Biology Instructional Segment: Structure and Function of Molecular Genetics--Sickle Cell Osmosis (Part 2 of 3)

Student Science Performance	
Course: Biology	**Title:** Stay Hydrated, Or Else
Topic: Cell Transport	

Performance Expectations for GSE:

SB1. Obtain, evaluate, and communicate information to analyze the nature of the relationships between structures and functions in living cells.

c. Construct arguments supported by evidence to relate the structure of macromolecules (carbohydrates, proteins, lipids, and nucleic acids) to their interactions in carrying out cellular processes. (*Clarification statement:* The function of proteins as enzymes is limited to a conceptual understanding.)

d. Plan and carry out investigations to determine the role of cellular transport (e.g., active, passive, and osmosis) in maintaining homeostasis.

Lesson Performance Expectations:

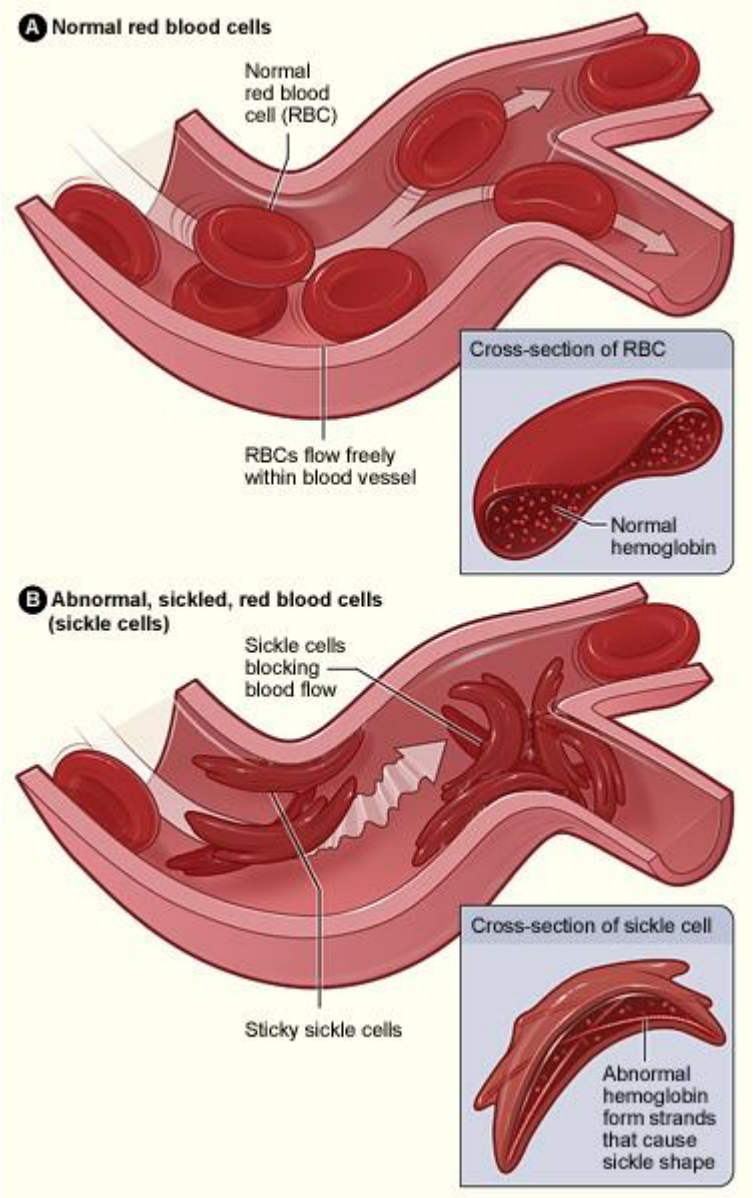
- Ask questions about the relationship between dehydration and sickling of red blood cells during a sickle cell crisis.
- Plan an investigation and collect evidence to determine the effect of macromolecule chain length on osmosis.
- Develop a model to explain why dehydration and sickling of red blood cells form a positive feedback loop.

