NGSS Lesson Plan

Grade/ Grade Band: 8th grade	**Topic:** Genetic Mutations	**Lesson #** 3 **in a series of** 5 **lessons**

Brief Lesson Description:

During the course of this lesson, students will act as genetic counselors. They will use the LEGO EV3 robot to analyze genetic information of different patients and cross-reference the results with each patient's medical history to diagnose if the patients have genetic disorders. Students will determine if certain genetic mutations will result in disorders, and if the diagnosed illnesses have a genetic basis. Students will also analyze data from the Centre for Disease Control on mortality rates of common cancers in males and females in the New York State.

Essential Question:

What are genetic mutations and what are their consequences?

Performance Expectation:

MS-LS3-1.

Develop and use a model to describe why structural changes to genes (mutations) located on chromosomes may affect proteins and may result in harmful, beneficial, or neutral effects to the structure and function of the organism.

[Clarification Statement: Emphasis is on conceptual understanding that changes in genetic material may result in making different proteins.] [Assessment Boundary: Assessment does not include specific changes at the molecular level, mechanisms for protein synthesis, or specific types of mutations.]

Specific Learning Outcomes:

1. SWBAT model the process of identification of mutations in the genetic code of a person by using the LEGO EV3 robot.
2. SWBAT cross-reference information from different sources to determine whether patient's symptoms indicate genetic or non-genetic disorders.
3. SWBAT create a circle graph/ pie chart using data collected from scientific text and technical information.

Narrative / Background Information

Prior Student Knowledge:

- Students should be familiar with the purpose and the basic structure of DNA.
- Students should have prepared a model of DNA structure as a homework assignment after a classroom activity.
- Students should know how to transcribe and translate a sequence of DNA.
- Students should know about the role of RNA and its role in protein synthesis.
- Students should be familiar with the concept of karyotypes.
- Students should be able to create and interpret pie charts.

Science & Engineering Practices (SEPs)	Disciplinary Core Ideas (DCIs)	Crosscutting Concepts (CCCs)
Developing and Using Models Modeling in 6–8 builds on K–5 experiences and progresses to developing, using, and revising models to describe, test, and predict more abstract phenomena and design systems. Develop and use a model to describe phenomena.	**LS3.A: Inheritance of Traits** 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.	**Structure and Function** Complex and microscopic structures and systems can be visualized, modeled, and used to describe how their function depends on the shapes, composition, and relationships among its parts, therefore complex natural structures/systems can be analyzed to determine how they function.

Common Core State Standards (CCSS)

ELA/Literacy -

RST.6-8.1 Cite specific textual evidence to support analysis of science and technical texts.

RST.6-8.4 Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grades 6-8 topics.

RST.6-8.7 Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually (e.g., in a flowchart, diagram, model, graph, or table).

SL.8.5 Integrate multimedia and visual displays into presentations to clarify information, strengthen claims and evidence, and add interest.

Mathematics -

6.SP.B.5 Summarize numerical data sets in relation to their context.

7.RP.2 Recognize and represent proportional relationships between quantities.
Decide whether two quantities are in a proportional relationship, e.g., by testing for equivalent ratios in a table or graphing.

7.RP.A.3 Use proportional relationships to solve multistep ratio and percent problems. Examples: simple interest, tax, markups and markdowns, gratuities and commissions, fees, percent increase and decrease, percent error.

Possible Preconceptions/Misconceptions:

- Only genes are responsible for all of our physical characteristics.
- Each gene codes for one trait.
- Each chromosome codes for only one trait.
- Mutation always causes a disease.
- Mutations are abnormal things to have.
- If a parent has a mutation, the child will definitely have it.
- All genetic diseases are inherited from the parents.

