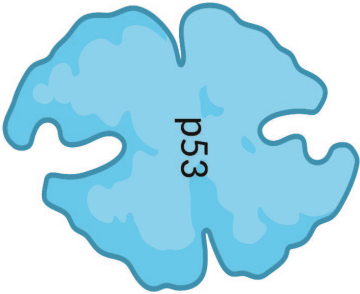
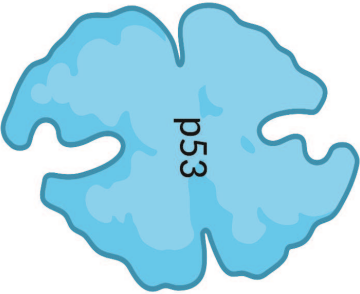
**p53 is working well!
You get an extra roll!**

Cellular Chance Card

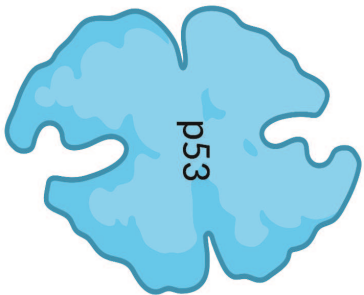


Illustrations created by
OpenScied in BioRender

**p53 is not working!
Move directly to Finish.
Collect a new RED cell chip and start the game
again.**

Illustrations created by OpenSciEd in BioRender  p53 is not working! p53 will not let you pass. You lose a turn!	Cellular Chance Card 
Illustrations created by OpenSciEd in BioRender  p53 is working well! You get an extra roll!	Cellular Chance Card 

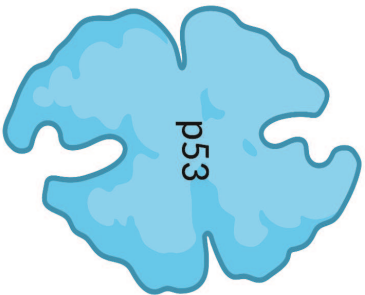
Cellular Chance Card



Illustrations created by
OpenSciEd in BioRender

p53 is not working!
Move ahead 3 spaces.

Cellular Chance Card



Illustrations created by
OpenSciEd in BioRender

p53 is not working!
**Skip ahead two checkpoints and check your
scorecard.**

**If there's only one checkpoint left, skip to the
final checkpoint and check your scorecard.**

Making Sense Key

Round 1: Making Sense

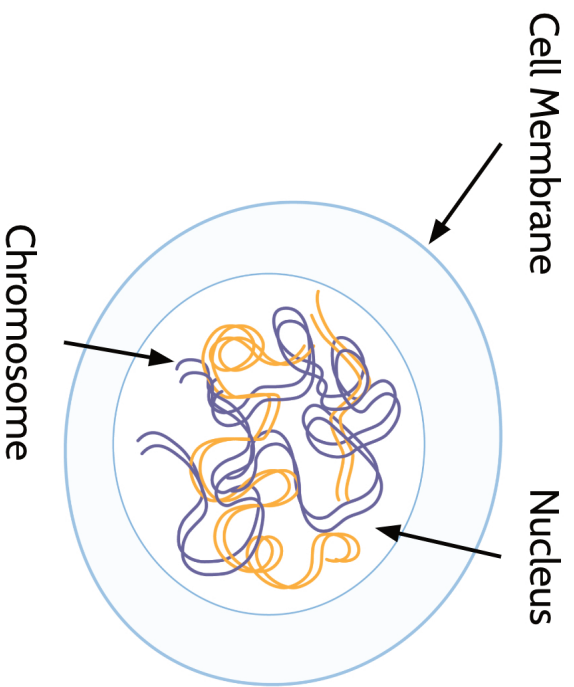
1. Fill in the table below.

	What happened in the game during this phase/checkpoint?	What do you think it could represent in a cell?	Feedback Guidance
Phase: G1	When we roll one, two, or three, we check off nutrients, proteins, and organelles.	The cell is growing by getting what it needs from its environment and/or making what it needs from resources it gets in its environment.	If students do not recognize that the cell is growing, ask them: <i>What happens when the cell adds new resources? What happens to you when you add new resources to your body?</i>
Checkpoint #1	We draw a card to see that we need at least three of everything to keep going. If we have less, we go back (fewer resources = more spaces). If we have zero, we have to start over.	p53 checks to see if the cell has enough of the resources it needs to move onto the next phase. If it does not have them, it has to go back and get them. If it has nothing in one of the categories, it gets destroyed.	If students do not distinguish between being sent back and being destroyed, ask: <i>Why is the cell sometimes sent back and sometimes destroyed?</i>
Phase: S	If we roll a four, we check off DNA.	The cell is getting more or making more DNA.	To prompt students to build toward future learning, ask: <i>Where do you think DNA comes from? Is the cell getting it from the environment or making it?</i>
Phase: G2	When we roll one, two, or three, we check off nutrients, proteins, and organelles.	The cell is growing by getting what it needs from its environment and/or making what it needs from resources it gets in its environment.	If students do not mention growth, ask: <i>It looks like similar things happen in phases A and C. What is happening to the cell here that happened in phase A?</i>
Checkpoint #2	We draw a card to see that we need at least four DNA and one of everything else to keep going. If we have less, we go back. If we have zero, we have to start over.	p53 checks to see if the cell has enough of the resources and DNA it needs to move onto the next phase. If it does not have them, it has to go back and get them. If it has nothing in one of the categories, it gets destroyed.	If students do not distinguish between being sent back and being destroyed, ask: <i>Why is the cell sometimes sent back and sometimes destroyed?</i>

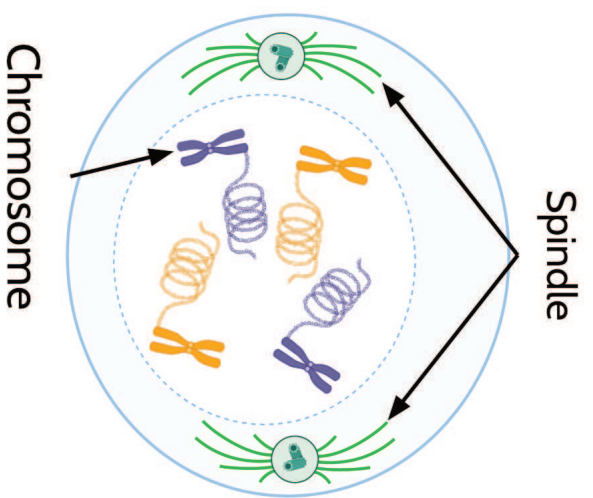
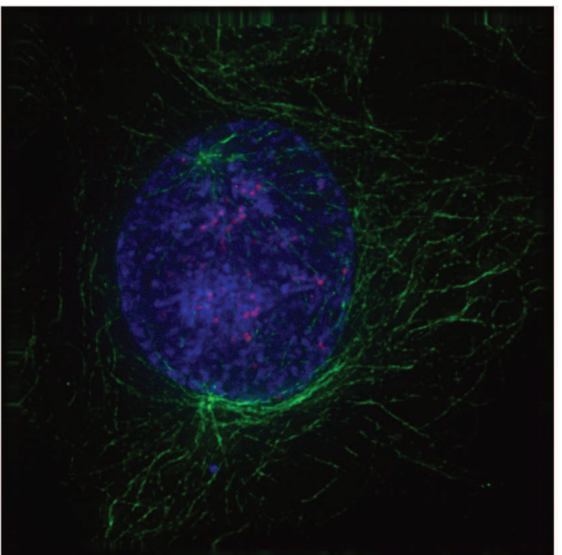
Phase: M	We have to roll one, two, three, four, five (in that order) to move through this phase.	The cell is moving in a set of ordered steps. We are not really sure exactly what is happening, just that it has to happen in this order.	To prompt students to build toward future learning, ask: <i>What could be happening in those ordered steps inside the cell?</i>
Checkpoint #3	We draw a card to see that we need three nutrients, protein, and organelle. We need at least four DNA. If we have everything, we get a blue cell chip.	If the cell makes it through all of these stops and has enough resources, it divides.	If students do not recognize that a new blue chip means the cell divided, ask: <i>What does it mean to get an additional blue chip?</i>

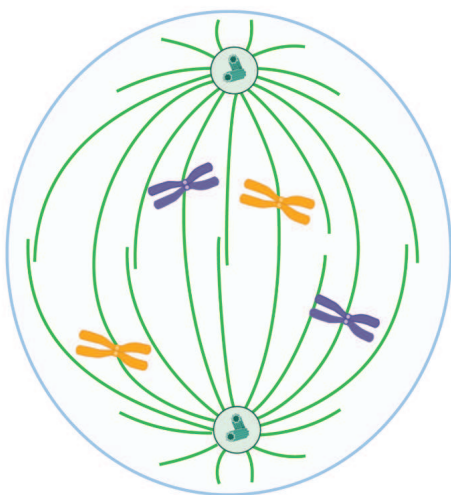
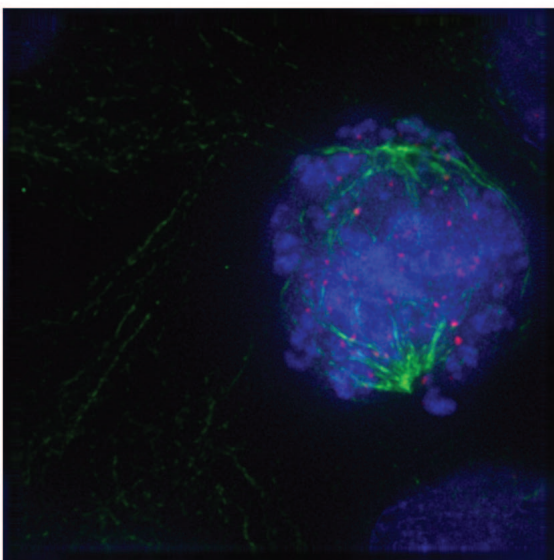
Mitosis Card Sort Key

START

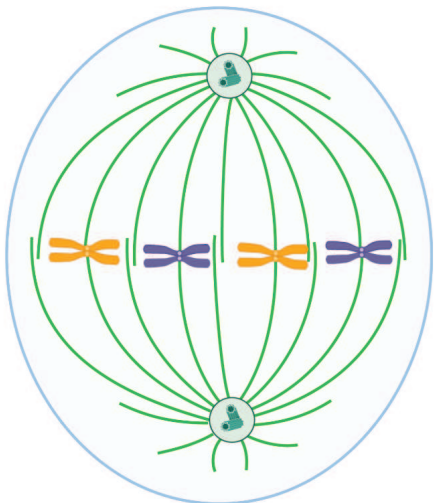
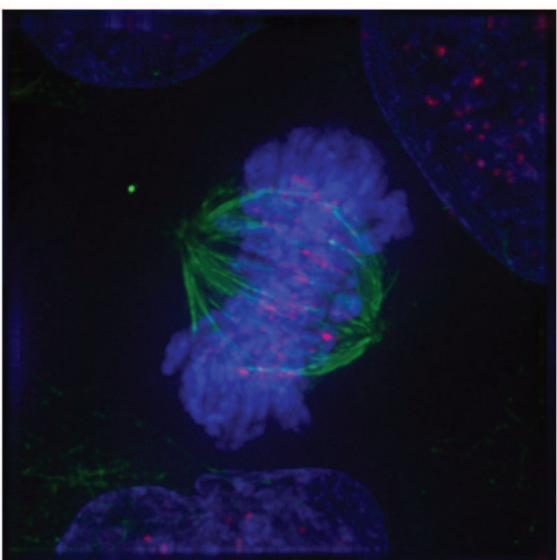


Start

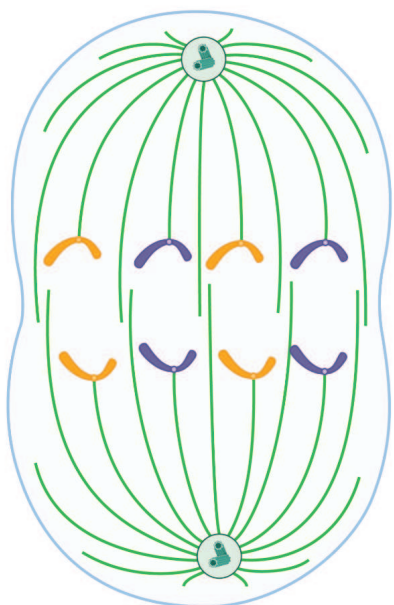
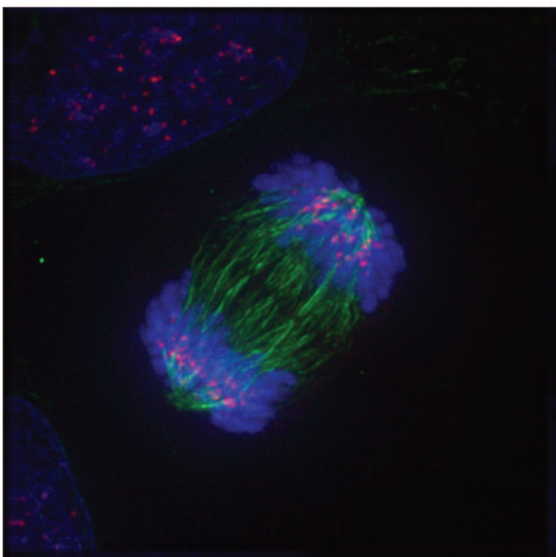




