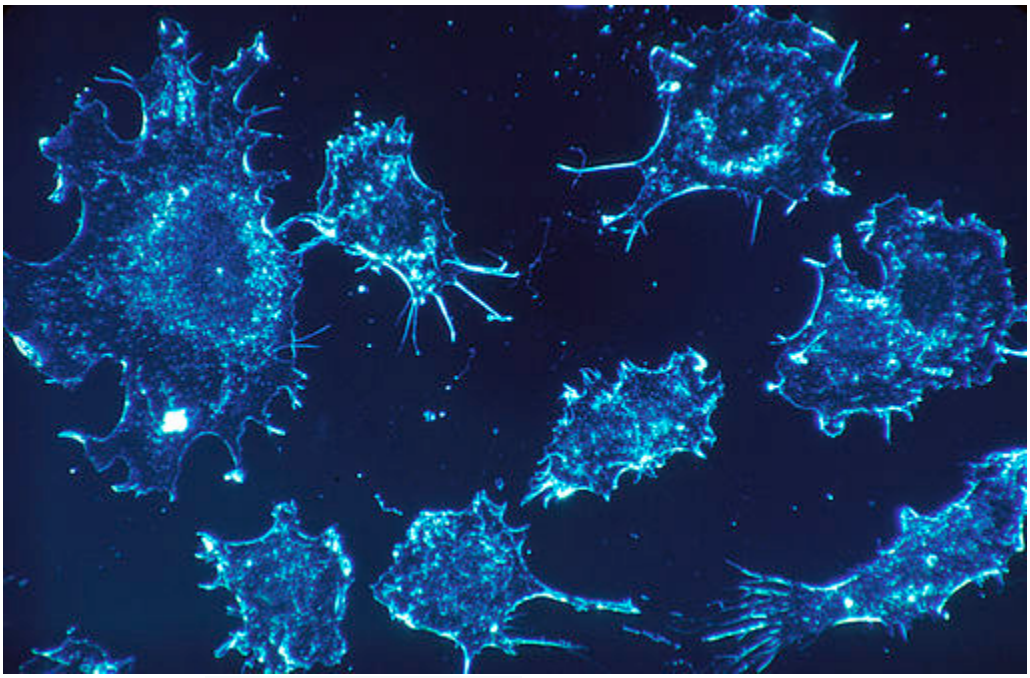

Cancer Cells [Photo by Dr. Cecil Fox via Wikimedia Commons]

Biology: Cell Division and Cancer

High School 9 - 12
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Materials adapted from "Not An Old Person's Disease" by National Center for Case Study Teaching in Science* and "A Case of Skin Cancer" by Science Take-Out**

* http://sciencecases.lib.buffalo.edu/cs/
** http://www.sciencetakeout.com/

Anchoring phenomenon:

Sofia, a young fair-skinned woman, observed concerning changes to a mole on her leg. Sofia's mole demonstrated the characteristics of melanoma as defined by the ABCDEs[1]. Her concern led her to a skin doctor for further diagnosis through biopsy. The biopsy reveals that she does in fact have melanoma, an aggressive form of skin cancer.

Essential question about phenomenon/unit:

- How do different cells within the skin function to provide protection against the elements like ultraviolet (UV) light?
- What effect does UV light have on cells and DNA?
- What are the effects of mutations on the functioning of the proteins?
- Why and how do cells divide?
- What is melanoma and why is it so dangerous?

Scientific explanation:

Sofia's skin is composed of three layers, the epidermis, dermis and hypodermis. It is the first layer, the epidermis, which provides her body protection from the elements, including UV light. The epidermis is made of two types of cells, keratinocytes and melanocytes. Keratinocytes form most of the epidermis and take the brunt of the environmental exposure; while melanocytes produce the pigment melanin that is distributed to keratinocytes. Melanin not only gives skin its pigmentation, but more importantly protects the DNA that lies within each cell's nucleus against UV damage by absorbing and scattering the energy. The more melanin a person produces the more UV protection they have. Moles are clumps or clusters of melanocytes that appear at the surface of the skin during the course of aging and more sun exposure.