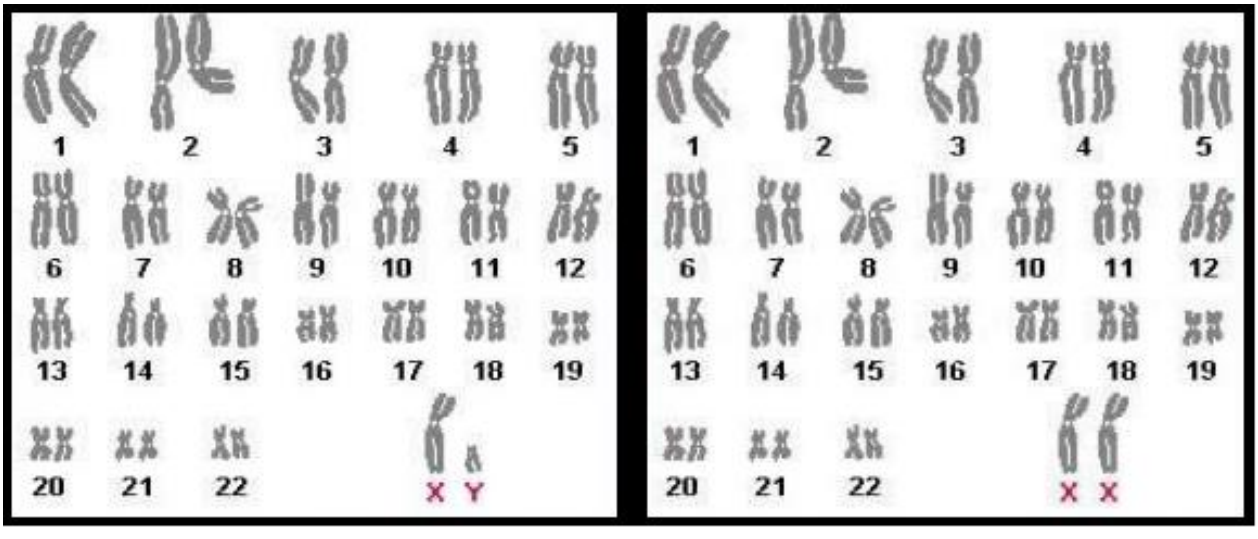
LESSON PLAN – 5-E Model

ENGAGE: Chromosomal and Genetic Mutations

Teacher will ask students to work in pairs and show the following images of human karyotypes to the entire class.

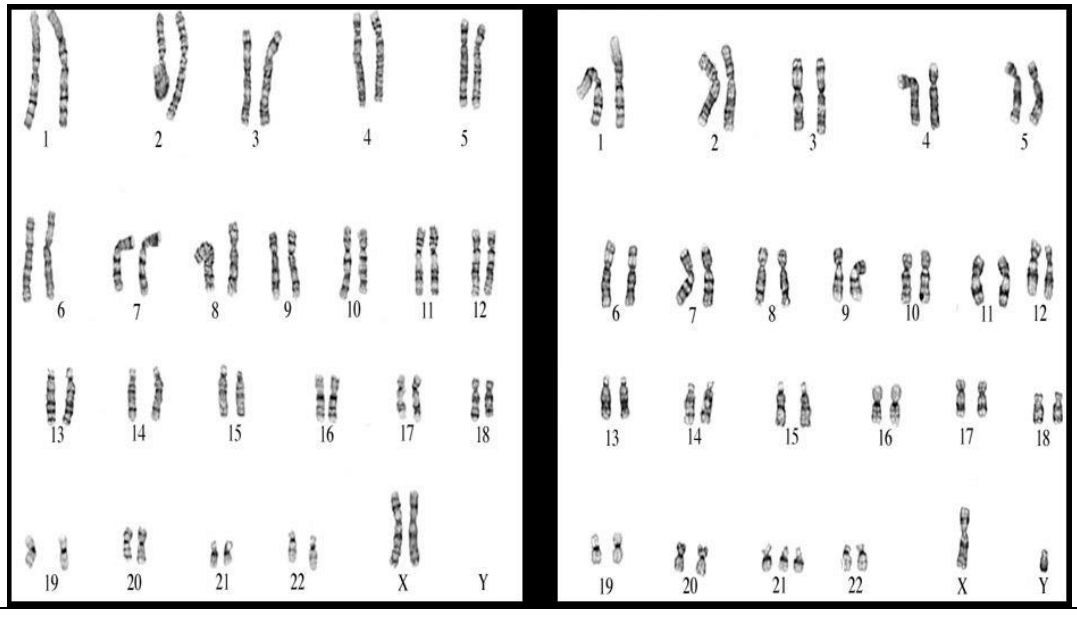
Students will:

- Identify the most significant difference between the two karyotypes.
- Discuss how this observed difference in karyotypes manifests itself.



Teacher will ask students to share their opinion of the effects of having extra chromosomes. Would it be desirable? Would it confer special abilities to a person?

Then the teacher will show the second set of images of human karyotypes and ask students to identify the most significant difference between two different karyotypes. Teacher will solicit student opinion on the effect of having an extra copy of chromosome 21 on an individual.