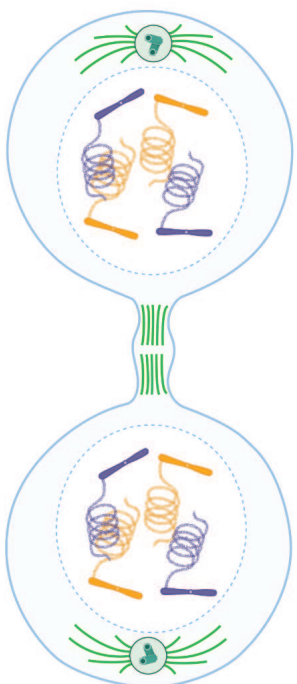
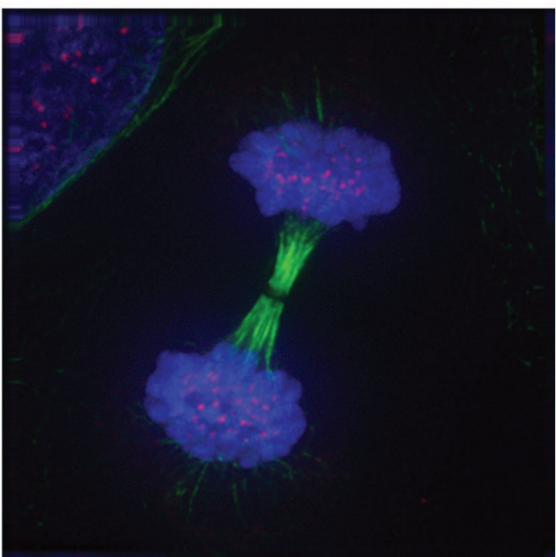
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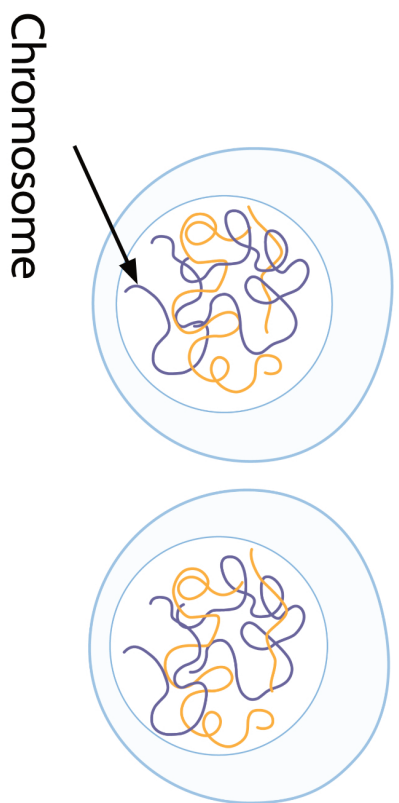


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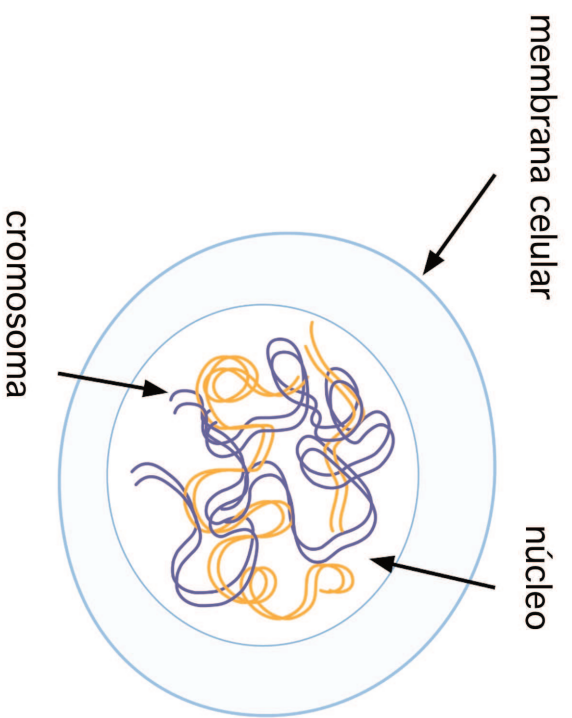
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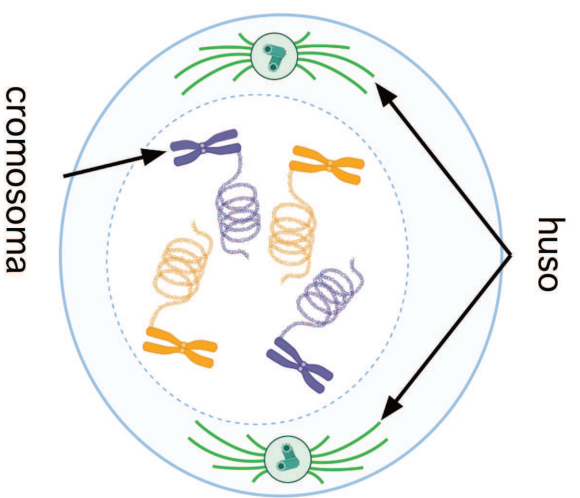
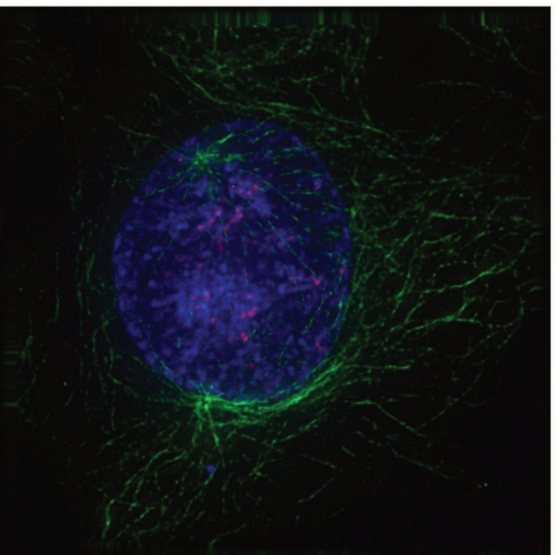
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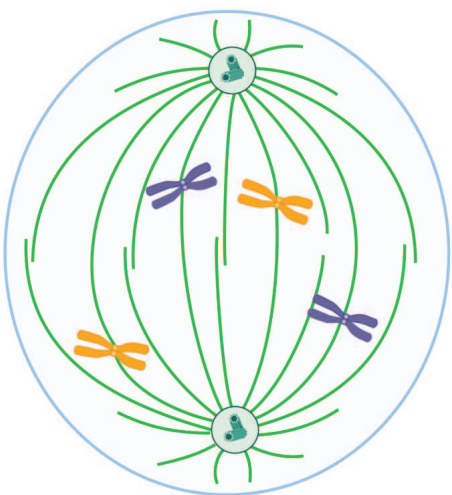
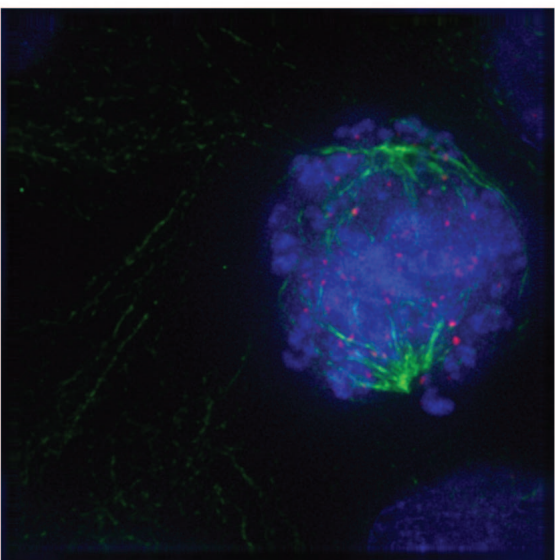
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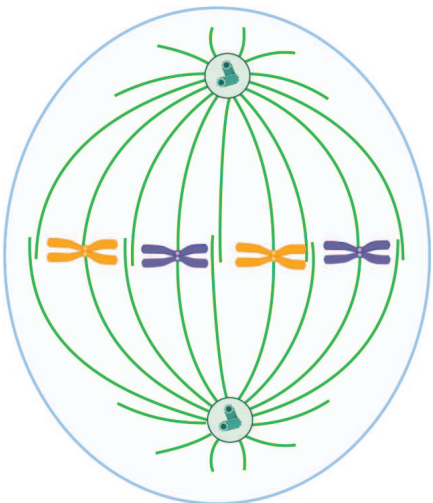
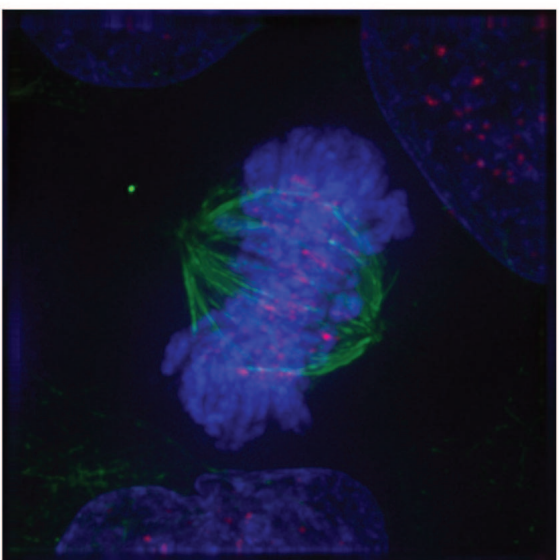
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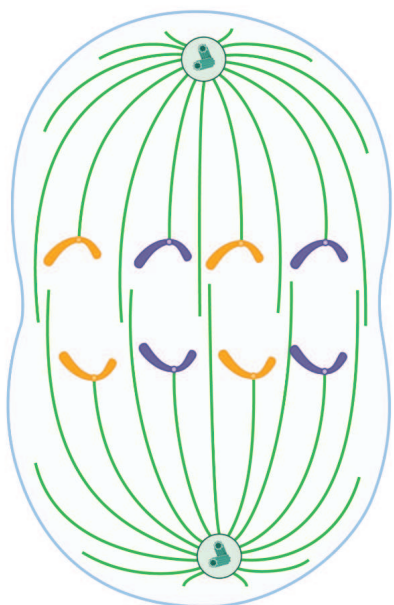
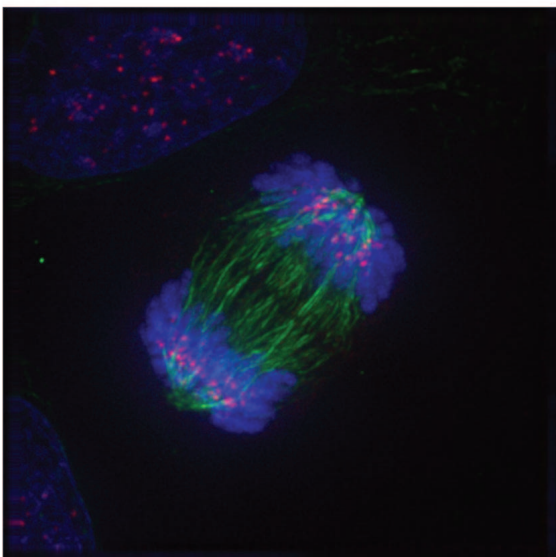
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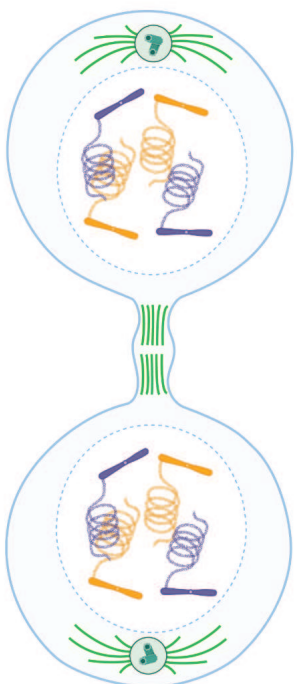
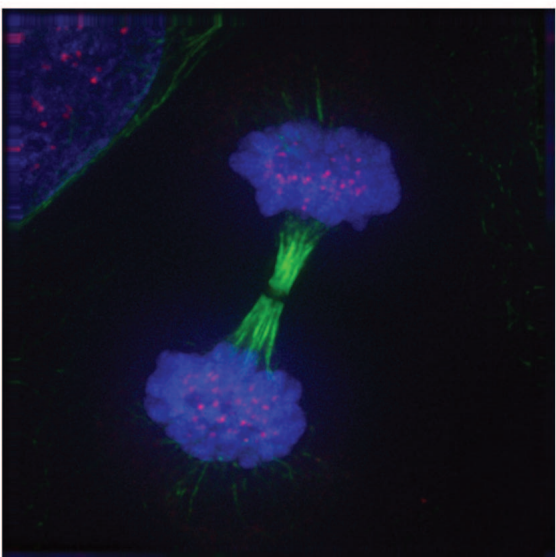
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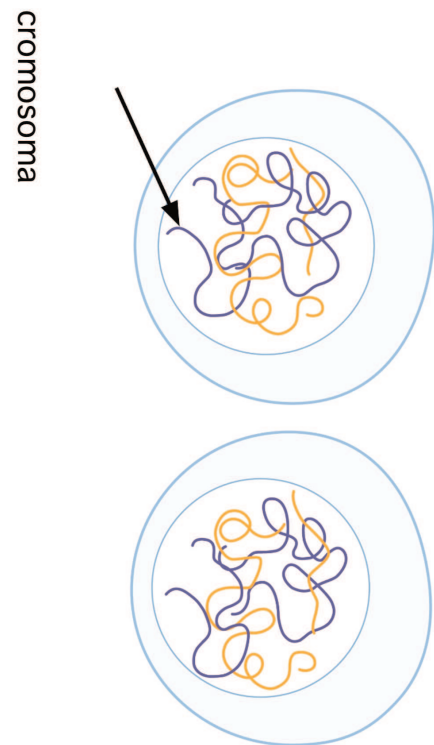