Sofia's quest for a tan throughout her life exposed her to more and more UV light. When exposed to UV light, the energy caused two nucleotides within DNA to stick together causing a kink in the double helix. Most of the time the kink can be fixed with cell machinery, but if the kink cannot be fixed the cell will die due to the inability to replicate its DNA. {When cells are exposed to too much UV, more parts of the DNA are damaged and the cell dies.} On some occasions, the cell machinery inaccurately fixed the DNA by replacing the joined nucleotides with different nucleotides, causing a mutation or a change in the DNA sequence.

Whether a mutation is harmful, helpful, or neutral depends on several factors, but most importantly whether or not the mutation occurred in a section of DNA called a gene. Genes contain the instructions for making proteins that carry out life functions. When the sequence of nucleotides in the gene is altered, the structure and functioning of the produced protein is altered as well.

[1] **a**symmetrical, **b**orders uneven, **c**olors varied, **d**iameter larger, **e**volving

One important life function within Sofia's skin is the continual regeneration of skin cells. In healthy cells, regeneration through cell division occurs via a controlled process called the cell cycle, in which cells go through phases of growth, DNA replication and mitosis with checkpoints in between each phase. At each checkpoint, proteins produced by cell cycle genes (proto-oncogenes and tumor suppressor genes) assess if each phase was successfully completed. In normal functioning cells, successful checkpoints lead to controlled cell division and differentiation, while unsuccessful ones' lead to a programmed cell death, also called *apoptosis*.

Unfortunately for Sofia, one or more genes responsible for producing the proteins needed for checkpoints became mutated. Functioning cell cycle genes (and cell cycle proteins) are necessary for the controlled cell division. Without this ability, her melanocytes began to divide uncontrollably leading to the changes she observed in her mole and the diagnosis of melanoma.

The observed changes of Sofia's mole were the signs of a larger problem occurring beneath the skin. After years of UV light exposure, at least one of Sofia's melanocytes within her mole had mutated cell cycle genes. These mutated cell cycle genes disrupted the function of the proteins that they code for and resulted in the uncontrolled cell division of that melanocyte. As that melanocyte began to divide uncontrollably, it produced the observed changes in the mole but also produced a tumor beneath the skin. Continued growth of the tumor could lead to more serious forms of melanoma, in which individual melanocytes break off from the tumor and spread through the bloodstream to other parts of the body. When a cancer cell spreads from its original tumor to other parts of the body it can disrupt the functioning of other organs and potentially lead to death.

The best approach for reducing one's risk for developing melanoma and other types of skin cancer is to reduce UV light exposure.

NGSS *Performance Expectations* addressed in this unit:

Standard	**PE**	**DCI**	**CCC**
HS-LS1-2	Develop and use a model to illustrate the hierarchical organization of interacting systems that provide specific functions within multicellular organisms.	**LS1.A: Structure and Function** 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.	Systems and System Models
HS-LS1-4	Use a model to illustrate the role of cellular division (mitosis) and differentiation in producing and maintaining complex organisms.	**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	Systems and System Models

		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.	
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.	**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. **LS3.B: Variation of Traits** Variations of inherited traits between parent and offspring arise from genetic differences that result from the subset of chromosomes (and therefore genes) inherited.	Structure and Function
HS-PS4-4	Evaluate the validity and reliability of claims in published materials of the effects that different frequencies of electromagnetic radiation have when absorbed by matter. {Specifically, shorter wavelength electromagnetic radiation (UV, X-rays, gamma rays) can ionize atoms and cause damage to living cells.}	**PS4.B: Electromagnetic Radiation** When light or longer wavelength electromagnetic radiation is absorbed in matter, it is generally converted into thermal energy (heat). Shorter wavelength electromagnetic radiation (ultraviolet, X-rays, gamma rays) can ionize atoms and cause damage to living cells.	Cause and Effect