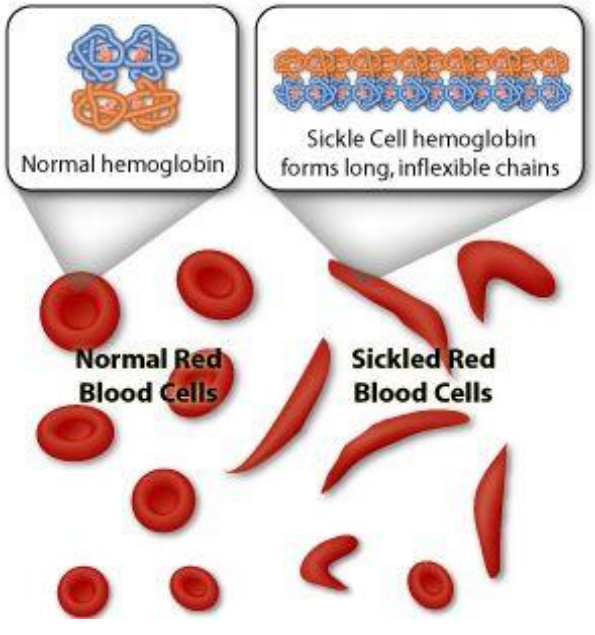


Answer Key: Down Syndrome occurs due to an error in which a person's cells have an extra copy of chromosome 21. This additional genetic material alters the course of development in a person and causes the characteristics associated with Down Syndrome.[1]

Following this activity, teacher informs and emphasizes that not all genetic diseases can be identified by using a karyotype. While some mutations occur at a chromosomal level – such as Trisomy21 (presence of an extra chromosome 21), mutations can also occur within the DNA sequence that cannot be seen by looking at a karyotype.

For example, Sickle Cell Anemia is a disorder caused by a mutation in a gene called HBB found on chromosome 11 which contains the code that cells need to make part of a protein called hemoglobin. This protein includes an iron-containing portion that gives red blood cells their red color. It also allows the red blood cells to transport oxygen molecules throughout the body. In sickle cell anemia, the mutation in HBB gene changes one of the building blocks of hemoglobin, which then causes red blood cells to become rigid, sticky, and crescent shaped. [2]

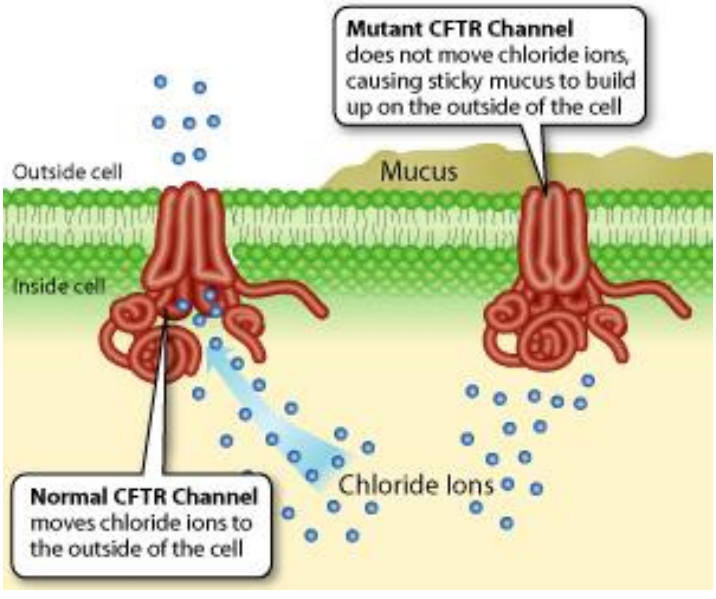
Teacher will ask students to discuss how these misshapen red blood cells will affect the human body.



Answer Key: Symptoms of Sickle Cell Anemia include anemia due to reduced life span of red blood cells, episodes of pain, painful swelling of hands and feet, frequent infections, delayed growth, and vision problems due to the sickled red blood cells getting stuck in small capillaries and their reduced oxygen carrying capacity.

Another example of a disorder stemming from a genetic mutation is Cystic Fibrosis (CF). In people with CF, mutations to the CTFR gene on chromosome 7 results in the CTFR protein being unable to move salt (chloride) to the cell surface and maintain a healthy watery mucus coating on them. This dysfunctional CTFR protein is unable to maintain the right balance of fluid and the mucus in various organs becomes thick and sticky leading to infections and inflammation.[3]

Teacher will ask students to discuss how the accumulation of thick and sticky mucus will affect the human body.



Teacher will show the following video which briefly describes what is cystic fibrosis and how it affects the human body through the voice of an actual patient: https://www.youtube.com/watch?v=tWWpPAXFEFs.

Mutations occur randomly AND constantly.