Anaphase Illustrations created by OpenSciEd in BioRender. Image Source: Roy van Heesbeen - Delta Vision Roy van Heesbeen



Telophase Illustrations created by OpenSciEd in BioRender. Image Source: Roy van Heesbeen - Roy

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Lesson 5: Answer Key 1

Checklist and Explanation Key

What evidence do you have and need to answer the lesson question:

How do cancer cells end up with differences in their chromosomes and what is the role of p53 in preventing the differences?

Ideas	Evidence I have	Source	Evidence I need
The relationship between DNA and chromosomes	Chromosomes are made of DNA.	Reading	Need to see exactly how DNA makes chromosomes.
Why/how/when is the DNA replicating	DNA replicates during the S phase of mitosis. DNA replicates by unwinding, unzipping, and matching up letter pairs.	Cell Game/L3 Simulation	Not sure. Need to know more about where this is happening in the cells.
Where/how/why errors occur during replication	Errors occur when the letters get mismatched during replication.	Simulation	
Where/how/why errors are corrected	p53 corrects the errors after replication.	Simulation	
What happens to the DNA after replication	It goes into a new cell.	Cell Game/L3	Not sure. Need to know where the DNA goes after it makes a copy.
How does the DNA with mutations relate to cancer cells with differences in their chromosomes	DNA makes up the chromosome and if they have mutations that do not get fixed, they become a part of cells that can be cancer cells.	Cell Game/L3, Simulation	Not sure. Need to know what happens to the DNA and how it gets to be in a cancer cell with different chromosomes.

Lesson 5: Answer Key 1

Student Explanation Key

4.A Construct an explanation based on evidence about how mutations can occur during DNA replication, resulting in differences in chromosomes, and the role of p53 in their repair. (SEP 6.2; DCI LS3.B.1; CCC 2.2)

3D Elements Addressed in this Assessment

SEP	Construct and revise an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future.
DCI	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.
CCC	Cause-and-effect relationships can be suggested and predicted for complex natural and human-designed systems by examining what is known about smaller-scale mechanisms within the system.

	Foundational Pieces	Linked Understanding	Organized Understanding
3D Elements	In this explanation, look for: Students' explanation includes elements of DNA replication, mutation and the role of p53 without linking these ideas. Students reference evidence from the computer simulation, the reading, and/or additional activities (i.e., Cell Game) to explain their ideas.	In this explanation, look for: Students' explanation includes elements of DNA replication, mutation and the role of p53 and begins to link the idea of mutations in DNA to differences in chromosomes and/or cancer cells. Students reference evidence from the computer simulation, the reading, and/or additional activities (i.e., Cell Game) to explain their ideas.	In this explanation, look for: Students' explanation includes the process of DNA replication, how mutations occur and how those mutations lead to differences in chromosomes in cancer cells. They also explain how p53 can help correct mutations by removing the mismatched base. When the mutations are fixed, the chromosomes are identical Although there are multiple versions of p53, only one of them plays this role. Students reference evidence from the computer simulation, the reading, and additional activities (i.e., Cell Game) to explain their ideas.

Example	DNA makes a copy of itself/replicates by matching up the bases. Mutations happen in this process when the bases are mismatched. p53 can fix mutations, but only one type does this. We saw evidence of this happening in the computer simulation.	DNA makes a copy of itself/replicates by matching up the bases. Mutations happen in this process when the bases are mismatched. p53 can fix mutations, but only one type does this. We saw this in the computer simulation. The DNA that has mutations causes the chromosomes in the cells to be different. We saw this in the cell game and in the data after the cell game. Those can be cancer cells.	During the cell cycle (S phase) the chromosomes duplicate. We saw this in the cell game. This happens by DNA replication/the DNA making a copy of itself. To do this, the DNA uncoils and unzips so that the bases that are part of the molecule are exposed. Then molecules with complementary bases match up (A-T, G-C) until the strand is complete. We saw this in the computer simulation. Sometimes an incorrect base is matched up. This is called a substitution or mutation. p53 molecules can then attach to the strand and take out any mismatches so the correct ones can be put in. There were multiple (3) kinds of p53 but only one of them was able to fix the mutations. We saw this in the computer simulation. If all the mutations are fixed, the DNA and chromosomes in new cells will be identical (non-cancer) if they are not fixed, they will be different (cancer).
Feedback/ What to Do	<i>Linking:</i> Ask students to consider how the DNA replication/mutations are related to the stages of the Cell Game and the chromosomes that doubled in the S phase.	<i>Organizing:</i> Ask students to think about cell division and what the chromosomes in the resulting cells look like when they have mutations/do not have mutations.	<i>Extending:</i> Ask students to consider how the cell got those different versions of p53 and why some of them function to correct mutations while others do not.

	Foundational Understanding	Linked Understanding	Organized Understanding
Ideas for Instruction	Return to the Cell Game from Lesson 3. Ask students to revisit each phase of the game (G1, S, G2, and M) and use sticky notes to add short explanations to serve as evidence about what is happening in the cells (including chromosomes) during each phase.	Ask students to develop a model to accompany their explanations. Their models should include the parent cell and explain how DNA replication can result in differences in the chromosomes between a parent cell and its resulting daughter cells. They should identify in the model places where they have evidence for their ideas.	Ask students to use the evidence they used in their explanation to predict what would happen to future daughter cells in cases where their cells only had one type of p53: a, b, or c.

Lesson 6: Teacher Reference 1

Exit Ticket Guidance

What are Electronic Exit Tickets?

These are short **formative** assessments that occur 2-3 times per unit in between other assessments. They include items to check for understanding of lesson-level PEs, to make connections between content and students' lives, and to elicit information about their experiences and to help students reflect on their own progress in focal SEPs and CCCs. **They are built in Google Forms, but can be ported to any survey software.**

How to create Electronic Exit Tickets

In *OpenSciEd Unit B.3: Who gets cancer and why? What can we do about it?* (Cancer Unit), the two Electronic Exit Tickets in this unit are found:

- at the end of Lesson 6 (slide P);
- and at the end of Lesson 8 (slide X).

Select the link for the Electronic Exit Ticket that corresponds with the lesson you are teaching.

Lesson 6: <https://docs.google.com/forms/d/1WgO8ZwtIMP-sIPVRp99vhwD1vXaS5rSAHHpcQhKAXQ/copy>.

Lesson 8: https://docs.google.com/forms/d/1MKGi-g_VgItXZslyEqUoKgjSxSakKX_RFqGSILQ_QE/copy.

Spanish versions are available here:

Lesson 6: <https://docs.google.com/forms/d/1k-HBPHTYpzpfetAdsgtRlGrOlGpTBsYvDo4314uMc/copy>.

Lesson 8: <https://docs.google.com/forms/d/1tE4p8kjbIKWXAIIeiG9IOQmRM1sZOHDoRDSjZpY5-Sg/copy>.

Attending to Equity

Some students may benefit from completing the Electronic Exit Tickets on a printed version. Complete the steps below to create a copy of the Electronic Exit Ticket. Once you have created a copy in your own Google Drive, click on the 3 dots in the upper right side of the form next to the SEND button. This should give you an option to print a paper copy of the Electronic Exit Ticket.

When you select the link, it will ask you to make a copy in your own Google Drive.

Copy document

Would you like to make a copy of **Family and Friends MRE Survey**?

Make a copy



The student survey will open in your own Google Drive.

Family and Friends MRE Survey ☆

Questions Responses

Family and Friends MRE Survey

⊕

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Send

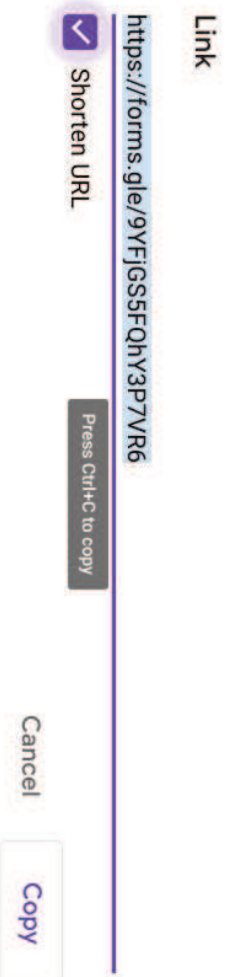
Select the "Send" button in the upper right corner to get a link to give to students.



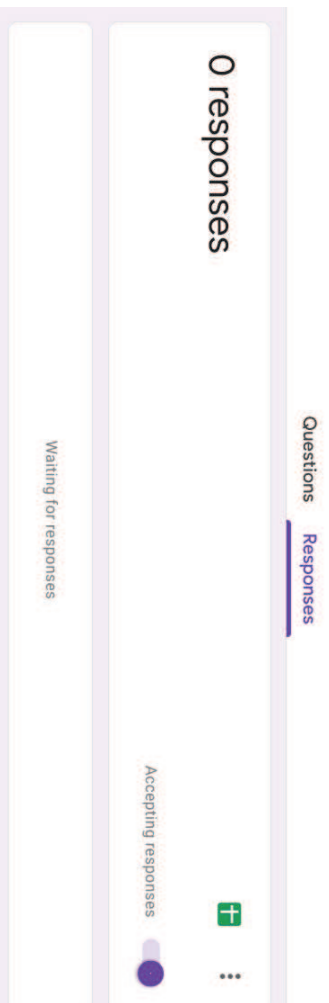
In the "Send via" panel, select the middle icon in order to choose to send the survey via a link.



Copy the link it provides you or select the "Shorten URL" box, then copy the link. This second option creates a link that will be easier for students to type.



Once people submit responses, they will show up in your Google Form under "Responses." Google will automatically provide you with some visualizations of these responses.



If you want to see the data in a spreadsheet format, click the sheet icon to create a Google Sheet of your data. It will automatically populate when people respond to the survey.

For each survey, you will need to repeat the process above. You can choose to make a copy of the survey for each of your classes or choose to have one survey for all your classes.

Lesson 6: Teacher Reference 2

Secuencias de ADN

Cut the strands into strips and put in an envelope.

To prepare your classroom for the simulation, you will need to determine where you will designate the Location 1 (nucleus) and the Location 2 (ribosome) in the classroom. You may need to move furniture so that students can get to the nucleus or ribosome and back at their tables safely.

HEBRA A: AAGCCAAGATCACGCCACTCCCCATAATGGTCCCTTCTG

HEBRA B: AAGCCAAGATCACGCCACTCCCCATAAGAATCCCGA

HEBRA C: AAGCCAAGATCACGCCACTCCCCATAATGGTCCTTTCTG

HEBRA A: AAGCCAAGATCACGCCACTCCCCATAATGGTCCCTTCTG

HEBRA B: AAGCCAAGATCACGCCACTCCCCATAAGAATCCCGA

HEBRA C: AAGCCAAGATCACGCCACTCCCCATAATGGTCCTTTCTG

HEBRA A: AAGCCAAGATCACGCCACTCCCCATAATGGTCCCTTCTG

HEBRA B: AAGCCAAGATCACGCCACTCCCCATAAGAATCCCGA

HEBRA C: AAGCCAAGATCACGCCACTCCCCATAATGGTCCTTTCTG

Lesson 6: Teacher Reference 2

DNA Sequences

Cut the strands into strips and put in an envelope.

To prepare your classroom for the simulation, you will need to determine where you will designate the Location 1 (nucleus) and the Location 2 (ribosome) in the classroom. You may need to move furniture so that students can get to the nucleus or ribosome and back at their tables safely.