Summary Table of Activities in Unit

Activity	*Learning Target*	*Evidence Students Could Gain*	*Connection to Phenomena*
Activity 1: Sofia, Melanoma & the ABCDE's (Initial Model)	**Develop a model** to explain your thinking about the **growth and development** of a woman's mole **over time.**	Sofia's mole shows all signs of melanoma (all ABCDEs).	Develop initial models using prior knowledge and background story.
Activity 2: How We Get Our Skin Color (Interactive animation using models to explain the structure and function of the skin).	**Use a model** of the **skin** to describe the **structure and function** of the **epidermis**.	The top layer of our skin is made of two cells that work together to provide protection. One (keratinocytes) form a waterproof barrier, the other (melanocytes) make melanin. Melanin helps protect our skin from UV light. It looks like an umbrella over the nucleus and absorbs UV light. This helps protect our DNA from damaging. A mole is a cluster of the cells that make the pigment melanin, and are not generally cancerous.	**HS-LS1-2** • The top layer of our skin (epidermis) protects us from our environment and is made of two cell types, melanocytes and keratinocytes. • Melanocytes make melanin and spread the melanin to the second type of cell. • Keratinocytes make up most of the top layer of our skin. These cells eventually die to form a waterproof barrier. • Melanin makes a protective cap like an umbrella over the nucleus to protect the DNA from UV light. • A mole is a cluster of melanocytes.
Activity 3: Simulating the effects of UV light on DNA	**Model** the **effects** of **UV light on DNA.**	UV light can cause changes in our DNA. If the DNA cannot be fixed a mutation could result.	**HS-PS4-4** • When exposed to UV light, the energy caused two nucleotides within DNA to stick together causing a kink in the double helix. • Most of the time the kink can be fixed with cell machinery, but if the kink cannot be fixed the cell will die due to the inability to replicate its DNA.

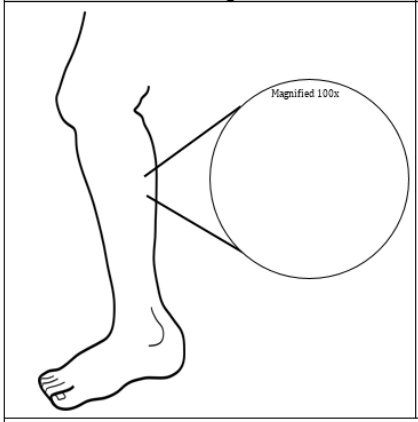
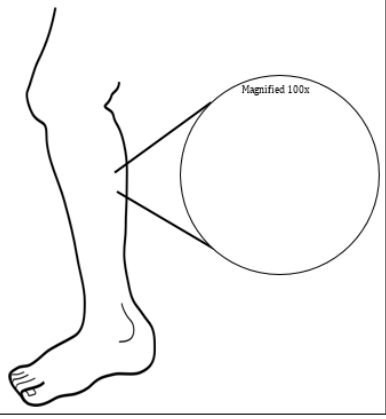
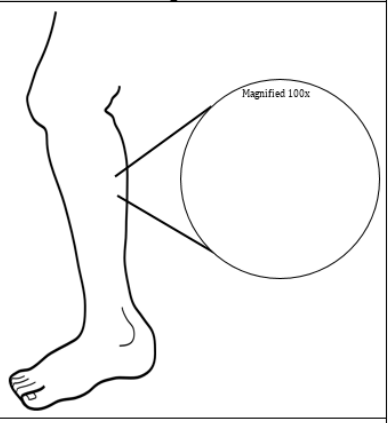
Activity 4: The Eukaryotic Cell Cycle & Cell Division	**Use a model** of the **cell cycle** to explain the **growth and development of cells overtime**.	The cell cycle is a sequence of events that ends with cell division. Cell division allows living things to grow and repair damage. Checkpoints make sure cell division is normal.	**HS-LS1-4** • Organisms require cell division for growth and regeneration of dead cells. • Cell division is a controlled process with phases. • Between each phase are checkpoints that determine if the cell continues through to the next to ultimately divide. • In normal cells, successful checkpoints lead to controlled cell division; while unsuccessful ones' lead to apoptosis (cell death).
Activity 5: Genes, Mutations, and Cancer	**Critically read scientific information** to explain the **cause and effect relationship** between **mutations and cancer**.	Mutations happen every day in our bodies. Our cells can fix most DNA damage, sometimes it can't. If a mutation happens in special cell cycle genes, it could lead cancer. One cancer cell divides uncontrollably and can take over healthy cells and may be spread to the rest of the body.	**MS-LS3-1** • Whether a mutation is harmful, helpful, or neutral depends on the mutation occurring in a section of DNA called a gene. • Genes contain the instructions for making proteins. When the sequence of nucleotides in the gene is altered, the structure and functioning of the protein is also altered. • When one or more genes responsible for producing the proteins needed for checkpoints in the cell cycle become mutated, uncontrolled cell division could result, leading to cancer.
Activity 6: Sun Safety Lab (Group designed lab to compare sunscreen and sunscreen	**Design and conduct an investigation** to **compare the effectiveness** of sunscreen to reducing **exposure to UV light**.	Damaging UV light can be reduced through several methods.	**HS-PS4-4** • The best approach for reducing one's risk for developing melanoma and other types of skin cancer is to reduce UV light exposure.