This Engage section addresses the **DCI** of Standard **MS-LS3-1** and ensures that students understand that genes are located on chromosomes. It illustrates how changes to genes that are responsible for production of particular proteins in the body can affect the structure and function of those proteins, and consequently the heath and wellbeing of an individual. The **CCC** of this standard is also addressed in this section through the example of Sickle Cell Anemia and Cystic Fibrosis which demonstrate that mutations in genes affect the structure and function of the proteins they code for, and of the overall human body.

Sources:

[1]About Down Syndrome: https://www.ndss.org/about-down-syndrome/down-syndrome/
[2]Causes of Sickle Cell Anemia: https://sicklecellanemianews.com/causes-sickle-cell-disease/
[3]Cystic Fibrosis: http://wiki.ggc.edu/wiki/Cystic_Fibrosis

Image Credits:

Karyotype Image 1: https://www.tutorvista.com/content/biology/biology-iii/cell-reproduction/karyotype.php
Karyotype Image 2: http://worms.zoology.wisc.edu/zooweb/Phelps/47XY_21.html
Sickle Cell Anemia Image: https://learn.genetics.utah.edu/content/disorders/singlegeneeg/
Cystic Fibrosis Image: http://wiki.ggc.edu/wiki/Cystic_Fibrosis

EXPLORE: Robotic activity to help students cross-reference multiple data sources to make diagnostic decisions

Teachers will give each student group a poster paper with the markings representing chromosomes. Each group will also be provided with a set of six 'Patient Medical History Cards' and told that each of these patients were asked to have a genetic test performed. Teachers will inform the students that they are genetic counselors who must use the LEGO EV3 robot to investigate the presence of possible mutations in the patients' genomes.

Activity 1:

1. Each group will place their poster paper with pre-drawn model of an individual genome on their desk or ground.
2. Students will place their robot on the starting point marked on the poster paper. They will then run the program named "Mutation" for the particular patient marked as "Patient #".
3. If the robot stops at any point along the patient's genome, it indicates the presence of a mutation. When the robot stops at an error, students will record the number of the chromosome on which mutation is found for the corresponding patient in Table 1.
4. Repeat steps 2 and 3 for each patient.
5. At this stage students can study the patient history cards and record any ideas or predications they might have about the patient diagnoses in the 'Brainstorming Notes' row in Table 1.

Table 1

	Patient 1	**Patient 2**	**Patient 3**	**Patient 4**	**Patient 5**	**Patient 6**
Is Mutation Present?	□ Present □ Absent	□ Present □ Absent	□ Present □ Absent	□ Present □ Absent	□ Present □ Absent	□ Present □ Absent
Mutation present on chromosome						
Brainstorming Notes						

Patient Medical History Cards		
Patient #1: Isabella is a 14-year-old girl with severe recurring coughs and excessive phlegm. She has been in and out of the hospital with several lung infections throughout her life. It is often very difficult for her to breath.	**Patient #2:** Sebastian is a 17-year-old boy who wants to try out for his high school basketball team. He's visiting the clinic to get bloodwork done. He sometimes feels tired and fatigued. On a recent trip to a wildlife reserve in South Africa, he found out that he was resistant to malaria.	**Patient #3:** Mr. and Mrs. Stark recently found that their one-year-old baby started having frequent seizures. Before this the baby was sitting and crawling, but recently she is not able to sit or crawl. The baby has stopped making sounds and responding to other people.
Patient #4: Peter recently got fired from his job for excessive absences. He has been searching for a new job for months but cannot find anything. He is not sleeping well at night and has very low appetite for food. He stopped hanging out with his family and friends and mostly just stays home.	**Patient #5:** Victoria is a 40-year-old woman who came to the doctor complaining about always being tired, lightheaded, and having muscle cramps. She is also starting to have heart palpitations at times.	**Patient #6:** Dalip (age 25) is about to get married and they were curious to find out more about their family history. He also recently started to experience uncontrolled muscle spasms and trouble making decisions. Bill's fiancé does not show any of the same symptoms.

Activity 2:

1. Each group of students will now be provided with a set of six 'Disorder Information Cards'.
2. Students will copy information from the 'Mutation present on chromosome' row from Table 1 into Table 2.
3. Using these 'Disorder Information Cards' and the 'Patient Medical History Cards' (provided in Activity 1), each group will write down their diagnosis in the space provided in Table 2.