STRAND A: AAGCCAAGATCACGCCACTCCCCATAATGGTCCCTTCTG

STRAND B: AAGCCAAGATCACGCCACTCCCCATAAGAATCCCGA

STRAND C: AAGCCAAGATCACGCCACTCCCCATAATGGTCCTTTTCTG

STRAND A: AAGCCAAGATCACGCCACTCCCCATAATGGTCCCTTCTG

STRAND B: AAGCCAAGATCACGCCACTCCCCATAAGAATCCCGA

STRAND C: AAGCCAAGATCACGCCACTCCCCATAATGGTCCTTTTCTG

STRAND A: AAGCCAAGATCACGCCACTCCCCATAATGGTCCCTTCTG

STRAND B: AAGCCAAGATCACGCCACTCCCCATAAGAATCCCGA

STRAND C: AAGCCAAGATCACGCCACTCCCCATAATGGTCCTTTTCTG

Amino Acid Cards

Phe I AAG	Ser am UCA	Arg a UCC	Gly p53 CCA	Ile protein UAA	Lys different UUU
Thr with UGG	Glu butterfly CUU	Asp shape CUG	Pro missing GAA	Ala piece CGA	Arg a UCC

Lesson 6: Answer Key 1

Gene Expression Simulation

Part 1: Kinesthetic Model Procedure

Step 1:

A. Go to Location 1 and pick up a segment of DNA.

B. Circle the DNA strand you chose. Strand A Strand B Strand C

C. Copy down the complement to the DNA strand.

Remember to use complementary bases, and instead of T, there is U. If there is a T in the DNA, it will pair with A in the copy, but if there is an A in the DNA, it will pair with a U in the copy.

UUC-GGU-UCU-AGU-GCG-GUG-AGG-GGU-AUU-ACC-AGG-GAA-GAC

Strand A mRNA (COPY)

UUC-GGU-UCU-AGU-GCG-GUG-AGG-GGU-AUU-CUU-AGG-GCU

Strand B mRNA (COPY)

UUC-GGU-UCU-AGU-GCG-GUG-AGG-GGU-AUU-ACC-AGG-AAA-GAC

Strand C mRNA (COPY)

Step 2:

A. Edit your copy. Your copied strand is organized into groups of three. Edit your copy by crossing out the following groups in the strand above: 2, 3, 5, and 6.

B. Rewrite the code for your strand on the lines below, leaving out the letters you crossed out in Step2.A.

UUC-AGU-AGG-GGU-AUU-ACC-AGG-GAA-GAC

Strand A mRNA (version 2)

UUC-AGU-AGG-GGU-AUU-CUU-AGG-GCU

Strand B mRNA (version 2)

UUC-AGU-AGG-GGU-AUU-ACC-AGG-AAA-GAC

Strand C mRNA (version 2)

Step 3:

- A. Go to location 2. Find the card that is the complement to each three-letter combination in your copy. For example, if your copy is UGC, you should look for ACG.

It may help to write the complement below so you know what you are looking for. Make sure you go in order.

- B. When you find your complement, write down code from your card. For example: Gly-Arg-Ile.

AAG-UCA-UCC-CCA-UAA-UGG-UCC-CUU-CUG

Strand A Phe-Ser-Arg-Gly-Ile-Thr-Arg-Glu-Asp

Strand B AAG-UCA-UCC-CCA-UAA-GAA-UCC-CGA

Phe-Ser-Arg-Gly-Ile-Pro-Arg-Ala

Strand C AAG-UCA-UCC-CCA-UAA-UGG-UCC-UUU-CUG

Phe-Ser-Arg-Gly-Ile-Thr-Arg-Lys-Asp

- C. Next, write down the words you find under the code.

Strand A I am a p53 protein with a butterfly shape.

Strand B I am a p53 protein missing a piece.

Strand C I am a p53 protein with a different shape.

Part 2: Making Sense

1. Complete the column titled *What it represents* in the table below.

Components of the model	What it represents	Additional information from the reading	Ways the model differs from the real world
Location 1	Where the DNA is in the cell.	Nucleus	
Paper DNA strand at location 1	DNA that has the code for p53.	p53 gene	There are 18,000 base pairs in the p53 gene. The model had 36-39.
Copy and edited copy in your handout	The message from the DNA that travels around the cell.	RNA	

Location 2	Where the protein gets made in the cell.	Ribosome	
Cards with codes and words	How the DNA gets turned into proteins.	amino acids	There are 375 amino acids in the p53 protein. The model had 8 or 9.
Sentence you wrote down in your handout	p53 protein.		

2. How does the model help you answer the question: *How do we make p53, and why is it different sometimes?*

We started with DNA and we made a protein. Different groups made different sentences because their DNA was different to start with.

3. Find a classmate that worked with the same DNA strand as you. Compare your sequence of amino acids and your sequence of words. How did they compare? If they are different, why do you think they are different?

Answers may vary. Mine was correct, but there were errors in their version. Both were correct.

If there were differences, errors could have been made in any of the places where code needed to be copied.

4. Find classmates that had different strands of DNA than you. How did they compare? If they are different, why do you think they are different?

The strands were very similar. The small changes there changed the words, which changed the sentence. This means that those changes changed the amino acid, which changed the protein. The changes were enough to stop the other versions of p53 from working.

Lesson 6: Answer Key 2

Electronic Exit Ticket Key

6.B Integrate information from multiple sources to answer questions about how changes to the structure of DNA in the p53 gene relates to protein function. (SEP 8.2 ; DCI LS1.A.2, DCI LS3.A.1; CCC 6.2)

Where these elements are addressed in this assessment.	8.2 Obtaining, Evaluating, and Communicating Information Compare, integrate, and evaluate sources of information presented in different media or formats (e.g., visually, quantitatively) as well as in words in order to address a scientific question or solve a problem.	LS1.A.2 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, which carry out most of the work of cells. (HS-LS1-1)	LS3.A.1 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.	6.2 Structure and Function The functions and properties of natural and designed objects and systems can be inferred from their overall structure, the way their components are shaped and used, and the molecular substructures of its various materials.
Q1	X	X		
Q2			X	X
Q3				
Q4	X			X
Q5	X			
Q6				X

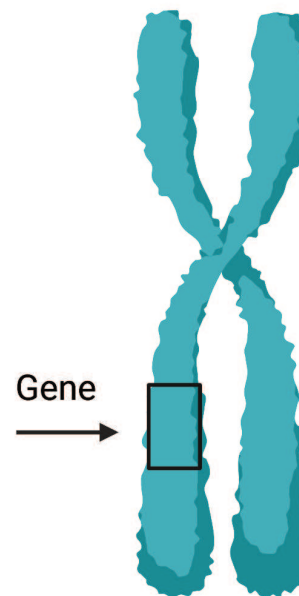
Question 1

Which of the following responses best answers the question *How is genetic information organized in cells?* by integrating information from both the text and the image?

All cells have DNA that contains genetic information. Long molecules of DNA are organized into chromosomes. Genes code for proteins that have many functions in cells.

Which of the following statements answers the question by summarizing **both** the information in the text AND the image?

- DNA makes up chromosomes, which are organized into genes and code for proteins.
- Chromosomes are made of DNA. Genes code for proteins.
- Genes are located on chromosomes.



Illustrations created by OpenSciEd in BioRender

Correct response:

- DNA makes up chromosomes, which are organized into genes and code for proteins..

Rationale for correct response: The text contains information about the DNA and genes code for proteins. The text does not contain any information about the location of genes on chromosomes. This information is included in the image.

What to do: Ask students to summarize the information in the image using words.

Question 2

Which of the following help explain why there are different versions of p53 that work differently.

- **All of the above.**
- Some p53 genes have mutations in the code.
- Different codes in DNA lead to proteins with different shapes.
- Different shapes fit better and worse with DNA.
- The better the fit, the better it can correct mutations.

Correct response:

All of the above.

Rationale: All of the responses help explain why there are different versions of p53 that work differently.

What to do: Ask students to return to *Unknown material with identifier: bi.l5.ho1* to review the different structures of DNA and the resulting proteins.

Question 3

How can you use structure and function to explain or ask questions about something you have seen or experienced in your everyday life?

What to look for in response:

Accept all responses. Validating these responses engages students in activating the **relevance** and **interest** in these issues, which can motivate future questions.

What to do:

Encourage students to use the structure and function of DNA and proteins to help them think about everyday examples. Partner or small-group discussion can help students generate ideas to draw on.

Question 4

In the simulation in Lesson 5, we saw that only one version of p53 protein (p53 a) fit with the DNA molecule and corrected mutations. Review the information below and select the response that best answers the question *How does the structure of the p53 protein differ in versions that correct mutations and versions that do not?*



p53 A amino acid sequence
Phe-Ser-Arg-Gly-Ile-Thr-Arg-Glu-Asp

p53 B amino acid sequence
Phe-Ser-Arg-Gly-Ile-Pro-Arg-Ala

Correct response:

All of the above.

The structure of p53a has 9 amino acids.

The structure of p53b has 8 amino acids and one is different.

The difference in the amino acids results in a different shape in the protein.

Rationale: All of the responses help explain the structure of the p53 protein and why it is different.

What to do: Ask students to return to the shapes of the p53 protein and the associated amino acid sequences. They can identify and explain the differences.

Question 5

How did [obtaining and communicating information from multiple sources](#) such as a kinesthetic simulation, reading, and images help you make sense of how we make p53 and why it is different sometimes?

What to look for in response: *Note: These could be different for each student.*

- Students may [identify which source was most useful to them](#).
- Students may mention how one [source helped them understand another or how they used them together](#).

What to do:

Encourage students to think about how [obtaining and communicating information from multiple sources](#) can help them answer questions and solve problems in many contexts in and outside of school.

Question 6

How did the crosscutting concept **structure and function** help you explain the lesson question: *How do we make p53, and why is it different sometimes?*

What to look for in response:

- Using **structure and function** helped them understand why p53 can have different shapes.
- Those different **shapes have various functions** in terms of correcting mutations.

What to do:

If students have difficulty answering, prompt them to review



and consider how each might fit differently on the DNA molecule.

Question 7

How did the revision process help make your responses answer the lesson question in a more clear/scientific way?

What to look for in response:

- Students articulate that each time they got more evidence, it helped them fill in more gaps in their understanding.
- The more chances that students got to share their ideas, the better they were able to articulate their thoughts.

What to do: Depending on student responses, it may be beneficial to revisit the Community Agreements.

- If many students do not name another student, spend time revisiting the Community Agreements to ensure that students are using the agreements as they work together to make progress on figuring out science and engineering ideas.
- If many students do not explain what the other student did to help them, revisiting the Community Agreements may encourage students to think about what specific agreement the classmate was adhering to that caused them to be helpful.

Lesson 8: Answer Key

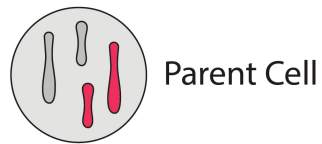
Electronic Exit Ticket Key

8.A Develop and use multiple models to explain how the **inheritance of p53 alleles** and other gene alleles can **cause cancer in multiple generations** of a family through **new combinations of alleles**. (SEP: 2.4; DCI: LS3.B.1; CCC: 2.2)

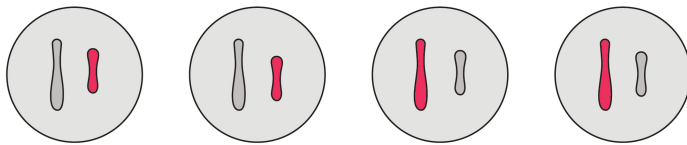
Where these elements are addressed in this assessment.	2.4 Developing and Using Models Develop and/or use multiple types of models to provide mechanistic accounts and/or predict phenomena and move flexibly between model types based on merits and limitations.	LS3.B.1 In sexual reproduction, chromosomes 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)	2.2 Cause and Effect Cause and effect relationships can be suggested and predicted for complex natural and human-designed systems by examining what is known about smaller-scale mechanisms within the system.
Q1	X	X	
Q2		X	X
Q3			
Q4	X		X
Q5	X		
Q6			X

Question 1

Population A

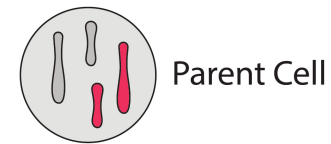


Meiosis WITHOUT crossing over

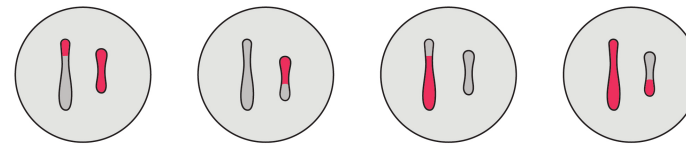


Gametes

Population B



Meiosis WITH crossing over



Gametes

Both populations A and B reproduce sexually. In population A, meiosis WITHOUT crossing over produces gametes (sperm or eggs). In population B, meiosis WITH crossing over produces gametes. Which population do you think will have more variation?