Additional notes on student supports

Engaging Learners	**Phenomenon** Maintaining sufficient fluid intake is an important part of staying healthy for someone with sickle cell disease, because dehydration and sickling of red blood cells form a positive feedback loop. *Obtaining* Students obtain information about the basics of sickle cell disease by watching *Sickle Cell Anemia: A Patient's Journey* from the American Society of Hematology. Students will then be introduced to the idea that dehydration can cause a sickle cell crisis by watching the video *Living With and Managing Sickle Cell Disease (Tiffany)* from the National Heart, Lung, and Blood Institute. Following the video, students should read the short passage in this handout about the positive feedback loop between dehydration and sickling of red blood cells. Ask Questions: After viewing the video and reading the short passage, students formulate questions to develop an initial explanation of the relationship between dehydration and sickling of red blood cells. Students can record their questions on the handout before sharing in a class discussion. *Teacher Notes: This lesson assesses and extends students basic understanding of osmosis and the role of solute concentrations in determining the direction and rate of net water movement. An understanding of the relationship between solute concentration and movement of water across a membrane is necessary for completion of this lesson and*

	accompanying lab. Students also need to understand that carbohydrates can be small single sugar rings (monosaccharides), double rings (disaccharides), or longer chains of sugar rings (polysaccharides). The opening phenomenon and the related explanation connect this learning experience to the yearlong phenomenon of sickle cell disease. The secondary phenomenon (carbohydrate lab) and the elaboration phenomenon (osmotic control in plant root cells) help students connect the concept of osmosis to plant cells, in addition to animal cells. *Evaluating* Construct an Explanation: Students in groups use their prior knowledge of osmosis and sickle cell disease to construct an initial explanation of how dehydration and sickling of red blood cells are related. *Communicating* Engage in Argument from Evidence: Students individually use their explanation to present an argument of how dehydration and sickling of red blood cells are related. *Additional notes on topic, focus, and phenomena.*
Exploring Revising Model	**Phenomenon** The length of a macromolecule chain affects the rate of osmosis across a semipermeable membrane. *Obtaining* Analyze and Interpret Data: Students will collect data as they carry out an investigation on the effects of three different carbohydrates (glucose, sucrose, and starch) on the rate of osmosis in dialysis bags. *Teacher Notes: Prepare 1% m/v solutions by adding 10 g of carbohydrate to 1 L of distilled water. Bring the solution to a boil, mix thoroughly, and then bring back up to 1 L, as needed. Cut three 20-cm pieces of dialysis tubing for each group of students. Soak the tubing in water for at least 15 minutes.* *Evaluating* In groups, students develop models to explain the pattern observed during the investigation. *Communicating* Individually, students construct an argument about whether the pattern observed during the investigation can be used to explain what happens during a sickle cell crisis.
Explaining Finalizing Model	**Phenomenon** Maintaining sufficient fluid intake is an important part of staying healthy for someone with sickle cell disease, because dehydration and sickling of red blood cells form a positive feedback loop (dehydration causes sickling of cells and sickling of cells causes dehydration). *Evaluating* Students individually develop a model to explain how the processes of dehydration and sickling of red blood cells can reinforce one another.

Questions and model to initiate class discussion:
Teacher Notes: Target conceptual model - Dehydration causes hemoglobin molecules to interact and bind together. In people with sickle cell disease, this causes long chains of hemoglobin to form and reduces the overall amount of solute inside the cell. As a result, water is more likely to move out of the cell into the hypertonic blood plasma. This increased cellular dehydration can cause the sickling of red blood cells to become irreversible, as the cycle will continue.



In this figure, the normal red blood cell has many free-floating solutes, whereas the sickled red blood cell has essentially one long chain of hemoglobin. The sickled cell has fewer solutes, which will cause water to leave the cell.

Q: How would dehydration affect the inside of red blood cells in a person with sickle cell disease?
Q: How would this affect the amount of free solute inside the cells?
Q: How would osmosis be affected by hemoglobin molecules binding together to form long strands?
Q: Would the formation of long hemoglobin strands make it more or less likely that water