Table 2

	Patient 1	**Patient 2**	**Patient 3**	**Patient 4**	**Patient 5**	**Patient 6**
Mutation present on chromosome						
Possible Genetic Diagnosis						

Disorder Information Cards

Tay-Sachs Disease

A rare inherited genetic disease caused by a mutation on the HEXA gene on chromosome 15. This mutation affects the production of an enzyme that breakdowns toxic substances in cells, thereby causing a buildup of toxins in the brain and spinal cord. Patients with this disease usually experiences seizures, loss of vision/hearing, intellectual disability and paralysis. Infant patients with a severe form of Tay-Sachs Disease live only into early childhood.[1]

Cystic Fibrosis

An inherited genetic disease characterized by progressive damage to the respiratory and chronic digestive system problems. This condition is caused by a mutation in the CFTR gene, on chromosome 7, that causes the body to produce abnormally thick and sticky mucus. Symptoms of this disorder include recurring lung infections. Patients with cystic fibrosis also suffer with the lack of nutrients due to mucus build up in the passageway between the pancreas and small intestines preventing enzymes from breaking down nutrients from food.[2]

Depression

This is a mood disorder characterized by consistent feeling of sadness and hopelessness. This common disorder can be caused by a combination of physiological, biological, and social stress factors. Symptoms of depression range from mild to serve and may include the following: loss of interest in routine activities, tiredness, changes in sleeping patterns, anxiety, loss of appetite, and frequent suicidal thoughts.[3]

Huntington's Disease

An inherited progressive brain disorder caused due to mutations in the HTT gene on chromosome 4 which leads to the production of abnormally long version of huntingtin protein. This elongated protein accumulates in nerve cells of the brain, disrupting the normal functions of these cells. Patients with Huntington's Disease usually have some of the following symptoms: uncontrolled muscle spasms, difficulty with balance, difficulty with learning new things and making decisions, and depression.[4]

Sickle Cell Anemia

This is an inherited disorder that is caused due to mutations in the HBB gene on chromosome 11 which produces an abnormal version of hemoglobin, which distort red blood cells into a sickle shape. The sickle shaped red blood cells die prematurely, causing anemia. The inflexible sickle shaped cells also get stuck in small blood vessels and prevent the blood cells from bringing oxygen to our cells which causes fatigue and severe pain. Carriers of the defective gene are known to be resistant to malaria.[5]

Down Syndrome

It is a chromosomal disorder, also known as Trisomy 21 as it is most commonly caused by the presence of three copies of chromosome 21 in each cell of the body. Symptoms include characteristic facial appearance, weak muscle tone, cognitive and developmental delays. Down Syndrome is the most common chromosomal disorder in the United States (1 in 700 babies are diagnosed each year).[6]

[1] Tay-Sachs Disease: https://ghr.nlm.nih.gov/condition/tay-sachs-disease#genes
[2] Cystic Fibrosis: https://ghr.nlm.nih.gov/condition/cystic-fibrosis#genes
[3] Men and Depression: https://www.nimh.nih.gov/health/publications/men-and-depression/index.shtml
[4] Huntington's Disease: https://ghr.nlm.nih.gov/condition/huntington-disease#genes
[5] Sickle Cell Anemia: https://ghr.nlm.nih.gov/condition/sickle-cell-disease#genes
[6] Down Syndrome: https://ghr.nlm.nih.gov/condition/down-syndrome#genes

Answer Key

Patient #	1	2	3	4	5	6
Mutation present on chromosome	7	11	15	n/a	n/a	4
Disorder	Cystic Fibrosis	Sickle Cell Trait	Tay-Sachs Disease	Depression	Dehydration	Huntington's Disease

The activities above align with the **SEP** of the Standard **MS-LS3-1** because students model the functions of genetic counsellors to diagnose possible genetic disorders for patients by cross-referencing medical history of patients with data collected by using the LEGO EV3 robot regarding presence of genetic mutations in their genome.

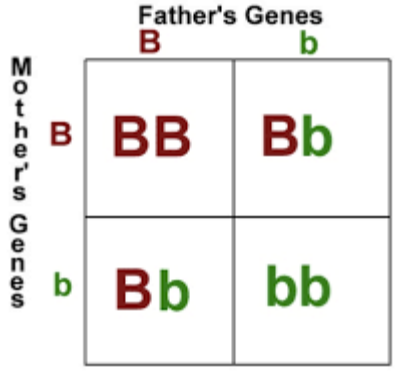
EXPLAIN: Genetic Disorders and Pedigree Analysis

1. Teachers will lead a discussion into the diagnoses made by different groups of students in the previous activities. Students will present their evidence based on the patients' medical history, presence of errors on different chromosomes, and the information about different disorders to support their responses.

2. Teachers will explain about recessive disorders. They will inform the students that some of the different diseases they learnt about in the previous sections, namely, Tay-Sachs, Cystic Fibrosis, Huntington's Disease, and Sickle Cell Anemia are examples of recessive diseases. This means that a person must have a mutation in both copies of the causal gene to have these diseases. If someone has a mutation in only one copy of a gene, and the other copy is normal, they do not have the disease but are a carrier of the disease.