- Population A
- **Population B**
- Neither population will have variation.

Correct response:

- **Population B**

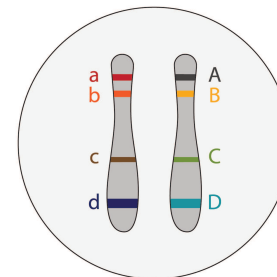
Rationale for correct response: The model shows the potential of gametes to have different combinations of alleles with crossing over. Population B has four different gametes, while A has two different gametes.

What to do: Ask students to compare the number of different gametes for the two populations in the model.

Question 2

Crossing over is least likely to happen between genes that are closer together on a chromosome. If crossing over occurs, which pair of alleles do you think are most likely to be inherited together?

- **ab**
- ac
- ad



Correct response: ab

Rationale: Crossing over is least likely to occur between a and b, so there will not be a new combination of alleles that gets passed on.

What to do: Ask students to consider the result of crossing over at different locations along the chromosome, then ask which location is least likely to have crossing over.

Question 3

How has the day's lesson helped you make progress toward a question that you contributed to the Driving Question Board (or to a related phenomenon on the DQB)?

What to look for in response:

Accept all responses. Validating these responses engages students in activating the **relevance** and **interest** in these issues, which can motivate future questions.

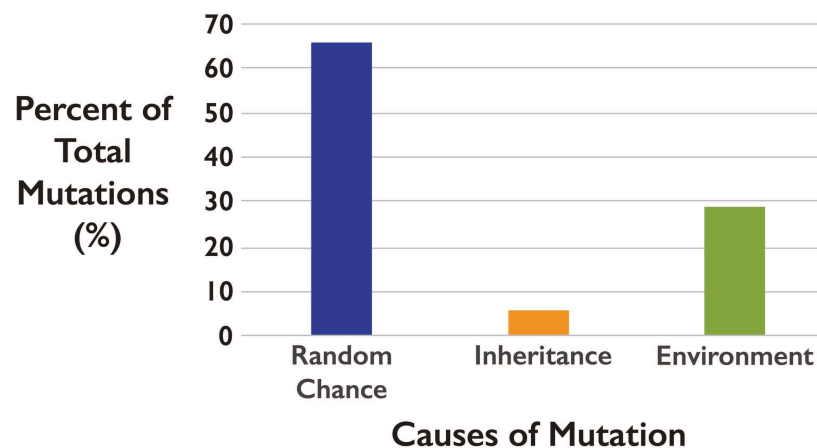
What to do:

Encourage students to use the structure and function of DNA and proteins to help them think about everyday examples. Partner or small-group discussion can help students generate ideas to draw on.

Question 4

Which of the following ideas about mutations have we not examined in our lessons?

- Random chance
- Inheritance
- Environment



Correct response: Environment

Rationale: In Lesson 7, we looked at random mutations that occur when somatic cells divide. In Lesson 8, we looked at how a mutation can be passed from parent to offspring during sexual reproduction.

What to do: Ask students to review their science notebook for clues about what we discussed in Lessons 7 and 8.

Question 5

How did [using pedigrees](#) and [creating models with the pipe cleaners and beads](#) help you make sense of why some cancers appear to run in families?

What to look for in response: *Note: These could be different for each student.*

- Students may mention how pedigrees showed patterns of inheritance of Li-Fraumeni in a family.
- Students may mention that by using the pipe cleaners as chromosomes and beads as alleles they could identify which chromosomes and alleles came from which parent and which grandparent.
- Students may mention that by using the pipe cleaners as chromosomes and beads as alleles they could illustrate meiosis and understand how crossing over can change combinations of alleles on a chromosome.

What to do:

Encourage students to think about how using multiple types of models can help them provide a mechanistic account of inheritance as well as the merits and limitations of each model.

Question 6

How did examining what is happening at the scale of chromosomes and genes help you make sense of why inheritance causes some cancers to run in families over multiple generations?

What to look for in response:

- Parents pass half of their chromosomes and their genes to their offspring through the sperm or egg.
- If a chromosome has a cancer allele, a parent can give that chromosome to their offspring and their offspring could get cancer.
- Meiosis is a process that happens in parents to produce cells with half their chromosomes. These chromosomes are passed to offspring and cause cancer.
- Sometimes parents pass on mixtures of their chromosome pairs (through crossing over) to their children instead of the exact same chromosome. As a result, children might have more or fewer cancer alleles than their parents.

What to do:

If students have difficulty answering, ask them to consider how their model helped explain Lakita's family pedigree or how some of the children in the two-gene pedigree did not have the same chances as the parent for developing cancer.

Question 7

How did you help a classmate/were you helped by a classmate today?

What to look for in response:

- Students articulate a possible struggle in the lesson, like deciding on which chromosome to use or interpreting a pedigree, and discuss the benefits of:
 - working in pairs to develop and clarify ideas
 - contributing to the class discussions
 - having an encouraging community and accessible teacher
 - using physical models to communicate their thoughts to others

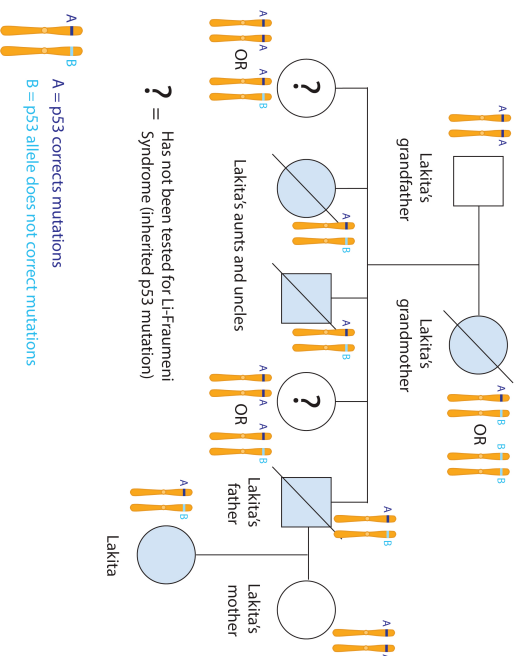
What to do: Depending on student responses, it may be beneficial to revisit the Community Agreements.

- If many students do not name another student, spend time revisiting the Community Agreements to ensure that students are using the agreements as they work together to make progress on figuring out science and engineering ideas.
- If many students do not explain what the other student did to help them, revisiting the Community Agreements may encourage students to think about what specific agreement the classmate was adhering to that caused them to be helpful.

Lakita's Pedigree Key

Making Sense

1. Use pictures and/or words to explain how you represented chromosome 17 and the p53 gene in Lakita's family in your pipe cleaner and bead model.



2. Where did the differences in the p53 alleles (versions of the p53 gene) come from?

They were caused by mutations that probably happened randomly.

3. How did Lakita get the p53 allele that caused her cancer?

She got the allele that does not correct mutations from her dad and the version that does correct mutations from her mom.

4. Do you think Lakita's dad had accumulated a mutation in his lifetime that gave him an allele for p53 that does not correct mutations or did he have it when he was born? Explain.

He would have had it in his regular body cells to cause his cancers and his sperm cells to pass it onto Lakita.

5. How did the p53 allele that Lakita has lead to her cancer?

It caused her DNA to not be able to fix mutations, which led her cells to grow out of control and turn into cancer.

Lesson 8: Answer Key

Two-Gene Pedigree

Fill in the table below based on the pedigree in *p53 BRCA1 Pedigree*.

Which two genes does the pedigree model?	p53			BRCA1		
For each gene, what are the possible genotypes an individual can have? <i>Note: The order of the alleles does not matter. AB is the same as BA.</i>	AB or BA	AA	BB	CD or DC	CC	DD
How are the genotypes related to cancer risk? What kind of cancer risk (phenotype) is associated with each genotype?	High when with CD. Medium when with CC.	Low	No information, but likely high.	High when with AB. Medium when with AA.	Low	No information, but likely high.

Which allele is associated with a higher risk of cancer? How do you know?

B because when A was by itself, there was low cancer risk, but when B was with A, it increased.

D because when C was by itself, there was low cancer risk, but when D was with C, it increased.

Making Sense

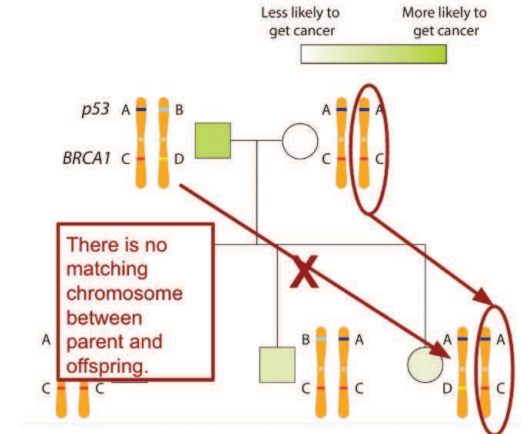
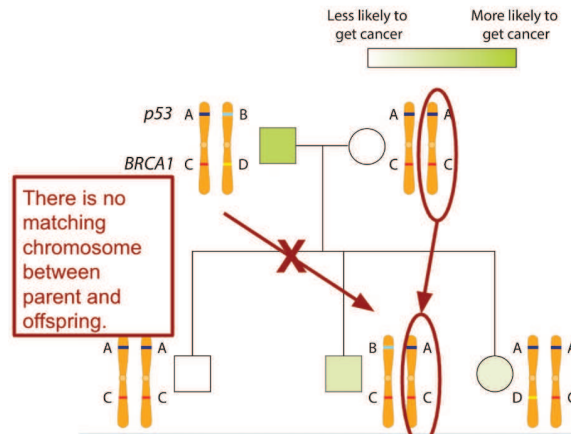
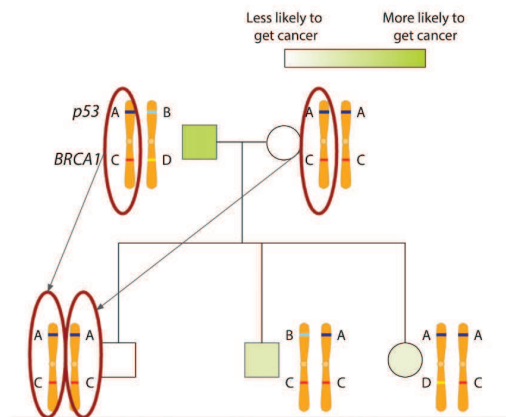
1. Which person on the pedigree is most likely to have the same genotype with Lauren? How does that relate to her decision to have a double mastectomy?

The male in the first generation is most likely to be like Lauren. If she had both a p53 allele that does not correct mutations and a BRCA1 allele that increases risk, her risk for cancer would be high and she would want to prevent it.

2. In the pedigree of Lakita's family, we saw a model where parents and the offspring had chromosomes with the same alleles on the chromosome. Review the alleles on the chromosomes of each offspring in generation two. Whose inheritance can and cannot be explained by what you saw in Lakita's family pedigree? Explain.

In generation 2, the first male offspring has one allele the same as his mother and one the same as his father, which is the same as Lakita's model.

The second male offspring and the third offspring (female) cannot be explained because they each have one chromosome that does not match either of their parents.



Environmental Factors and Cancer Preparation

Preparation Guidance

Ordering materials 3-4 weeks before investigation	- Order your kit so it arrives 3-4 weeks prior to the class investigation. The kit contains all materials except for the live yeast. Instead, the kit contains instructions for ordering the live yeast. - Order your yeast so it arrives 1-2 weeks before the investigation. You will need one week to prepare the yeast ahead of time. - When the yeast arrives, store it in a refrigerator at 4 degrees Celsius, keeping the UV-sensitive strain wrapped in foil. Yeast that is older than 3-4 weeks may behave unpredictably and yield unexpected results.
Pouring plates for each class 4-7 days before investigation	Follow these instructions to pour each set of class plates (2 plates per group): 1. Wash hands to reduce the potential of contamination. 2. Create a sterile work environment by cleaning surfaces with a mild bleach solution (10% bleach, 90% water), or with a 70% isopropyl alcohol solution. 3. Wear indirectly vented chemical splash goggles, nitrile gloves and non-latex apron during the set-up, preparation and take down. 4. Melt the agar using a water bath or microwave: • If using water bath: • Loosen cap. • Place bottle in 95-100°C water bath for 30-90 minutes. • Be sure water level in bath is equal or above agar in bottle (weigh the water bottle down if needed). • If using microwave: • Loosen cap. • Decrease microwave power to 70%. • Heat bottle for 1-minute intervals, swirling between intervals (be sure agar does not boil out of the bottle). • Make sure agar is melted completely before pouring. Though the yeast can still grow on an uneven surface, spreading the cells will prove to be more difficult. (The melted agar will be extremely hot. Use heat-resistant protection when handling) • Allow agar to cool until you can touch the bottle comfortably with your hand. Very hot agar will warp or crack the plate. 5. Pour 20-25 mL of agar into each plate until agar is approximately 0.5 cm. 6. Place a lid on each plate and allow agar to rest undisturbed until solid (at least 30 minutes). 7. Refrigerate and store all agar plates in a sealed bag until ready to plate yeast. Sealed and refrigerated plates are usable for up to one week.