alternatives.)			
Activity 7: Final Model/Explanation	**Develop a model based explanation** to explain the **growth and development** of a woman's mole **over time**.	The observed changes of Sofia's mole were the signs of a larger problem occurring beneath the skin. After years of UV light exposure, at least one of Sofia's melanocytes within her mole had mutated cell cycle genes. These mutated cell cycle genes disrupted the function of the proteins that they code for and resulted in the uncontrolled cell division of that melanocyte. As that melanocyte began to divide uncontrollably, it produced the observed changes in the mole but also produced a tumor beneath the skin. Continued growth of the tumor could lead to more serious forms of melanoma, in which individual melanocytes break off from the tumor and spread through the bloodstream to other parts of the body. When a cancer cell spreads from its original tumor to other parts of the body it can disrupt the functioning of other organs and potentially lead to death.	

Model Template

How can continued sun exposure cause cancerous changes in our skin?

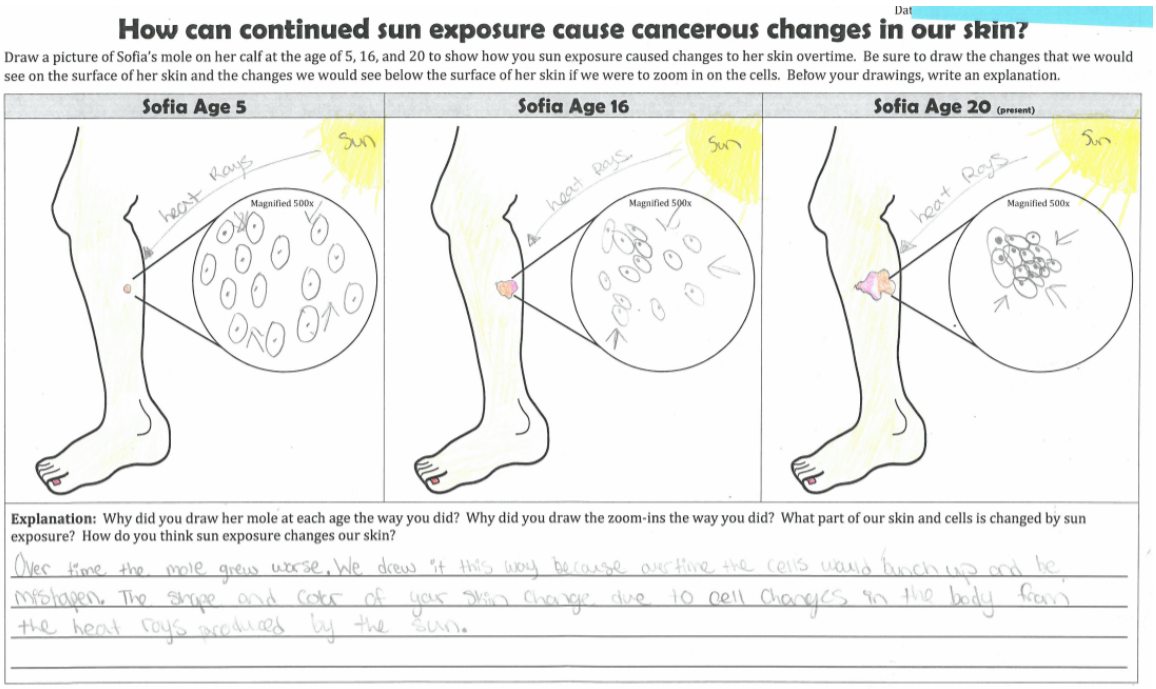
Draw a picture of Sofia's mole on her calf at the age of 5, 16, and 20 to show how you sun exposure caused changes to her skin overtime. Be sure to draw the changes that we would see on the surface of her skin and the changes we would see below the surface of her skin if we were to zoom in on the cells. Below your drawings, write an explanation.