3. Teachers will present the Punnett Square, which is used to determine the probability of a child having a recessive disorder based on the genotypes of the parents. If both the father and mother carry the genetic mutation for a particular genetic disorder, how will it affect their child?

   _____ % probability of the child having the disease
   _____ % probability of the child being a carrier
   _____ % probability of the child being disease free



B = normal gene
b = mutated gene

4. Then the teacher will explain the difference between people who have Sickle Cell Trait and those who have Sickle Cell Anemia. People who have inherited one gene for normal hemoglobin and one for sickle hemoglobin, are carriers and are said to have Sickle Cell Trait. One characteristic of individuals with Sickle Cell Trait is their resistance to malaria. Sickle Cell Anemia occurs when a person inherits two sickle cell genes, one from each parent.
5. Teacher will now ask the students to revise their responses in Table 2, if they so wish, based on the new information that they have learned.

Vocabulary Defined:

1. Genes
2. Chromosomes
3. Karyotype
4. Genome
5. Mutation
6. Carriers
7. Cystic Fibrosis
8. Tay-Sachs disease
9. Sickle Cell Anemia
10. Sickle Cell Trait
11. Huntington's Disease
12. Down Syndrome
13. Recessive Pattern
14. Pedigree Analysis
15. Punnett Square

This section of the lesson addresses the **DCI** and **CCC** of standard **MS-LS3-1**. Students discuss the structure and function of different proteins in the body and learn more about how the presence of mutations in genes that code for them can lead to certain disorders.

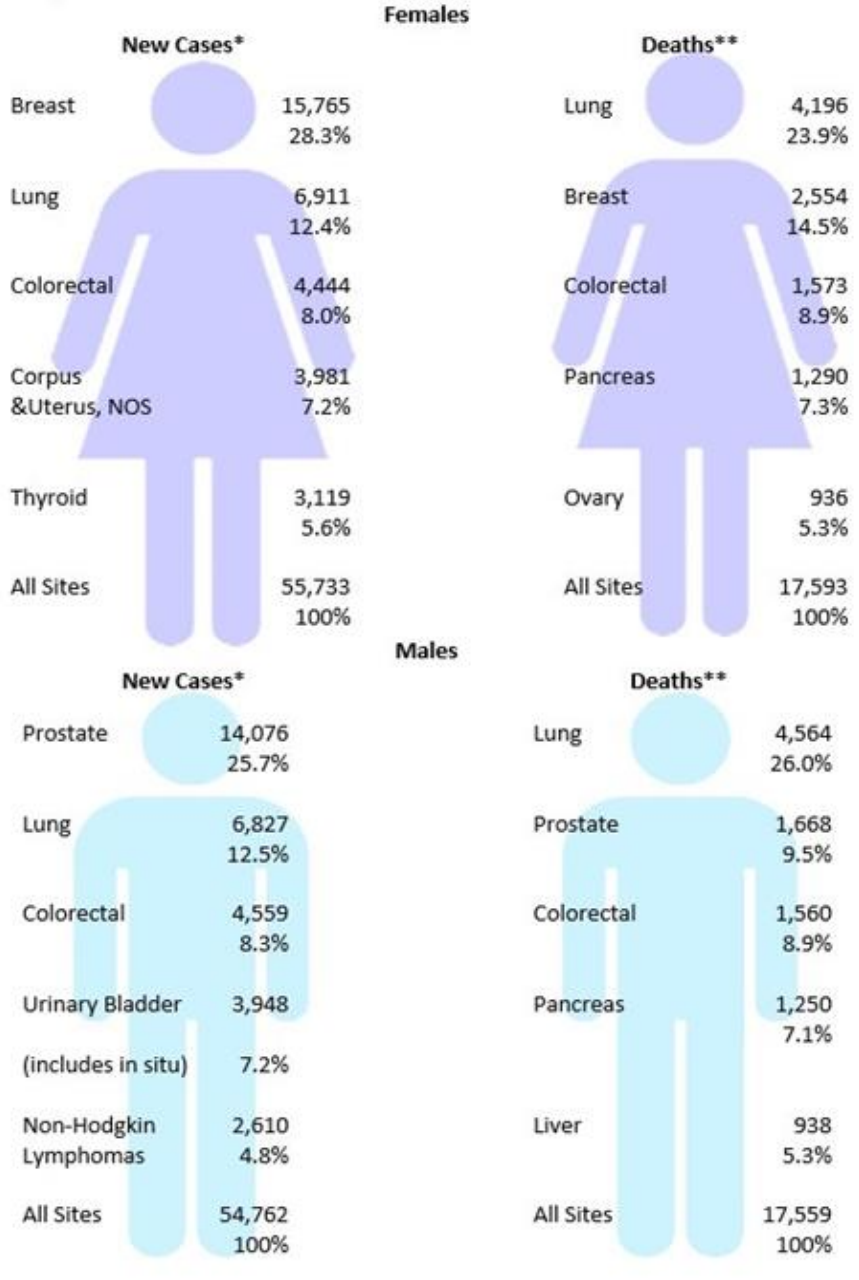
Image Credit:
Punnett Square Image: https://sites.google.com/a/wyckoffschools.org/genetics-challenge/2-pedigree-analysis