Streaking the master plates 3-4 days before investigation	Follow these instructions to streak the master plates for UV-sensitive and wild-type yeast: 1. Wash hands to reduce the potential of contamination. 2. Create a sterile work environment by cleaning surfaces with a mild bleach solution (10% bleach, 90% water), or with a 70% isopropyl alcohol solution. 3. Wear indirectly vented chemical splash goggles, nitrile gloves and non-latex apron during the set-up, preparation and take down. 4. On the underside of the plates, use a permanent marker to label two master plates: one, "Mutant master - A" and the other, "Wild-type master - B" 5. Streak the two master plates with samples from the appropriate vials of yeast. • Pick one sterile toothpick from the box by holding it at the center, being careful not to touch the ends. • Touch the sterile toothpick to the UV-sensitive yeast growing in the appropriate vial. • Spread the yeast by gliding the toothpick in a zigzag pattern across one-third of the mutant master plate. Discard the toothpick. • Rotate the plate roughly 90 degrees and use a new toothpick to spread yeast across another one-third of the plate. Discard the toothpick. • Rotate the plate and spread yeast one more time with a new toothpick ensuring that yeast has been spread across most of the plate. 6. Repeat the above step to make the wild-type master plate. 7. Incubate the two master plates overnight at 30°C or for two days at room temperature. • Be sure plates are covered to minimize light exposure. • Place plates upside down to prevent condensation from falling onto the agar. 8. Store original yeast vials in the refrigerator for later use, or in case you need to prepare more master plates. <u>Reminder:</u> The wild-type yeast is set up as a control to demonstrate growth of yeast with a working DNA repair mechanism. This is an analogy for human cells with a properly functioning p53 gene.
Preparing transfer yeast solutions Just before students set up their plates	1. Using a sterile pipette, put 1 mL of sterile water into each of two transfer test tubes, one for the UV-sensitive yeast and the other for the wild-type yeast. 2. Using a sterile toothpick, remove an approximately 1 mm clump of yeast from Mutant master plate A. Close and cover the plate immediately to avoid added exposure to light. • Carefully open a test tube marked "A" and smear the toothpick with the yeast on the inside of the tube as close to the water as possible. • Discard the toothpick. • Fill the tube up to the 5 mL line, close the cap, and swirl the tube to mix the yeast with the water. A slightly cloudy solution will result. 3. Repeat step #2 to prepare a transfer tube of wild-type yeast marked "B." <u>Preparation Tip:</u> Groups will remove 0.25 mL of yeast solution for each plate. So each tube should be enough for approximately 20 plates. However, since measuring precisely with pipettes may be difficult, we recommend making one extra transfer tube for each yeast strain. One extra tube for each strain will likely be enough for all your classes combined.

Please be sure students follow these safety precautions:

- Wear indirectly vented chemical splash goggles, nitrile gloves and non-latex apron during the set-up, preparation and take down.

- Hand sanitizer wipes must be provided for participant use at the completion of the activities.
- Clean up any liquid spills on the floor - slip/fall hazards.
- Use caution when working with UV radiation sources. Sources can damage eyes and skin after exposure.

- Use caution when working with glass bulbs, they can break/shatter and cut skin.
- Use caution when working with heated liquids--they can burn skin!
- Yeast is generally safe for use however, in case of inhalation, move to fresh air and rest. If accidentally swallowed, seek medical advice. In case of contact with eyes or skin, rinse immediately with water.
- Follow procedures set up by the instructor for disposal of materials.
- Wash hands with soap and water or use hand sanitizer wipes immediately after completing this activity.
- Direct supervision will be required during all aspects of these activities.

Students will then follow the procedure below, also found on *Investigation Plan: Environmental Factors and Cancer*

Obtain your groups supplies from your teacher.

Use a permanent marker to label each petri dish (lid and bottom) with your group number or initials. Make sure to write near the edge so it will not obstruct your view later.

Open your petri dish, and place four sterile glass beads in the lid of the petri dish.

Gently close your petri dish with the agar side down. The glass beads should now rest on top of the agar inside.

Use a 1 mL sterile transfer pipette to transfer 0.25 mL of yeast cell suspension to the center of the dish by opening the petri dish like it is a clamshell. Close your dish when finished. Note: Be sure to label your petri dish so it matches the yeast provided. For example, if you take yeast from a tube marked "A," then label your dish "A."

Gently tip the covered petri dish from side to side to allow the glass beads to spread the yeast cells around the agar. Note: Simply swirling the glass beads around the edge of the plate will not spread the yeast across the middle of the plate.

Wait approximately 2 minutes or until all the liquid on the dish is absorbed.

Open the petri dish like a clamshell and tip the glass beads into the container provided by your teacher.

Repeat the steps 2-8 for each dish given to your group. Use new glass beads for each dish.

Follow your class-designed protocol for setting up the investigation and exposing your petri dishes to UV radiation.

After exposure to UV radiation, turn each dish upside down and cover it to avoid added exposure to light. Store plates for incubation.

The next steps will depend on both the investigative question and the variable students chose to manipulate. Please note, if using sunscreen, students will need to open the petri dishes and carefully cover them tightly with plastic cling wrap. The sunscreen should be placed on top of the plastic. When finished exposing the plate to UV radiation, the plastic wrap can be discarded and replaced with the lid. If using different types of fabric or similar material, those can cover the petri dish directly.

Sample student protocol

- Investigative Question: What is the effect of sunscreen on the growth of UV-sensitive and wild-type yeast cells?
- Selected Variable: Sunscreen

For 7 groups of 5 students:

- Provide each group with 2 petri dishes with agar: one for UV-sensitive yeast and one for wild-type yeast.

- Each group could be assigned different amounts of sunscreen, which you will need to source ahead of time. For example:
 - Group 1: No SPF
 - Group 2: SPF 15
 - Group 3: SPF 18
 - Group 4: SPF 20
 - Group 5: SPF 30
 - Group 6: SPF 50
 - Group 7: No SPF and covered in aluminum foil

For incubation, use an incubator at 30 degrees Celsius or in a warm location in your classroom, such as on top of a refrigerator.

Guidelines for UV Exposure

Depending on when during the year you conduct this investigation, use the table below to help determine the approximate UV exposure time (calculated for mid-latitude locations). For example, if it is winter and you plan to begin at 10am, then you will need to expose the yeast to approximately 160 minutes of outdoor UV sunlight.

Exposure Time	Winter	Spring/Fall	Summer
8:00 am	-	45	30
9:00 am	200	40	25
10:00 am	160	30	20
11:00 am	130	20	15
12:00 pm	90	15	10
1:00 pm	90	15	10
2:00 pm	120	15	10
3:00 pm	130	20	15
4:00 pm	-	25	20

If you decide to run this investigation indoors, please note that most window materials block UV-B radiation (shorter wavelength, high energy which causes DNA damage) but do not block UV-A radiation (typically associated with skin aging). Therefore, it may take considerably longer to notice any effects unless you use a special lamp.

If you decide to use a lamp, we recommend using a lamp that emits at least some light in the UV spectrum. Typically, fluorescent bulbs emit enough UV light (in the form of UV-C radiation) to mimic outdoor sunlight, but not enough to cause any harm. Black lights are typically fluorescent bulbs with a different coating material that allows for more UV-A radiation to be emitted. Germicidal lamps generally use a fluorescent bulb, which emits high amounts of UV-B and will be strong enough to kill even yeast with DNA damage repair mechanisms (wild type). For this reason and safety reasons, do not use a germicidal lamp for this investigation.

Halogen bulbs typically emit UV radiation that closely mimics natural sunlight. However, most halogen light fixtures also have a glass protective cover that blocks most UV radiation. If you remove the glass covering, then the halogen can produce sufficient UV radiation for this investigation. Please also take caution as this UV radiation, like that from the sun, can damage eyes and skin after longer exposures.

Specialized plant growth lights commonly available at hardware stores emit sufficient UV radiation for this investigation, though the required exposure times may be significantly longer.

If you use a UV-specific lamp, please take care to shield eyes as this invisible light can cause retinal damage. Be sure to always read all instructions and warnings supplied with any light source as they vary widely across types and manufacturers.

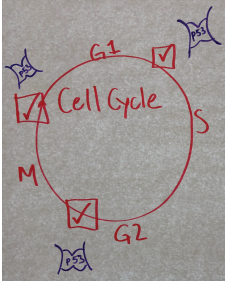
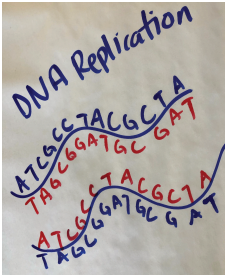
Using the wild-type yeast. It's helpful to have a comparison so students can compare what happens to yeast that has a DNA repair mechanism. There should be enough materials to use the wild-type strain to set up a series of wild-type plates that are exposed to the same conditions as the UV-sensitive strain. Should materials be limited, try to set up one plate in full light and one in full dark for comparison. If the variable student chose is gradient-based (e.g., varying strengths of sunscreen SPF 8-50), try to set one plate of wild type in the middle of the gradient.

Adapted from: DNA Damage: Studying the Impact of UV Light. Teacher's Manual and Student Guide. Carolina Biological Supply (2018)

Lesson 9: Answer Key

Sample Progress Tracker

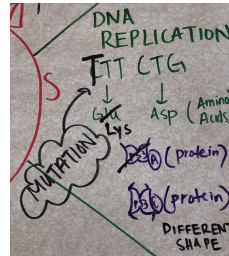
	What I figured out in pictures and/or words	Questions I have
Lesson 1 Who gets cancer and why?	Some cancers are more deadly and some are more common in people. Depending on where you live, there are different types of cancer. The taller and older you are, the more cancer you get. p53 keeps some animals from getting cancer.	What is cancer? How are cancer cells different from non-cancer cells?
Lesson 2 What is cancer?	Cancer cells look different from non-cancer cells. Cancer cells clump together. Cancer cells form tumors, which take over the tissue, stop the system from working properly, and make us sick.	How do non-cancer cells become cancer cells?

Lesson 3 How do non-cancer cells become cancer cells?	Cancer cells form when p53 is not working in the cell cycle. Normally, cells grow and make new chromosomes and divide, and p53 checks to make sure it has everything it needs before it divides. If it is not working correctly, the cells that get made do not have everything they need but get made anyway. They are different because they have different chromosomes. 	What does it mean that the chromosomes are different? How did they get to be different?
Lesson 4 How do cancer cells end up with differences in their chromosomes and what is the role of p53 in preventing the differences?	DNA makes up chromosomes. When DNA gets copied (replicates), sometimes there are errors called mutations. Mutations happen when the letters/bases do not pair with their match. p53 can correct mutations. Some of the p53s did not correct mutations. 	How do we get p53? Why did some of the p53 fix mutations and some did not? Why did the p53 have different shapes?

Lesson 5

How do we make p53, and why is it different sometimes?

DNA is in genes on chromosomes. Each gene codes for an amino acid, which codes for a protein. If you change the DNA, then you may also change the shape of the protein, which may change how it works. This is called gene expression.

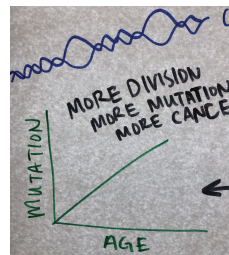


How much have we figured out already?

Lesson 7

Why are some kinds of cancer more common than others in older and taller people?

Different types of cells divide at different rates. The more a cell divides, the more mutations it can get. The more mutations a cell accumulates, cancer will result. Taller people and older people have more cellular division than shorter or younger people.



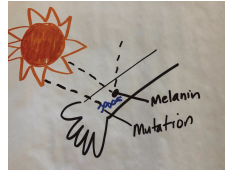
Why does it seem that cancer runs in families?

How does a person's environment affect whether or not they get cancer?

Lesson 9

How do genes interact with the environment to affect who gets cancer?

UV radiation causes mutations in DNA, which can change the structure and function of proteins. Melanin can have protective properties against damage from UV radiation. Because there are different amounts of UV radiation and different amounts of melanin in the skin, there are different amounts of cancer in the population.



Why do different people in different places get cancer at different rates?

Genetics Transfer Task Key

10.B 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. (SEP: 7.5; DCI: LS3.B.1 & LS3.B.2; CCC: 2.1)

3D Elements Addressed in this Assessment				
SEPs	1	2	3	4
7.5 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.			X	X
DCIs				
LS3.B.1 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.	X	X	X	
LS3.B.2 Environmental factors also affect expression of traits, and hence affect the probability of occurrences of traits in a population. Thus the variation and distribution of traits observed depends on both genetic and environmental factors.				X
CCCs		X	X	X
2.1 Cause and Effect Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.				