	would move into or out of red blood cells? Q: What is a positive feedback loop? How would this be different than a negative feedback loop? *Teacher Notes: During discussion of the student models, focus on the crosscutting concepts of structure & function, stability and change, and cause & effect.* *Communicating* Students use a model to communicate their explanations of how the processes of dehydration and sickling of red blood cells can reinforce one another. **Assessment of Student Learning** *Models provide a clear picture of student thinking and provide the teacher with an opportunity to provide feedback and to ask guiding questions.*
Elaborating Applying Model to Solve a Problems	**Phenomenon** Plants can control the movement of water into and out of their cells partly by converting sugar (sucrose) to starch. *Obtaining* Obtaining Information: Plants take up water from the soil through osmosis in their root cells. Plants can control this process partly by converting sugar to starch, and vice versa. Imagine two different scenarios for a plant. In the first case, the soil is very moist and the movement of water through osmosis into the root cells is occurring at a faster rate than is needed by the plant. In the second case, the soil is dry, and the plant needs to increase the rate of water uptake. *Evaluating* Revisit the data from your lab to determine how the plant would most likely deal with each situation described above. Would the plant be more likely to convert sugar to starch or to convert starch to sugar in each situation? *Communicating* Construct an argument, based on evidence from the lab, about how the plant would be most likely to deal with each situation described above
Evaluation	**Assessment of Student Learning** Arguments will provide evidence of whether students can transfer their understanding of osmosis from the sickle cell phenomenon to a phenomenon in plants. Explanations will provide evidence of how well students can generalize their understanding of osmosis and how it is affected by macromolecule chain length. *Evaluating/Communicating* Students individually construct a written explanation for how the length of a macromolecule chain affects the movement of water into or out of a cell through osmosis.
SEP, CCC, DCI	**Science Essentials**

Science and Engineering Practices	• Constructing explanations • Engaging in argument from evidence • Planning and carrying out investigations • Developing and using models
Crosscutting Concepts	• Structure and Function • Stability and Change • Cause and Effect • Patterns
Disciplinary Core Ideas	From ***A Framework for K-12 Science Education:*** LS1.A: Structure and Function LS1.C: Organization for Matter and Energy Flow in Organisms

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Dehydration & Red Blood Cell Sickling:
An Example of Positive Feedback

In her video, Tiffany stated that one of the main ways she stays healthy is by maintaining her fluid intake. Dehydration is one factor that can trigger a sickle cell crisis. Scientists have also learned that sickling (clogging) of red blood cells during a crisis can lead to even more dehydration in a person with sickle cell. When two factors reinforce each other like this (dehydration causes sickling of cells and then sickling of cells causes more dehydration), it is called a positive feedback loop (Figure 1). Why do dehydration and sickling of red blood cells form a positive feedback loop? It turns out that you can use your understanding of osmosis to develop an explanation that answers this question.

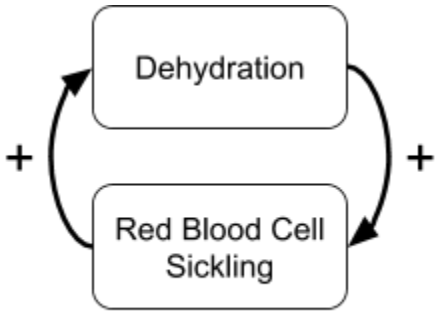

Figure 1: A positive feedback loop

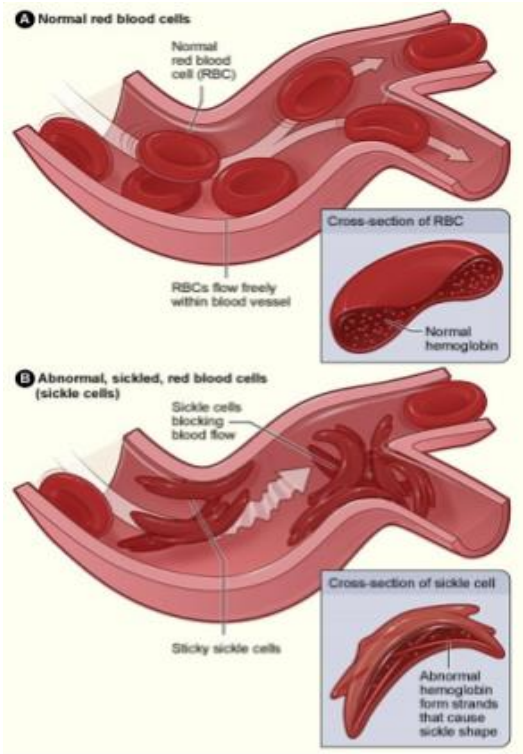

Figure 2. Red Blood Cell Sickling
Figure A shows normal red blood cells flowing freely in a blood vessel. The inset image shows a cross-section of a normal red blood cell with normal hemoglobin. Figure B shows abnormal, sickled red blood cells blocking blood flow in a blood vessel. The inset image shows a cross-section of a sickle cell with abnormal (sickle) hemoglobin forming abnormal stiff rods.
Source: https://www.nhlbi.nih.gov/health/health-topics/topics/sca