ELABORATE: Genetic Mutations and Cancer

The teacher will reiterate to students how mutations can result in the production of abnormal proteins. Some of these abnormal proteins can affect how cells reproduce (i.e. cell division) and cause them to multiply uncontrollably. Thus, cancers are the result of genetic mutation.

The teacher will the ask the students to study the following data regarding the incidence and mortality rates of the most common types of cancers:

Figure 1. Most frequently diagnosed cancer types and causes of cancer death in males and females, New York State, 2011-2015



*Average annual incident cases, New York State, 2011-2015
** Average annual deaths, New York State, 2011-2015
Source of data: New York State Cancer Registry

The teacher will ask the students will create four circle graphs/pie charts showing the top four common cancers in terms of number of 'New Cases' detected and the number of 'Deaths' recorded in New York State for males and females separately using Excel.

Note: At the discretion of the teacher, one may choose to divide students into small groups to complete their circle graphs and allow students to analyze one circle graph at a time.

The teacher will then ask students to compare and contrast their pie charts with each other, in order to answer the following questions:

1. Which type of cancer is most common in both men and women in terms number of 'New Cases'?

2. What differences do you observe between the number of 'New Cases' and number of 'Deaths' caused by this type of cancer in men and women?

3. Observe the circle graph for the Percentages of Deaths in Males. Predict why are cancers of the pancreas and liver present in this graph, but not present in the graph for the Percentages of New Cases.

The teacher will then lead a discussion into the reason for the difference in survival rates for different types of cancers. They will ask students to think about the effect of a certain cancer based on whether it can spread to or invade other parts of the body.

The activity in this section aligns with the **SEP** of the Standard **MS-LS3-1** as students will be developing a model using pie charts/ circle graphs to describe the relationship between the number of new diagnosed cases of common cancers in New York State and the number of deaths as a result of the most commonly diagnosed types of cancers.

EVALUATE:
Formative Monitoring (Questioning / Discussion):

Teachers may use the following questions as Exit Ticket Questions:

1. Claim: A mutation is always harmful. Support or refute this claim using evidence from your activity and your own knowledge/research.

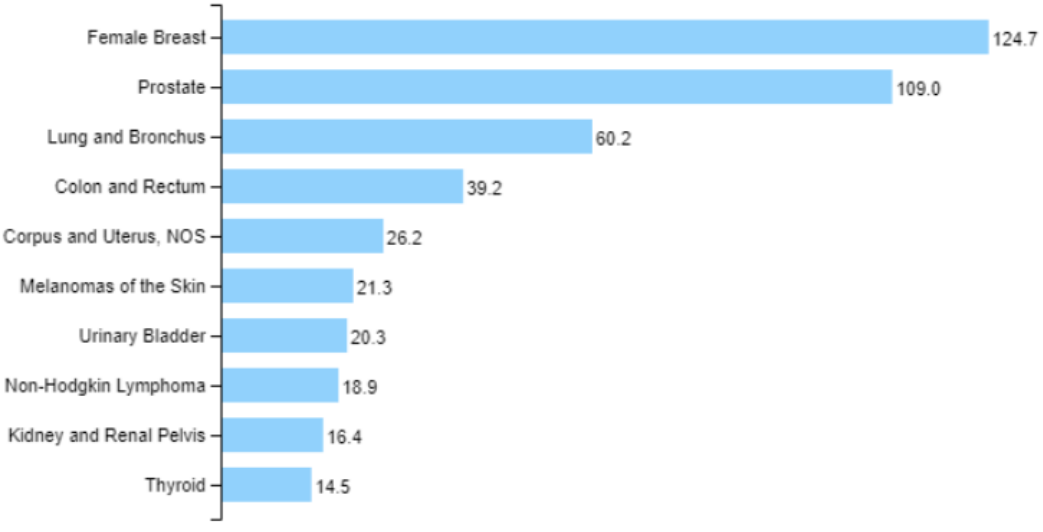
2. Calculate the probability that Patient #6 from Activity 1 will have a child with Huntington's Disease given that his future wife does not have the disease and is not a carrier of the disease. Show your calculations.