Figure 1: Medicare Payments for Genetic Tests

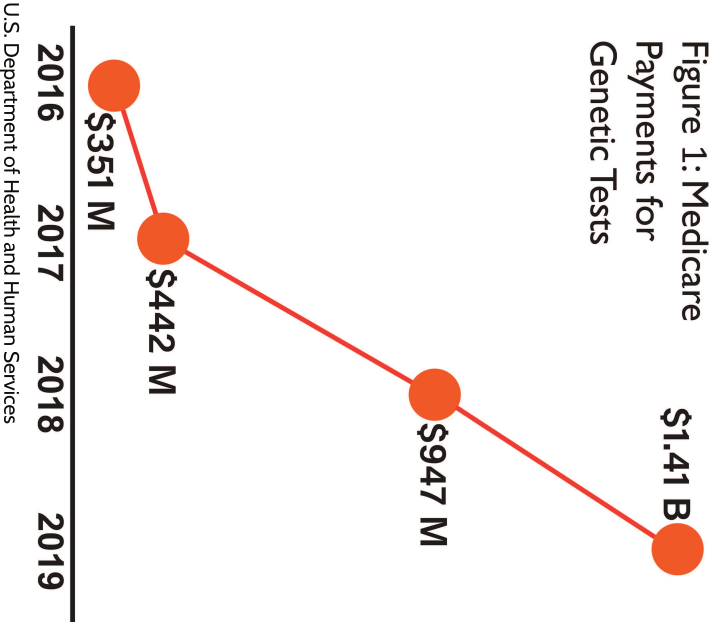
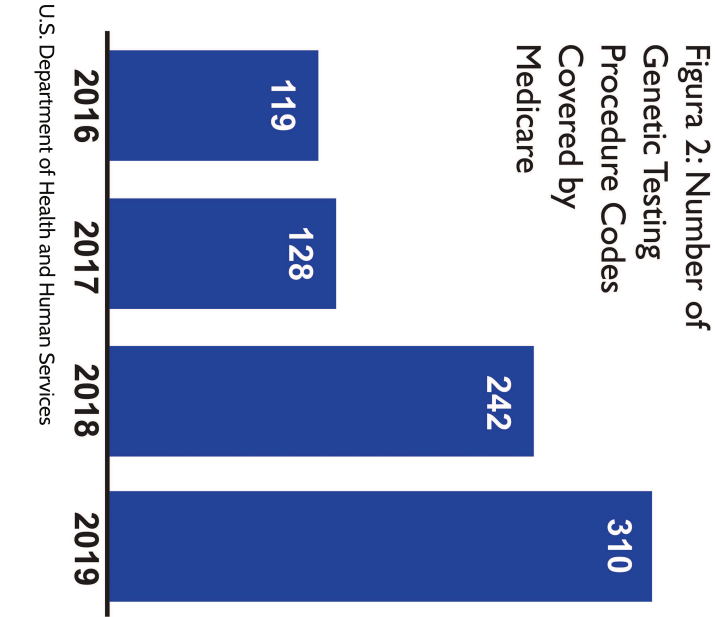


Figure 2: Number of Genetic Testing Procedure Codes Covered by Medicare



There has been a dramatic increase in the number of people getting genetic tests in the past few years. Figure 1 and 2 above report how many requests and payments have been made to and by medicare, the government healthcare system.

In this task you will investigate the following question:
What are these genetic tests for and what information can they provide?

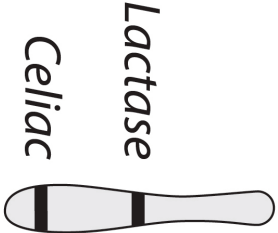
Part 1: Genetic tests with a family history

There are different types of genetic tests. Some tests are designed to look for a specific gene or genes. Usually, people get these kinds of tests when a certain genetic condition is known to be in their family. In the scenario below, you will investigate a case study of José, whose doctor sent him to get a genetic test.

José is a 15-year-old biological male who has been having problems with feeling sick after he eats. He visited the doctor several times. Since José's father has both **lactose intolerance**, which keeps him from digesting dairy products, and **celiac disease**, which keeps him from digesting wheat, his doctor sent him to get a genetic test to find out if he inherited either of these conditions from his father. This information can help him adjust his diet so he can feel better.

There are two genes on chromosome 2 that code for proteins that are associated with digesting milk (lactase) and wheat (celiac).

Chromosome 2



Traits	Allele Versions	
Lactose Intolerance Problems digesting dairy	Lactase 1 No problems digesting dairy	Lactase 2 Problems digesting dairy
Celiac Disease Problems digesting wheat	Celiac 3 No problems digesting wheat	Celiac 4 Problems digesting wheat

Consider the pedigree below showing chromosome 2 for José and his parents.

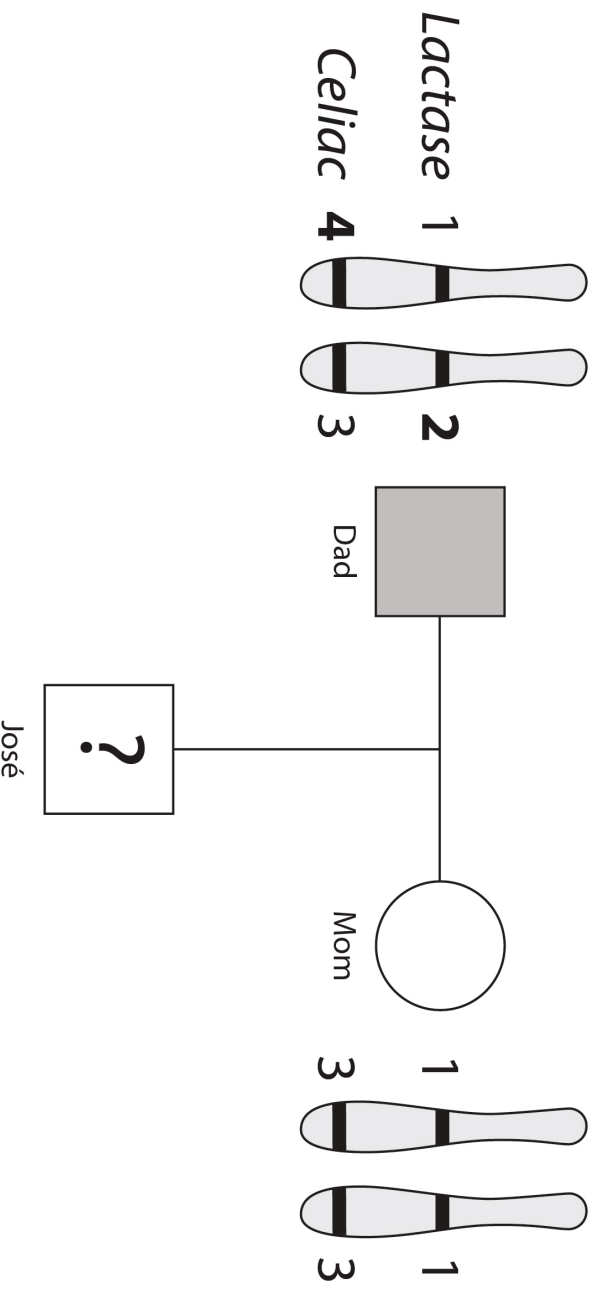
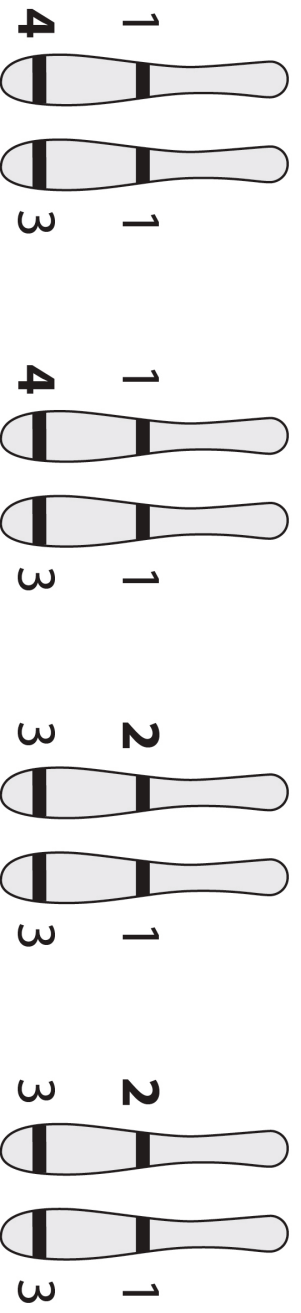


Figure 4. A family pedigree showing Lactase and Celiac alleles on chromosome 2.

1. Without mutation or crossing over, write the combinations of Lactase and Celiac that José could inherit from his parents.

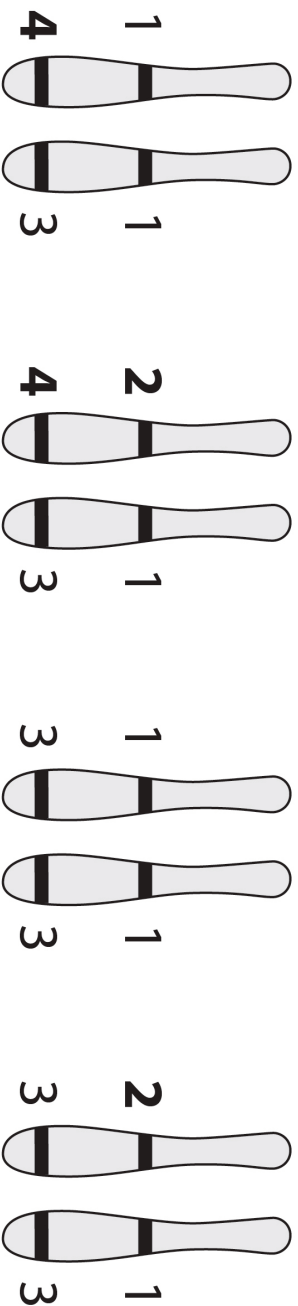
No Crossing Over



José inherits half their genetic material from each parent. One chromosome came from the mom. Eggs from the mom could only have a chromosome with alleles 1 and 3. One chromosome also came from the dad. Sperm from the dad could have alleles 1 and 4 or 2 and 3 only if NO crossing over occurred between the genes during meiosis.

2. José's doctor tells him that he has inherited BOTH Celiac 4 and Lactase 2. Explain using pictures and/or words what could have caused this. .

Crossing Over



José inherits half their genetic material from each parent. One chromosome came from the mom. Eggs from the mom could only have a chromosome with alleles 1 and 3. One chromosome also came from the dad. Sperm from the dad could have four different possibilities: alleles 1 and 4 or 2 and 3 (like dad's chromosomes) or 2 and 4 or 1 and 3 if crossing over occurs during meiosis.

Part 2: Genetic tests without a family history

Some people get genetic tests even when they do not have a history of a genetic condition in their family. In this case, Victoria bought a genetic test from a company who would analyze her genome for 14 health concerns, including **Age-Related Macular Degeneration**.

Age-Related Macular Degeneration (AMD) is the most common cause of irreversible vision loss among older adults. The disease results in damage to the central part of the retina, impairing vision needed for reading, driving, or even recognizing faces.

According to the genetic testing company, they test for the two most common variants associated with an increased risk of developing AMD.

When Victoria gets her results back, it says both of the genetic variants they tested for are present. It also says that "People with this result have a slightly increased risk of developing AMD. Lifestyle and other factors can also affect your risk."

Currently Victoria's risk is low; however, it is possible for Victoria to be diagnosed with AMD later in life. Choose one of the claims below. Support this claim with evidence that could explain how Victoria could get AMD.

3. Circle one:

Claim 1: Victoria gets AMD caused by random mutation.

Claim 2: Victoria gets AMD caused by exposure to the environment.

Provide evidence to support your claim below. Use pictures and/or words.