We also need to think about what is happening to the red blood cells during a sickle cell crisis. As shown in Figure 2, normal red blood cells have thousands of individual molecules called hemoglobin floating freely in the cytoplasm of the cells. For a person with sickle cell disease, ***dehydration can cause their hemoglobin molecules to stick together and form long strands.*** These strands cause the red blood cells to take on a sickle shape, and the cells are then much more likely to get stuck in blood vessels and slow down blood flow to the organs. This reduced blood flow leads to the pain associated with a sickle cell crisis.

So, why do dehydration and sickling of red blood cells form a positive feedback loop? In other words, if dehydration causes sickling of cells, why does sickling of cells cause more dehydration? Think of some questions that will help you figure this out and record them below.

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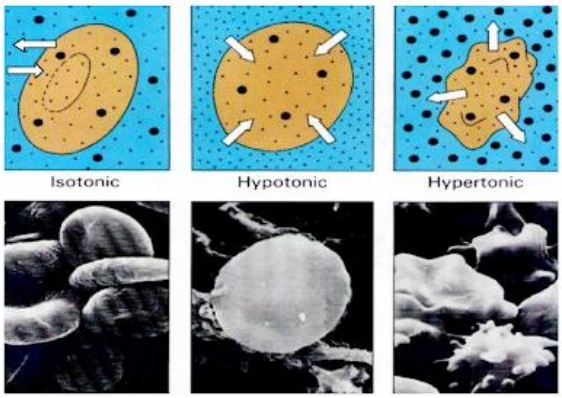
Investigating the Effect of Macromolecule Chain Length on the Amount of Solutes in a Cell and the Rate of Osmosis

Introduction

During a sickle cell crisis, hemoglobin molecules bind together to form ***long chains*** inside the red blood cells, and this ***reduces the number of solute molecules*** floating around the cytoplasm of the red blood cells. Remembering what you know about solutes and the movement of water across a membrane (water moves to the area with the most solutes), we would expect this to affect the process of osmosis in those red blood cells.



You will investigate this effect in the following lab.

Guiding Question

How does the length of a macromolecule chain dissolved in a solution affect the rate of osmosis between that solution and pure water?

Pre-Lab Activity

1. Review the materials and procedure below.
2. Research the structure of glucose, sucrose, and starch.

Carbohydrate	Chemical Formula	Molecular Weight	Number of Sugar Subunits

1. Make a prediction about the relationship that you will observe in this investigation.

Longer chain carbohydrate molecules will have a **smaller / larger** (circle one) effect on osmosis.

Materials

1% mass/volume carbohydrate solutions

  - glucose
  - maltose
  - starch
- Volumetric pipettes or graduated
- Dialysis tubing with bag (three 20-cm pieces per group)
- Balances
- 8 or 10 oz. drinking cups or beakers
- Graduated cylinders

Procedure

1. Label three cups with carbohydrate: glucose, sucrose, starch, respectively.
2. Tie a knot in one end of a piece of dialysis tubing.
3. Fill the bag with 10 mL of carbohydrate solution.
4. Remove most of the air from the tubing. Then tie a knot in the other end of the tubing, leaving ample space between the solution and your knot.
5. Tare the appropriately labeled cup on a balance, then place the tube in the cup.
6. Record the initial mass of the dialysis bag in your data table, then set aside.
7. Repeat steps 2-6 for the remaining carbohydrates.
8. Fill each cup about 2/3 full of distilled water. Be sure each bag is submerged in the water.
9. Let the bags stand for 30 minutes.
10. At the end of 30 minutes, measure the mass of each dialysis bag. Record your data in Table 1 below.
11. Determine the mass difference of each bag (Final – Initial), then determine the % change in mass ((Initial/Final) x 100).
12. Collect class data and record it in Table 2 below.