Sofia Age 5	Sofia Age 16	Sofia Age 20 (present)
		

Explanation: Why did you draw her mole at each age the way you did? Why did you draw the zoom-ins the way you did? What part of our skin and cells is changed by sun exposure? How do you think sun exposure changes our skin?

Additional Documents

Initial Model Example



How can continued sun exposure cause cancerous changes in our skin?

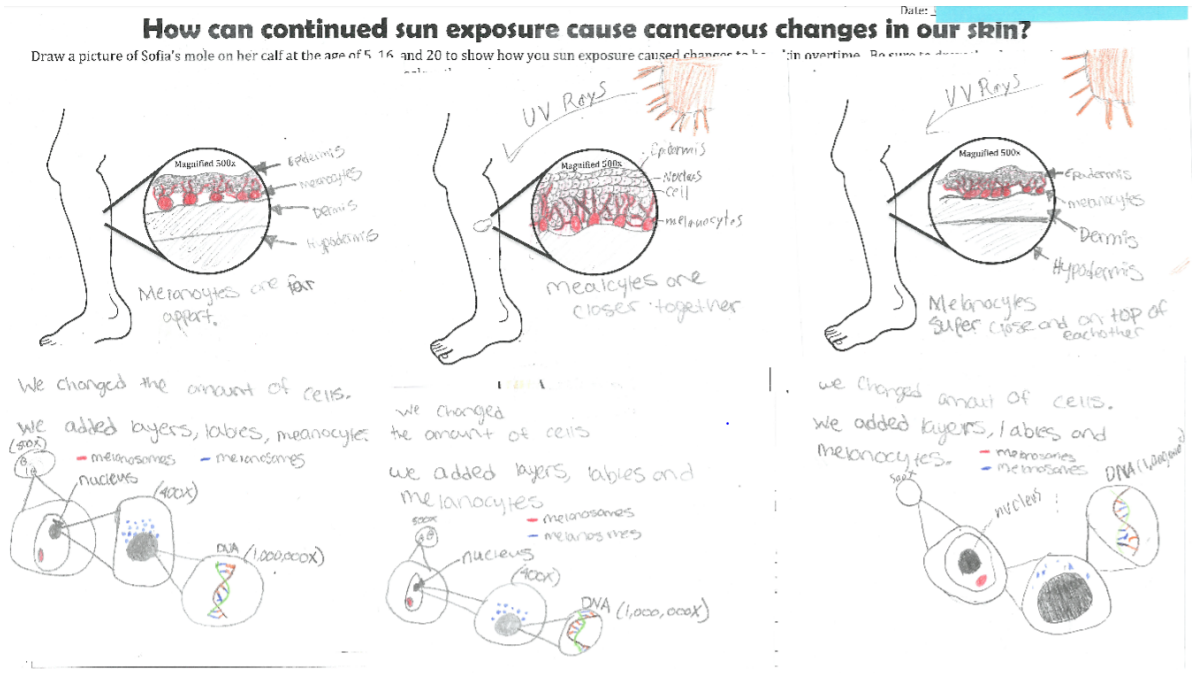
Draw a picture of Sofia's mole on her calf at the age of 5, 16, and 20 to show how you sun exposure caused changes to her skin overtime. Be sure to draw the changes that we would see on the surface of her skin and the changes we would see below the surface of her skin if we were to zoom in on the cells. Below your drawings, write an explanation.

Sofia Age 5	Sofia Age 16	Sofia Age 20 (present)
Sun, heat rays, Magnified 500x	Sun, heat rays, Magnified 500x	Sun, heat rays, Magnified 500x

Explanation: Why did you draw her mole at each age the way you did? Why did you draw the zoom-ins the way you did? What part of our skin and cells is changed by sun exposure? How do you think sun exposure changes our skin?

Over time the mole grew worse. We drew it this way because overtime the cells would bunch up and be misshapen. The shape and color of your skin change due to cell changes in the body from the heat rays produced by the sun.

Model Revision Example



How can continued sun exposure cause cancerous changes in our skin?

Draw a picture of Sofia's mole on her calf at the age of 5, 16, and 20 to show how you sun exposure caused changes to her skin overtime. Be sure to draw the changes that we would see on the surface of her skin and the changes we would see below the surface of her skin if we were to zoom in on the cells. Below your drawings, write an explanation.