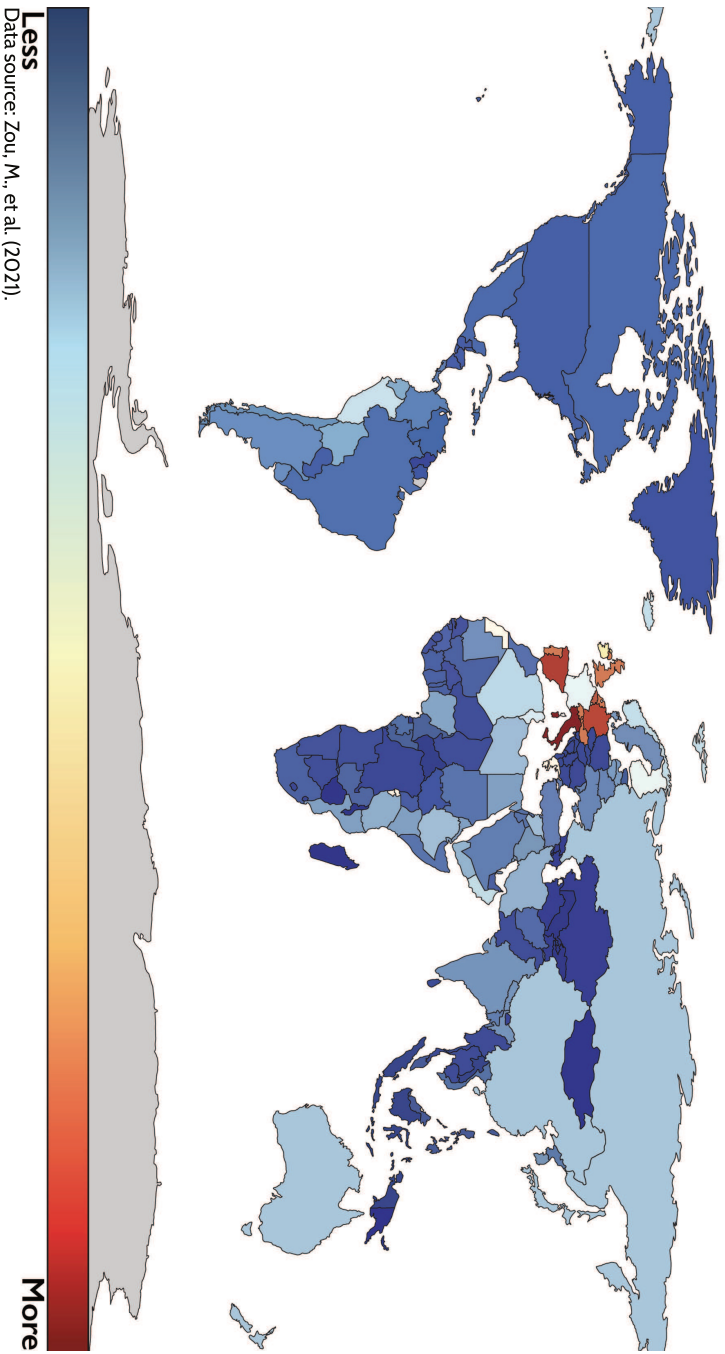
	Foundational Pieces	Linked Understanding	Organized Understanding
3D Elements	In this evidence, look for: Claim 1: Student references the computer simulation and/or that more mutations happen as people age. Claim 2: Student references the yeast investigation and/or that the environment has a role in mutations .	In this evidence, look for: Claim 1: Student references the computer simulation and that more mutations happen as people age. They link cell division to mutation. Claim 2: Student references the yeast investigation and that the environment has a role in mutations . They link environmental factors to mutation.	In this evidence, look for: Claim 1: Student provides evidence from the computer simulation that mutations can accumulate as people age and that those mutations can cause cancer . Claim 2: Student provides evidence from the yeast investigation that mutations can be caused by the environment and can lead to cancer .

Example	Claim 1: In the computer simulation, cells were dividing, OR the more they divided, the more mutation there was. Claim 2: In the yeast investigation, UV light caused mutations, OR environment causes mutation.	Claim 1: In the computer simulation, cells were dividing. The more they divided, the more mutation there was. Claim 2: In the yeast investigation, UV light caused mutations.	Claim 1: In the computer simulation, we saw that over time as more cells divided, there was a higher chance of getting a mutation. This could happen with AMD as people get older and have more cell divisions. These mutations could cause cancer. Claim 2: In the yeast investigation, we saw that environmental factors like UV radiation could cause mutations. This could be true with AMD as well. DNA mutations could be caused by the environment, and this could lead to cancer.
Feedback /What to Do	Linking: Ask students to explain how the evidence is connected to cancer. Provide students with an opportunity to review materials from Lesson 7, such as the simulation, or Lesson 9.	Organizing: Ask students to consider how the mutations caused cancer. Ask students to review their Progress Trackers and to revise their responses.	Extending: Ask students to illustrate this relationship with a graph.

Part 3

The number of people with AMD varies around the world. While genetics determine many cases of AMD, other factors are associated with increased and decreased risk of AMD. Figure X below shows a high rate of AMD in some European countries.

Age-associated macular degeneration 2017 Male and female, all ages, per 100,000



Factors associated with increased risk	Factors associated with decreased risk
• age • blood pressure • smoking • alcohol consumption	• increased fish in diet • certain vitamins such as C, D and E

4. While these factors are correlated with AMD, we do not have evidence that they cause or prevent AMD. Choose the evidence below that would best support the following claim: Diet causes AMD.
- Data that shows how the ages of people are in each country.
 - Data that show the mechanism that causes the interaction between AMD and diet.
 - Data that shows how many people live in each country.
 - Data that shows what people eat in each country.

Ideas for Instruction	Foundational Understanding	Linked Understanding	Organized Understanding
	Return to the simulation from Lesson 7 to review mutation rate over time.	Review the class consensus model.	Ask students to predict how environmental factors could cause differences across the world based on a single environmental factor.

Lesson 11: Answer Key 2

Treatment Organizer

Treatment Type	Mechanism	Side Effects	Cost and Other Considerations
Chemotherapy	Uses chemicals to stop growth. Taxol stops the spindle in mitosis, and carboplatin links the DNA so it cannot unwind and replicate.	Stops non-cancer cells from growing too. Hair loss, tiredness, weakened immune system.	It can be expensive, especially if you do not have insurance. You might have to take a lot of time to go to doctor appointments.
Radiation	It used a ray to disrupt the DNA in cells so it cannot replicate and the cell cannot divide.	Non-cancer cells can also be damaged. It can cause tiredness and weakness.	It can be expensive and unsafe if you do it too much.
Surgery	It removes the cancer cells from the body.	You can get an infection or have an organ removed, which makes body systems less effective.	It can be painful, require a lot of recovery, and have high costs.
Immunotherapy	Uses the body's immune system to destroy cancer cells.	It can take a long time and cause skin reactions, flu symptoms, and inflammation.	It is new and there is not as much known about it.

Lesson 12: Answer Key

Social Determinants Table Key

Instructions: Complete the table with the key takeaways from the discussion.

	How does this determinant impact health and wellness?	How could this determinant be a constraint for cancer treatment options and outcomes?
Education	Depending on your education, you have access to more money. People with more education would have the resources needed to engage in more behaviors that would prevent cancer.	Without an education, it may be difficult to get access to resources that would be needed to have the most treatment options, so it could mean that their opportunity for survival is reduced.
Income & Wealth	Income gives you the chance to live in better neighborhoods that give you more access to a higher quality of life.	If your income does not allow you to live in places that are “healthy,” you may be exposed to more environmental factors that increase cancer risk. If you get cancer, you may not be able to afford the treatment, and you may die.
Employment	Most people get their health insurance and other means for income from employment (work). Some high paying jobs keep you from the types of work that could expose you to cancer.	Most cancer treatments are expensive, and having health insurance helps people pay for their treatments. If you don’t have insurance and no way to pay for your treatments, the chance of survival is not as high as someone who has insurance or can pay.
Health Systems & Services	Your ability to access quality health care and prevent serious disease.	Without access to quality healthcare, it may be difficult to access health care options that could help treat your cancer.
Housing	Having a safe, clean home in a safe, clean neighborhood is a part of keeping you healthy.	Your housing (or lack of housing) can also contribute to making you sick.
Physical Environment	Being able to relax, be social, participate in activities in green and open spaces all help add to your health and wellness.	The stress of not having access to green spaces and being able to enjoy cultural activities reduces your health and increases cancer risk.

Transportation	Having access to reliable transportation makes it easier to get to work, recreation, and access to healthcare.	Without transportation, you may have to rely on others, have less reliable options, or be exposed to pollution, which can reduce where you are able to access your healthcare or even keep a job.
Social Environment	Having friends and healthy relationships are all necessary to staying healthy. You and your social network may even participate in the behaviors that could keep you from getting cancer.	Not having a social network can decrease your health and affect cancer survival. You may need people to help you get to treatment or even in the days that follow treatment, but if you do not have people, then your chances of survival could go down.
Public Safety	If you are in places where public safety is high, then you have a higher chance of remaining healthy.	Not being safe could reduce your survival as well as cause stress that could increase cancer risk.

Sample Interview Protocol Key

Use the table below to develop interview protocols that can help you be an effective health care navigator for a loved one who is visiting a doctor about a disease with a genetic component. An interview protocol is a list of questions to ask.

For each question, say what you hope to learn, and why you are asking it. When developing your justification for why it is important to ask each question you propose, draw on what you have learned in this unit about genetics. Also draw on what you have learned about how both disease and healing from disease are shaped by genetics and the environment.

Some terms to use in answering the “why” question are: *gene, DNA, protein, allele, express/expression, mutation, sexual reproduction, inherit, meiosis, fertilization, mitosis, function, social determinant*.

Interview Protocol for Loved One

Develop a list of questions to ask your loved one that are necessary to understand their condition and aspects of their environment that (1) could explain what is happening in their bodies and (2) could affect their ability to get treatment.

Question I Would Ask	What I Want to Learn From Asking This Question	Why It Is Important To Ask/Learn This Information
Did anyone else in your family have this condition?	Whether a family member experienced symptoms of or perhaps died from the condition.	Many diseases that have a genetic component are inherited from parents. This includes some genetic diseases where a mutation is passed on from one generation to another.
Was anyone in the family tested for whether they carried a genetic mutation that was linked to this condition? If so, which family members carried that gene?	Whether a carrier is in the family or not. Any relative with the genetic mutation could be a carrier.	Not all people who carry genetic mutations that can cause a condition show symptoms. Genetic mutations run in families. The closer the relative (e.g., parents, siblings), the higher the likelihood of transmitting to the loved one.
What symptoms are you experiencing that helped you know you were sick?	How the disease is affecting their overall functioning and health.	Genes code for proteins, which perform many different kinds of functions in cells. When genes mutate, they can prevent proteins from being made or from performing the functions that maintain the health of the organism. The “symptoms” someone experiences are often a clue about what functions have been affected.

How far do you live from the nearest hospital, and how would you get there if you had to go?	How accessible health care specialists are to the loved one.	One of the barriers to treatment is distance to specialists, which is a social determinant of health outcomes. The farther someone lives from a specialist, the worse the outcome for cancer.
If you needed treatment that required you to stop doing what you typically do every day, who could help you?	How available other family members and friends are, in case treatments have side effects that prevent healthy functioning.	Many treatments (e.g., radiation) can have side effects that make it hard for a person to live as they typically do. Some require care from family members.
Do you have some kind of health insurance?	Whether or not the loved one has the ability to pay for treatment.	One of the barriers to treatment is cost. Access to health insurance is a social determinant of health that is correlated with treatment outcomes.

Interview Protocol for a Medical Professional (e.g., a doctor or nurse practitioner)

Develop a list of questions to ask a medical professional that are necessary to understand the causes of their condition, including what is changing (or has changed) inside the cells of the body and how the environment may have contributed to their condition. You should also develop questions to ask about possible treatments that will help your loved one get the best care for their illness.

Question I Would Ask	What I Want to Learn	Why It Is Important To Ask
If this is a genetic disease, how are my loved one's cells functioning differently?	About how cells' functioning has been changed as a result of the disease.	Genetic diseases typically impact the functioning of cells by making it so that proteins needed to support cell functions either aren't produced or don't work as they do when only wild-type genes are present in cells.
What is the role of the DNA or genes in causing the changes to the cells?	About whether some genetic mutation or combination of genetic mutations is the cause of the disease.	Wild-type genes code for proteins that perform particular functions; when a mutation is present, they may not produce the protein needed for that function or may produce a non-functioning version of it.

Is this disease inherited? If so, how is it inherited?	Whether particular alleles might be passed on from a parent to the loved one.	Each gene can have several variants, called alleles, which code for different variants of the trait in question. Each human cell contains two variants of each chromosome, one inherited from each parent. In some diseases, both parents need to carry a mutation that causes a disease. In other cases, only one parent needs to carry the mutation. In still others, the disease is inherited but is not the result of passing down a mutation. It is the result of a mutation that occurs during meiosis or fertilization.
If the genes are factors in the disease, but it's not inherited, what are some other possible causes of the disease?	Whether genes may have been damaged due to something in the environment.	Things in the environment (e.g., exposure to radiation) or that a person does (e.g., smoking) can cause damage to genes and therefore affect their ability to produce proteins that help maintain cellular functions.
What treatments have proven effective from clinical trials?	The existence of treatments with evidence of effectiveness.	The best treatments are those that have undergone extensive testing in clinical trials, where people have been randomly assigned to receive a treatment or a placebo.
What are possible side effects of the treatment?	What may happen to the body during or after treatment and how it might affect a person's or a family's daily routine.	Many treatments (e.g., radiation) can have side effects that make it hard for a person to live as they typically do. Some require care from family members.
How costly are the treatments, and will insurance cover the costs?	Whether the treatments are affordable for my loved one.	One of the barriers to treatment is cost. Access to health insurance is a social determinant of health that is correlated with treatment outcomes.
Where will we need to go to get treatment?	Whether it is easy to access treatment because it is close by.	One of the barriers to treatment is distance to specialists, which is a social determinant of health outcomes. The farther someone lives from a specialist, the worse the outcome for cancer.