Data Table 1: Group Results

Carbohydrate Solution	Initial Mass (g)	Final Mass (g)	Mass Difference	% Change in Mass
glucose				
sucrose				
starch				

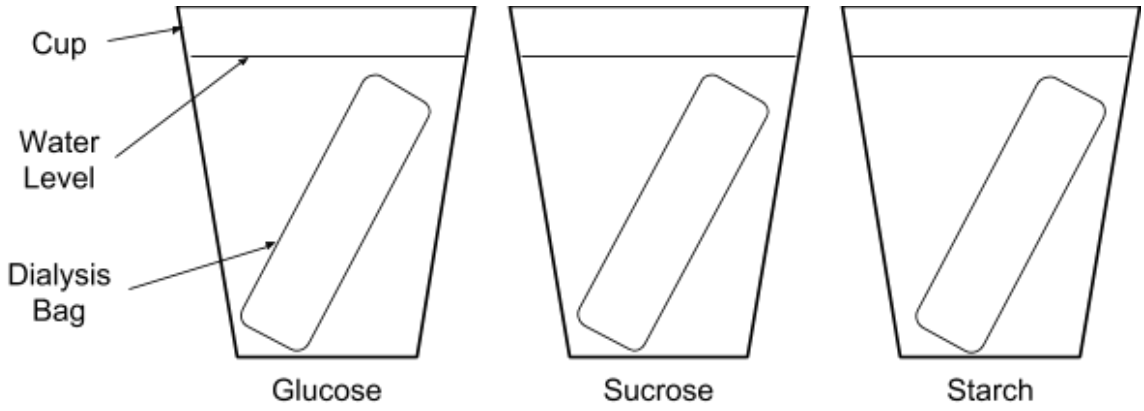
Data Table 2: Class Results

Carbo-hydrate Solution	% Change in Mass								
	Group 1	Group 2	Group 3	Group 4	Group 5	Group 6	Group 7	Group 8	Class Average
glucose									
sucrose									
starch									

Analysis

1. Describe the relationship between carbohydrate chain length and osmosis you observed in this investigation.

1. Use the diagrams below to develop a model that explains the pattern you described above. Be sure to represent the difference in chain length among glucose, sucrose, and starch in your drawing. Include an explanation of your model in the box below.



1. Can we relate the pattern observed in this investigation to what happens during a sickle cell crisis? We know that dehydration causes long chains of hemoglobin to form in the cells. How could these long chains then cause more dehydration? Construct an argument to answer this question.

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Structure & Function of Molecular Genetics GSE: **SB1a, SB1b, SB1c, SB2a, SB2b, SB2c, SB3c, SB4c, SB6a, SB6c**			
Anchoring Phenomenon: Sickle cell disease is a genetic mutation that may be reversed with gene therapy.			
Topic	**Focus**	**Lesson Phenomenon**	**GSE/Notes/Language**
Asexual Reproduction	Process of asexual reproduction seen in various organisms; include advantages and disadvantages that will be revisited in comparison with sexual reproduction.	**Biotechnology Link:** Bacteria are used in the production of insulin they can reproduce quickly through binary fission. Sea stars and salamanders can regrow lost limbs. Marine iguanas on the Galapagos Islands may be a result of parthenogenesis.	SB1b/SB2c/SB3c Reviewing the Cell Theory may be useful in connecting with instructional segments in **Patterns in Living Systems** units. Connect "All living organisms are composed of cells that are the basic unit of structure and function" with "All cells arise from preexisting cells". Marine iguanas are a great connection to revisit when discussing advantages and disadvantages of sexual reproduction (and connecting them back to asexual reproduction) in **Patterns of Heredity & Selection** instructional segment.
Mitosis & the Cell Cycle	Compare and contrast binary fission and mitosis; overview the phases of the cell cycle (G0, G1, S, G2); emphasize the phases of mitosis and chromosome movement; a parent diploid cell divides into two genetically identical diploid daughter cells.	Humans lose approximately one million skin cells daily. Brain MRIs show the loss of brain tissue in CTE and Alzheimer's patients.	SB1b Segue from asexual reproduction seen in other organisms to asexual reproduction seen in humans. Mental Image: Corded telephones are coiled to prevent tangles and allows for condensed storage. (DNA condenses into chromosomes.)