3. Draw circle graphs/ pie charts for the following data to show the top three cancers in terms of New Cases for both the whole US and New York State. Predict why there is a difference in the rate of new cancer cases of the most common type of cancer in the state of New York as compared to the entire country.

Centers for Disease Control and Prevention
CDC 24/7: Saving Lives, Protecting People™

Top 10 Cancers by Rates of New Cancer Cases

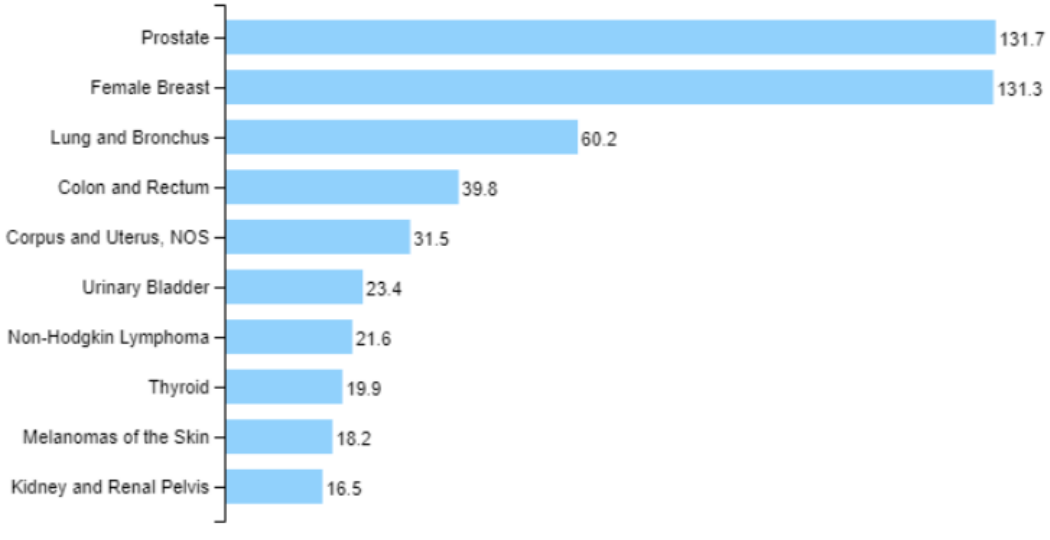
All Types of Cancer, United States, 2011-2015



Rate per 100,000 people

Top 10 Cancers by Rates of New Cancer Cases

All Types of Cancer, New York, 2011-2015



Rate per 100,000 people

The questions in this section ensure that students have mastered the **PE** of the standard **MS-LS3-1**. These questions should help students make the connection that genetic mutations may be beneficial, harmful, or neutral.

Elaborate Further / Reflect:

Encourage students to conduct further research on the importance of genetic testing and the ethics of using genetic information.

Reading article:
"Ancestry, 23andMe, and Others Say They Will Follow these rules when giving DNA data to businesses and police"
https://www.washingtonpost.com/technology/2018/07/31/ancestry-andme-others-say-they-will-follow-these-rules-when-giving-dna-data-businesses-or-police/?noredirect=on&utm_term=.ecce8dfb29b3

Guiding Question: Based on the article, why is it important to protect someone's genetic information?

Students may also choose to learn more about how genetic disorders affect athletes.

Reading article:
"Fantasy Football: How Does the Sickle Cell Trait Impact Players?"
https://www.thefantasyfootballers.com/articles/fantasy-football-how-does-the-sickle-cell-trait-impact-players/

Guiding Question: Based on the article, how are football players with the Sickle Cell Anemia affected by this mutation?

The questions in this section ensure that students have mastered the **PE** of the standard **MS-LS3-1**. These questions should help students understand that genetic mutations may be beneficial, harmful, or neutral.

Materials Required for This Lesson/Activity

Quantity	Description	Potential Supplier (item #)	Estimated Price
1 set per group	Patient Medical History Cards	n/a	n/a
1 robot per group	LEGO EV3	n/a	n/a
1 per group	Poster Paper with Chromosome Markings	n/a	n/a
1 set per group	Disorder Information Cards	n/a	n/a
1 set per group	Protractor, Ruler, Compass, Pencil, and Eraser	n/a	n/a