Sofia Age 5	Sofia Age 16	Sofia Age 20 (present)
Magnified 500x, Epidermis, melanocytes, Dermis, Hypodermis; Melanocytes are far apart.	UV Rays, Magnified 500x, Epidermis, Nucleus, Cell, melanocytes; melanocytes are closer together	UV Rays, Magnified 500x, Epidermis, melanocytes, Dermis, Hypodermis; Melanocytes super close and on top of eachother
We changed the amount of cells. We added layers, tables, melanocytes. melanosomes, melanosomes, nucleus, (400x), DNA (1,000,000x)	we changed the amount of cells we added layers, tables and melanocytes melanosomes, melanosomes, nucleus, (400x), DNA (1,000,000x)	we changed amount of cells. We added layers, tables and melanocytes. melanosomes, melanosomes, DNA, nucleus

How can continued sun exposure cause cancerous changes in our skin?

Over the last three weeks, we've learned about the function of the epidermis and how UV exposure can damage our DNA, leading to cancer. To finish this unit, you will answer the above question with a model-based explanation. You will create a model to show the changes happening in Sofia's skin (mole) overtime and write an explanation connecting to your model.

Vocab Checklist:

- ☑ Keratinocyte
- ☐ Melanocyte
- ☑ Melanin/ Melanosome
- ☑ DNA
- ☐ Nucleus
- ☑ UV Rays
- ☐ Mutation
- ☐ Cell cycle genes
- ☐ Cell Cycle/Cell division

Model Checklist:

- ☑ Shows Sofia's mole changing overtime
- ☑ Includes the cells of Sofia's mole at each point in time (uses the 100x zoom-in).
- ☑ Shows how UV light causes mutations.
- ☑ Labels parts of the model and/or includes a key
- ☑ Add additional zoom-ins
- ☑ Model is neat and adds color

Explanation Checklist:

- ☑ Describes the characteristics of Sofia's mole at age 20 and the changes that occurred overtime from when she was 5.
- ☑ Explain the role of keratinocytes and melanocytes in the epidermis, including a description of melanin/melanosomes.
- ☑ Explain how UV light causes mutations that could lead to cancer developing.
- ☑ Explain what cancer is and how cancer cells are different from normal cells. Includes explanation of cell cycle genes and cell division.
- ☑ Cite sources for information. Follow the Claim-Evidence-Reasoning cards to help you write your explanation.

Write an explanation on the lines below to explain how Sofia's continued sun exposure caused cancerous changes in her skin. Be sure to review the **Vocab Checklist, Explanation Checklist,** and **Rubric**. Your written explanation should connect to your model.

Sofia's mole at age 5 was a normal sized mole, the skin cells are healthy and the **melanocytes** are separated apart giving the cells **melanin**. At age 16 the melanocytes started to come together but still were a good distance away from each other and the skin cells were still getting enough melanin. At age 20 her mole was sticking out a bit and was a red and brown color, all the melanocytes were stacked on top of one another and broke the barrier of the epidermis.

Keratinocytes are what hold the **nucleus** of the skin cell. They form a layer of dead keratinocytes on the surface of your skin which is waterproof and protects from dirt and dust. They also hold the melanin that protects the nucleus from **UV light**. Melanocytes give the keratinocytes the melanin and proteins they need to protect the nucleus and **DNA**. Melanin is what protects the nucleus and DNA inside the nucleus so there will be no mutations, but sometimes mutations can occur.

UV light are rays that come from the sun and go into our body. Melanosomes protect us from UV rays getting to our DNA but sometimes they make mistakes. If a UV light ray hits our DNA it can cause a mutation that changes the DNA sequence completely and can not be changed back. This mutation could lead to cancer which is lethal to humans if not treated right away.

Cancer is uncontrolled cell growth and in Sofia's case she has melanoma skin cancer. Cancer cells are different from normal cells because they divide and grow at a much faster rate than normal cells. In five days of normal cell division 32 cells are produced, but in five days of cancer cell division 1480 cells are produced. There are also **cell cycle genes** proto-oncogenes and tumor suppressor genes. Proto-oncogenes are genes that help the cell grow but if mutated can make them grow uncontrollably and tumor suppressor genes help slow down **cell division** but if mutated can cause uncontrolled cell division

Cited Sources:

1. How We Get Our Skin Color
2. Genes and Cancer notes
3. The Cell Cycle
4. Skin Cancer Unit Test Review
5. Science Notebook

Final Model Example