Cancer and DNA Mutations	Emphasize that cancer is a result of uncontrolled mitosis that can arise from damaged DNA (inherited or from environmental factors).	The HPV vaccine is recommended for both sexes to help reduce the number of cancer cases. X-ray and UV radiation can cause cancer. Doctors use family medical histories of cancer when assessing patients.	SB2b/SB1b/SB3c/SB4c Make connections between cancerous cells with damaged DNA reproduce asexually via mitosis; these cancerous cells will produce genetically identical cancerous cells which can lead to the development of a tumor. Use the HPV phenomenon to review viral structure and brief overview of replication. Preview--Caused by a mutation in DNA that is copied during the S phase of Cell Cycle
Structure of DNA and Nucleotides	Nucleic acids are macromolecules formed from nucleotides; emphasize structure of nucleotide and connect to the structure of DNA.	The Human Genome Project mapped out the complete sequence for each chromosome.	SB1c/SB2a Practice complementary base pairing to prepare for protein synthesis. Emphasize hydrogen bonding to prepare for DNA replication. Connect nitrogenous bases to the nitrogen cycle with an emphasis on bacteria.
DNA Replication	Emphasize replication is a semi-conservative process needed to make an identical copy for asexual reproduction.	**Biotechnology Link:** The DNA segment that codes for Insulin are inserted into bacteria for mass production.	SB2a Preview the function of enzyme (speed up reaction) when discussing enzymes necessary for DNA replication: DNA helicase, DNA polymerase, and DNA ligase.
Protein Synthesis	Translation: DNA to RNA Emphasize RNA	The Human Genome Project mapped out the complete sequence for	SB2a/SB2c Use the genetic code to analyze a DNA

	structure and the process of transcription; compare and contrast between DNA and RNA structure while noting both are nucleic acids composed of many nucleotides.	each chromosome. **Biotechnology Link:** The DNA segment that codes for Insulin are inserted into bacteria for mass production.	sequence. It may be beneficial to show students different examples of the code. (table/wheel) **Biotechnology Link:** Relate the medical and agricultural uses of DNA back to evolution with increasing fitness and/or combating resistance.
	Transcription: RNA to protein Emphasize that a codon codes for one amino acid; these amino acids are the monomers of proteins.	**Biotechnology Link:** Bt-corn is now able to ward off pests because of the insertion of a gene from *Bacillus thuringiensis.* Viruses cannot reproduce without infecting a host cell.	Extend with macromolecule connection: Nucleic acids are composed of nucleotides that are genetic instructions, directing the production of an amino acid sequence that composes proteins. The connection between living organisms and viruses can be enhanced here. Viruses are composed of nucleic acid and a protein capsid. However, they lack ribosomes to produce the protein capsid. They are unable to produce the necessary proteins by themselves, so they must inject their nucleic acid into a host cell for protein synthesis to occur.
Effects of Gene Mutations	Effect of point and frameshift gene mutations (insertion, deletion, substitution) on the creation of proteins	Sickle cell disease is a point mutation that affects a red blood cell's shape and ability to carry oxygen. **Biotechnology Link:** Sickle cell disease may be reversed using gene	SB2a/SB2b/SB2c/SB6a/SB6c Make connections between these DNA mutations with natural selection arising from random genetic mutations.

		therapy.	
Biotechnology	Enzymes are used to cut DNA at specific points into fragments that are used to create a DNA fingerprint through gel electrophoresis.	Investigators can use crime scene DNA evidence to determine suspects. DNA is used in determining paternity and maternity.	SB2c Compare DNA fingerprints from a variety of scenarios: crime scene, paternity, etc. Discussions on why DNA fingerprints and physical appearance of offspring are different from parents and non-identical siblings may be beneficial in connecting the instructional segment, **Patterns in Heredity & Selection**. Emphasizing that sexual reproduction allowed the passage of mutated DNA for sickle cell and lactose tolerance to pass from parent to offspring may also be beneficial in the connection.
Biotechnology Connections	Several examples of genetic modification and genetic engineering may be addressed throughout this unit. Involve students in discussions on the scientific process and the advantages and disadvantages in each example. Discuss the logistics as well as impact on society, humans, ecosystems, and evolution/heredity. Preview for Patterns in Heredity & Selection by discussing how inserted genes pass from parent to offspring.		

Anchoring Phenomenon:

Sickle cell disease is a genetic mutation that may be reversed with gene therapy.

Students will explain the phenomenon using the following concepts:

- Sickle cell disease is caused by a single point mutation in the DNA sequence.
- Because the mutated DNA sequence undergoes DNA replication, exact copies of the mutated sequence are in all somatic cells produces through mitosis.
- The mutated DNA is transcribed and translated into a misshapen protein that is not able to be used effectively.
- Using biotechnology, scientists are attempting to reverse sickle cell disease with gene therapy.

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Additional Supports for struggling learners:

The following supports are suggestions for this lesson and are not the only options to support students in the classroom. These supports target students that struggle with science material, this lesson or a previous lesson. These are generalized supports and do not take the place of IEP accommodations as required by each student's Individualized Education Program.

General supports for the following categories:

Reading:	Writing:	Math:
1. Provide reading support by reading aloud or doing partner reads 2. Have the teacher model what they are thinking when reading the text 3. Annotate the text with students so that they may refer to it as they work through the lab	1. The teacher can provide a sentence starter for the students. 2. The teacher can give students an audience to write to (i.e. Write a letter to your sibling explaining this topic). 3. The teacher can provide constructive feedback during the writing process to help students understand the expectations.	1. The teacher should model data collection in the activity 2. The teacher should work the change in mass problem on the board and then walk around to assist students with this part of the lab. 3. Calculators may be needed for some students.

Supports for this specific lesson if needed:

Performance expectations for instruction:

1. Make sure to provide time for struggling learners to create their models.
2. The students may need help understanding a feedback loop and seeing the connections with real world phenomenon.
3. At the end of the lesson the teacher should reflect on the following topics:
   -The teacher should reflect on grouping of students. Was it beneficial and were all students able to contribute? Why or Why not?
   -The teacher should reflect on supports for struggling learners. Were the supports enough for the student population? Why or why not? Then make a list of other supports that the teacher can try in the classroom.

Engaging Learners:

Obtaining

1. The teacher should provide the video handout prior to showing the video so that students may record questions as they watch.
2. Students with processing issues may need to watch the video more than once to be able to formulate questions that can be used to develop an initial explanation.

3. For the article provided the teacher can lead a read aloud or facilitate a paired reading to help struggling readers with the material.
4. Provide a graphic organizer to help students identify the topics covered in the articles or video and assist in the students identifying questions that they have from the reading.
5. Students with disabilities may be hesitant to share in a class discussion and so the teacher should be sure to go by and look at the questions that these students have generated. Reluctance to share with the class could indicate that they need additional help, or it could mean that the student is afraid of being embarrassed. Many struggling students generate thoughtful questions that could add value, but they may need additional individual encouragement to share.

Evaluating and Communicating

6. Students may need to use various formats to construct the initial explanation (i.e. picture, cartoon, slides presentation, or verbally).
7. The teacher should provide the students with a reminder of the definition of a scientific argument.
8. Students may require assistance setting up a scientific argument.

Exploring:

1. The teacher can lead a read aloud for the beginning of the lab to help with struggling readers and students that have processing issues. Have the students highlight the important information to refer to as they work. The teacher should make sure to help students with definitions of words that they do not understand.
2. The teacher should help the students fill in the carbohydrate column on the chart to ensure that everyone is working in the same order. This will make gathering class data easier for students.
3. Struggling readers and the students with processing disorders may need the teacher to model the steps of using dialysis tubing to keep from wasting materials.
4. In the analysis portion of the lab the teacher could provide a sentence starter to give the students a jump off point and make it easier for students to get their thoughts down on paper.
5. Students may need to use various formats to construct the model to communicate their explanation (i.e. picture, cartoon, slides presentation, or verbally).

Explaining:

1. This is vocabulary that students may or may not have been exposed to in the past. The teacher should explain the concept behind a positive feedback loop because even if struggling learners have seen it in the past there may be trouble with recall. Provide students with images, videos and descriptions to help them understand the concepts and build on their knowledge or recall the vocabulary terms as needed.
2. The teacher should be intentional in including everyone during the class discussion rather than just calling on a few students to answer the questions. The teacher might consider using some random system of choosing students to answer so that no student gets too much "floor" time and no student gets left out.
3. Communication and assessment options should be presented for struggling learners. Options could include discussions, writing, analysis of images or models.

Elaborating:

1. The teacher should use images to reinforce the description of how plants take up water and the scenarios that go with the description.

2. Remind students that they can refer to the lab to help explain the concept of osmosis. 3. Communication and assessment options should be presented for struggling learners. Options could include discussions, writing, analysis of images or models.
Evaluating: 1. Students may need additional time to construct a model 2. Writing can be a major struggle for some students. Some choice as to how students express their knowledge may be warranted. Students could express their knowledge in the form of a picture, cartoon, slides presentation, or verbally.

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